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Concept Mapping - Connecting Educators
Proceedings of the Third Conference on Concept Mapping

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Volume 2. Full papers, part two

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EXPLOITING COMPASS AS A TOOL FOR TEACHING AND LEARNING

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Abstract. In this paper, an overview of the concept mapping learning environment COMPASS is given. The most important features of COMPASS are the support of students in working out various concept mapping activities, the analysis of students' concept maps, the qualitative and quantitative estimation of their knowledge, the provision of different forms of feedback and feedback components, the adaptive functionality of the feedback process and the CAT tool, which enables teachers to author mapping activities and monitor students' progress. The results revealed from an experimental study conducted in a classroom setting are positive and encouraging, regarding the exploitation of COMPASS as an alternative teaching and learning tool.

1 Introduction

In educational settings, concept maps have become a valuable tool of a teaching, assessment and learning toolbox, as they enhance learning, promote reflection and creativity and enable students to externalise their knowledge structures (Novak & Gowin, 1984). The most natural way to construct concept maps seems to be the use of paper and pencil or the "Post-it" notes. However, this form poses constraints, such as the inhibition of the construction, revision, assessment and feedback processes. Over the last years, the introduction of information and communication technologies in the educational practice resulted into the development of a number of computer-based and web-based concept mapping environments, aiming to compensate these constraints and to eliminate communication restrictions. The available concept mapping software environments are either commercial such as Inspiration (http://www.inspiration .com) or have been developed in the context of research programs. In research level, the environments aim to (i) support students in working out concept mapping activities, support instruction with the use of concept maps and enable teachers to design and organize their lessons, such as TPL-KATS (Hoeft et al., 2003), CM-ED (Rueda et al., 2004) and LEO (Coffey & Canas, 2003; Coffey, 2007), (ii) promote and facilitate collaborative learning, such as CmapTools (Cañas et al., 2004), and (iii) support the assessment and feedback process during the elaboration of an activity, such as RFA (Conlon, 2006), Java Mapper (Hsieh & O' Neil, 2002) and Verified Concept Mapper (Cimolino et al., 2003).

In this line of research and having as an objective to support the learning process and to assess learner's understanding, we developed an adaptive concept mapping learning environment, referred to as COMPASS (COncept MaP ASSessment and learning environment). The discriminative characteristics of COMPASS are (i) the possibility of students to work out various concept mapping activities, which employ different concept mapping tasks, (ii) the analysis of students' maps and the application of an assessment scheme for the qualitative and quantitative estimation of their knowledge, (iii) the provision of different forms of feedback (text-, graphical- and dialogue-based) and feedback components, which serve processes of informing, guiding/tutoring and reflection, (iv) the adaptivity of the feedback process that accommodates students' knowledge level, preferences and interaction behaviour, (v) the learner control over the feedback process, and (vi) the teacher-expert support through the CAT tool (COMPASS Authoring Tool), which enables the design/authoring of concept mapping activities and feedback components, the definition/configuration of the assessment scheme applied and the monitoring of students' progress. The rest of the paper is structured as follows. In Section 2, an overview of COMPASS is given. In Section 3, the results of an experimental study are presented, focusing on the effectiveness of COMPASS in teaching and learning and on students' opinion. The paper ends, in Section 4, with the main points of our work and our near future plans.

2 An Overview of COMPASS

COMPASS (http://hermes.di.uoa.gr/compass) is a discipline-independent concept mapping learning environment, developed at the Educational & Language Technology Laboratory of the Department of Informatics & Telecommunications at the University of Athens (Gouli et al., 2004; 2006). In Figure 1, the main screen of COMPASS is shown, which consists of (i) the menu and toolbar, providing direct access to several facilities such as feedback, student model and analysis of the map, and (ii) the Working Area, on which the central concept or the activity map (e.g. the map that students have to evaluate/correct, extend, complete or annotate) is presented. COMPASS was designed to support any language at user interface level (currently English and Greek interface is supported). In the following sub-sections, a brief description of the domain knowledge of COMPASS, the assessment scheme applied for the evaluation of students' concept maps, the feedback process followed and the CAT tool is given.

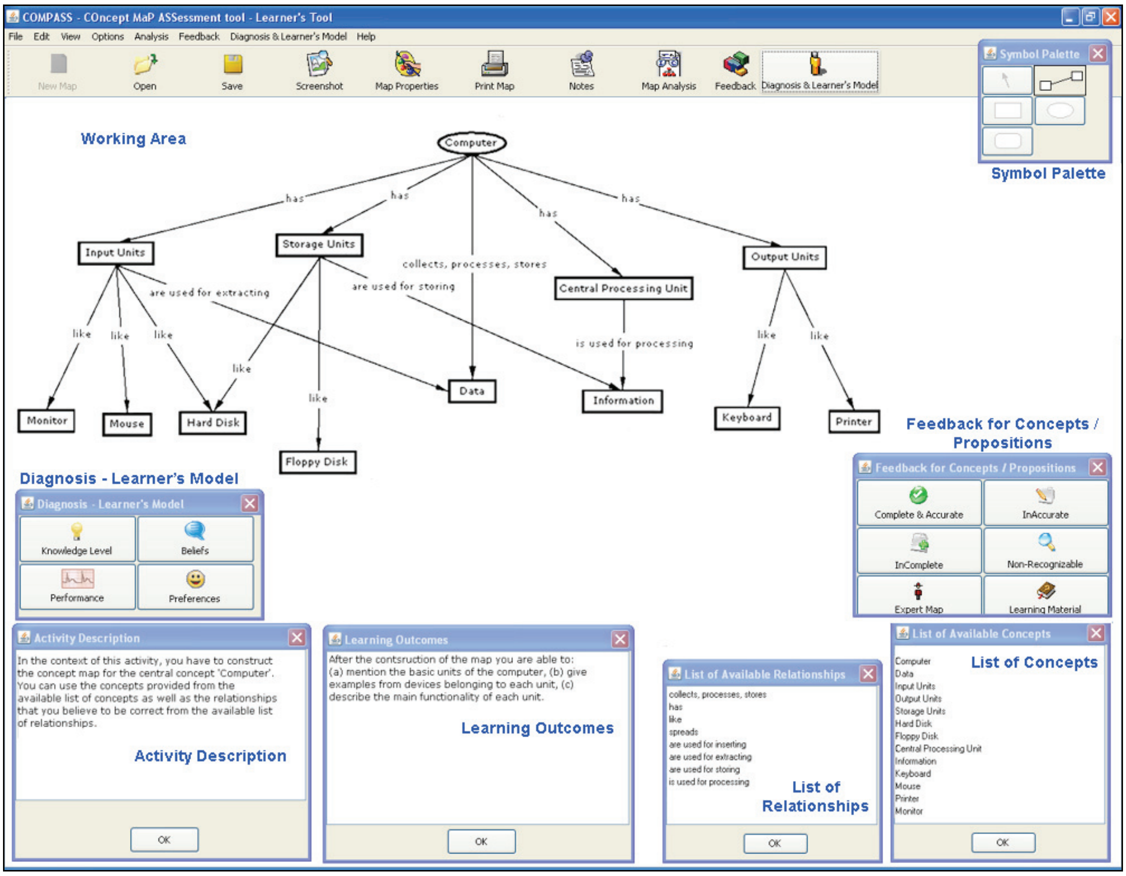

Figure 1. The main screen of COMPASS. The Working Area presents a concept map constructed by a student in the context of a construction mapping task supported with a list of concepts and relationships. The specific task is one of the activities provided in the context of the learning goal "Computer Architecture".

2.1 The Domain Knowledge of COMPASS

The domain knowledge of COMPASS is based on the notion of a learning goal that student can select. A goal corresponds to a fundamental topic of the subject matter and is further analysed to specific learning outcomes, which are realised through various learning concept mapping activities. An activity accomplishes specific educational functions, such as ascertaining students' prior knowledge, promoting knowledge construction/ identifying conceptual changes, and assessing knowledge construction (Gouli et al., 2004). Depending on the outcomes and the functions, the activities may employ various concept mapping tasks, such as the construction of a map, the evaluation/correction, the extension, the annotation and the completion of a given map or combinations of the abovementioned tasks (e.g. evaluation and completion of a given map); each of these tasks provides a different perspective of student's understanding. The concept mapping tasks are characterized along a directedness continuum from high-directed to low-directed, based on the context of the task and the support provided to students; students may have at their disposal a list of concepts and/or a list of relationships and/or may be free to add the desired concepts/relationships on their maps. The provided lists may contain not only the required concepts/ relationships but also concepts/relationships that play the role of distracters (i.e. concepts that can be characterized as superfluous and relationships that are incorrect). Also, the domain knowledge of COMPASS contains the feedback components, which are available through the feedback process and the model of teacher's knowledge. In Figure 2, the constituent parts of the domain knowledge of COMPASS are presented, while in Figure 3, the model of a concept mapping activity in COMPASS is depicted.

2.2 The Assessment Scheme in COMPASS

Depending on the attributes of the activity, student's concept map may be assessed either automatically by COMPASS (by activating the "Map Analysis" button from the toolbar or the "Analysis" menu), or by teacher through the CAT tool or by peers through the PECASSE (PEer and Collaborative ASSessment Environment)

environment (Gouli et al., 2008). A scheme has been developed for the assessment of concept maps and subsequently for the evaluation of student's knowledge level on the central concept of the map. The proposed scheme adopts the relational method by examining the accuracy and completeness of the presented propositions on student's map, taking into account the missing ones, with respect to the propositions represented on the expert map (Gouli et al., 2005). The analysis of the map (i) is based on the assessment of the propositions according to specific criteria, such as completeness, accuracy, superfluity, missing out and non-recognizability, (ii) results into the identification of specific error categories (e.g. incomplete relationship, incorrect concept, superfluous relationship, missing proposition), and (iii) is discriminated in the qualitative and quantitative analysis. The qualitative analysis is based on the qualitative characterization of the errors and aims to contribute to the qualitative diagnosis of student's knowledge; that is student's incomplete understanding/ beliefs and false beliefs. The quantitative analysis aims to evaluate student's knowledge level and is based on the weights assigned to each error category as well as to each concept and proposition that appear on expert map, reflecting their degree of importance. Pre-defined weights for error categories are supported; the teacher has the possibility to personalize the assessment process and configure the weights through the CAT tool when s/he constructs the expert map, with respect to the learning outcomes addressed by the activity under consideration. The results derived from the analysis are represented to students in an appropriate form during the feedback process.

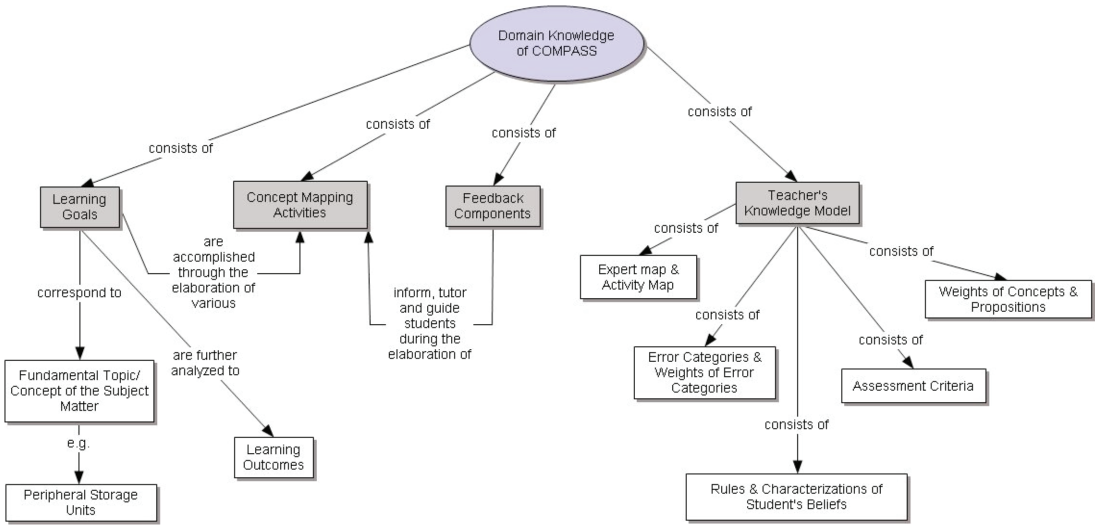

Figure 3. A representation of the domain knowledge of COMPASS.

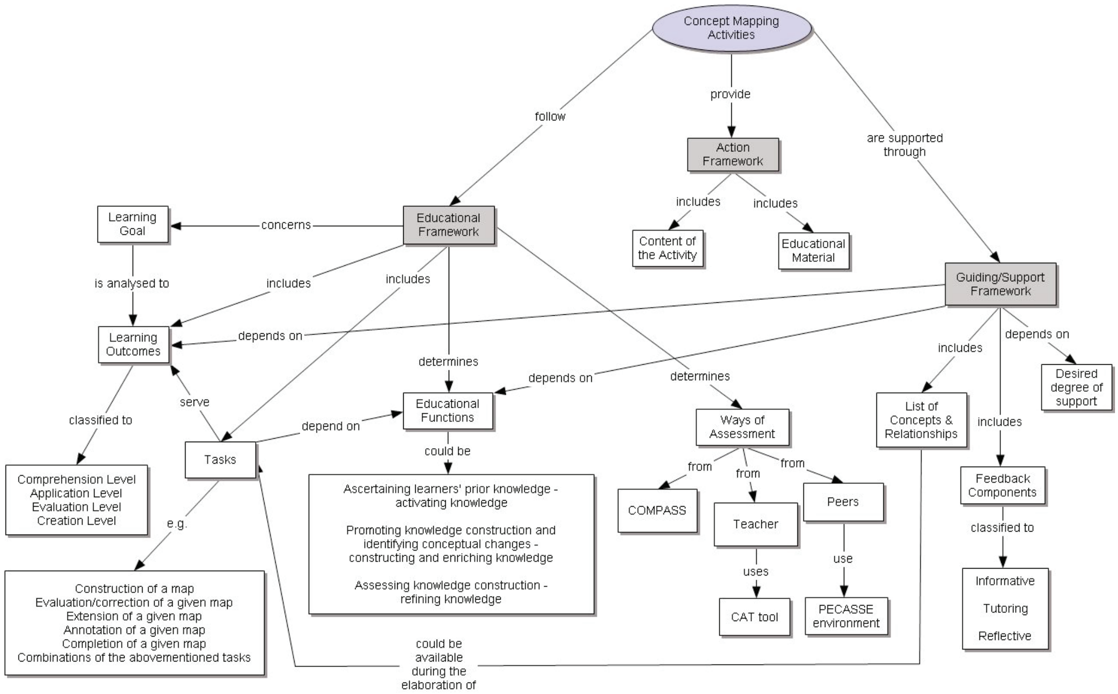

Figure 4. The model of a concept mapping activity in COMPASS.

2.3 The Feedback Process in COMPASS

The provision of feedback in COMPASS aims to (i) inform students about their performance and their "current" state, (ii) guide and tutor students in order to identify their false beliefs, focus on specific errors, reconstruct their knowledge and achieve specific learning outcomes addressed by the activity/task, and (iii) support reflection in terms of encouraging students to "stop and think" and giving them hints on what to think about, indicating potentially productive directions for reflection (Gouli et al., 2006). Different forms of feedback (i.e. text-based, graphical-based and dialogue-based form) are supported with respect to the addressed learning outcomes and students' preferences and multiple Informative, Tutoring and Reflective Feedback Components (ITRFC) are available during the feedback process. The Informative Feedback Components (i.e. Correctness-Incorrectness of Concept/Proposition & Type of Error, Correct Proposition, Expert Map and Performance Feedback) aim to inform students about the correctness of their answer and their performance. The Tutoring Feedback Components (i.e. Tutoring Feedback Units and Explanation of the Proposition) aim to tutor students by enabling them to review learning material relevant to the attributes of the concept/proposition represented on expert/student map and/or the concepts included in the provided list of concepts. Finally, the Reflective Feedback Components (i.e. Belief Prompt-Rethink Write, Error-Related and Inquiry-Related Reflective Questions) aim to promote reflection and guide students' thinking, in order to explore situational cues and underlying meanings relevant to the error identified. The ITRFC are structured in multiple layers and their stepwise presentation supports the gradual provision of feedback and enables students to elaborate on the feedback information and return to their map in order to correct any errors.

The adaptive functionality of COMPASS is reflected to the personalization of the provided feedback in order to accommodate a diversity of students' individual characteristics and is implemented through (i) the technology of adaptive presentation that supports the provision of various alternative forms of feedback and feedback components, and (ii) the stepwise presentation of the feedback components in the dialogue-based form of feedback. Specific student's characteristics (i.e. knowledge level, preferences, interaction behaviour), which are maintained in student model and recorded either through student's interaction with the environment or defined by the student explicitly, are used as a source of adaptation. COMPASS incorporates various strategies in order to determine the feedback components that should be presented, depending on the sources of adaptation (Gouli et al., 2006). Moreover, COMPASS gives students the possibility to (i) personalize the feedback process by accessing and initiating/updating their student model in terms of the feedback presentation parameters (e.g. preferences on types of feedback components and characteristics that could be used as source of adaptation), and (ii) have control over the feedback presentation process at any time during their interaction with the environment by selecting the preferred form of feedback and by intervening in the stepwise presentation process of the dialogue in order to activate the desired stage and select the desired feedback components. Also, at any stage of the dialogue, students have the possibility to inactivate the adaptation of the feedback process.

2.4 The CAT tool

The CAT tool (COMPASS Authoring Tool) supports teachers in developing concept mapping activities and monitoring students' progress. More specifically, the CAT tool:

(i) enables teachers to author concept mapping activities that students can work out through COMPASS. In particular, the teacher has the possibility to (a) configure the characteristics of a concept mapping activity (e.g. the learning goal, the learning outcomes, the task, the form of feedback and the components that could be available during the elaboration of the activity, the assessment scheme, the weights of the various error categories), (b) construct the expert map and the activity map (i.e. when the task refers to the evaluation, extension, completion, or annotation of a given map), and (c) author the tutoring feedback units, the reflective questions and the explanation of the propositions for the various concepts and propositions, which are depicted on the expert map or could be represented on the student map,

(ii) supports teachers in assessing students' concept maps, that are not automatically assessed by COMPASS and providing feedback and comments to students for their work,

(iii) enables teachers to monitor students' progress by having access to their students' model, the log files maintained and the various versions of the maps recorded during the elaboration of the activity, and

(iv) supports the collaboration of teachers in authoring concept mapping activities. In particular, teachers have the possibility to (a) access concept mapping activities that have been created and published by others, (b) evaluate published activities and send comments to their authors, and (c) collaborate with other authors for designing an activity or creating feedback units through an asynchronous communication tool.

3 Experimental Study

The focus of the study was to examine the hypotheses that COMPASS could be used effectively as a teaching tool and would help students positively on learning. In particular, the aim of the study was to investigate the effects on students' learning following different teaching methods (concept mapping with COMPASS vs. traditional teaching) and to record students' opinions of the COMPASS environment. A pre-post design with (i) an experimental group, exploiting COMPASS as a teaching and learning tool, and (ii) a control group, participating in a traditional teaching lesson, was employed.

Sixty-five students (n=65), 35 females and 30 males, participated in the study. The students were 13-14 years old and selected randomly from four classes of a junior high school in Athens, Greece. The students were studying their second semester course of Informatics. Students were already familiar with the concept mapping technique, as it was used from the beginning of the school year, as the main teaching and assessing strategy. Prior to the intervention, all students were administered pre-tests in achievement. After the pre-test, students were randomly assigned to one of the groups (experimental vs. control). No significant difference was found on the *t*-test performed, comparing the two groups on pre-test performance (t=-0.255, df=63, 2-tailed p=0,799).

The concept of 'Peripheral Storage Units' in informatics teaching was used as the experimental content. Two experienced informatics teachers selected the concepts that would be represented on the expert map (20 concepts). With the selected list of concepts, each teacher constructed a concept map. The similarity index between the two expert maps, as it results from the similarity index algorithm of Goldsmith et al. (1991), was 0.85. The expert map used in all the phases of the study resulted from teachers' collaboration and negotiation and included 20 concepts and 28 propositions. The teachers also collaborated and negotiated on (i) the lists of concepts and relationships that were available during the activities (performed in COMPASS and in pre-post tests); the provided list of concepts included the 20 concepts represented on the expert map and a number of concepts playing the role of distracters, and (ii) the appropriate weights (error categories, concepts and propositions) for the assessment of students' concept maps by COMPASS. At the end, the two teachers cooperatively constructed the feedback material available in COMPASS (i.e. tutoring feedback units, inquiry-related reflective questions and explanations of propositions).

3.1 Procedure

The five week experimental study consisted of the following phases:

(i) *introduction to COMPASS environment* (1st and 2nd week) - lasted 1 ½ hour: The functionality of COMPASS was demonstrated and all the students worked out a concept mapping activity (construction task) concerning the concept of 'Main Memory' (already taught).

(ii) *pre-testing* (2nd week) – lasted 30 minutes: All the students took the pre-achievement test.

(iii) *studying the central concept of 'Peripheral Storage Units'* (3rd week) – lasted 2 hours:

- The experimental group studied the central concept by using the COMPASS environment. Students were asked to construct a concept map concerning the specific central concept. They had at their disposal a list of 24 concepts and a list of 21 relationships and were asked to represent the appropriate concepts from the available list and relate them with the appropriate relationships, ignoring the ones playing the role of distracters. For each concept of the list, students had the possibility, at any time of the task, to access the available tutoring feedback units (i.e. a description or a definition of the concept, an image, an example, a counterexample, a task or a case). Also, during the elaboration of the task, students had the possibility to activate the analysis of their map, to receive feedback in dialogue-based form and to access the expert map and the performance feedback. Moreover, the feedback components that were available are: the correctness-incorrectness of concept/proposition & type of error, the correct proposition, the explanation of the proposition, the tutoring feedback units, the belief prompt-rethink write, and the error- and inquiry-related reflective questions. The role of the teacher was guiding and supportive as far as the functionality of the COMPASS environment was concerned.
- The control group participated in a lecture, where the teacher introduced the specific central concept following a traditional classroom teaching. During the lesson, the teacher asked students questions in order to ascertain their prior knowledge for the concepts being taught, introduced the unknown concepts, discussed with students the problems that they encountered in understanding the taught concepts and finally asked questions in order to assess their knowledge.

(iv) *filling the questionnaire* (4th week) – lasted 20 minutes: The students of the experimental group were asked to answer six open questions, concerning their opinion of the COMPASS environment. Indicative questions are: 'Do you believe that the COMPASS environment helps you to learn the central concept?', 'Which facilities of the system, do you think that help you more during the elaboration of the activity?'.

(v) *post-testing* (5th week) – lasted 1 hour: All the students took the post-achievement test.

3.2 Pre-test & Post-test

The pre-test was composed of a concept mapping activity on the central concept of ‘Peripheral Storage Units’. Students were asked to construct a concept map of the central concept with paper-and-pencil using a list of 20 concepts (e.g. ‘Hard disk’, ‘Optical Storage Units’, ‘Capacity’, ‘Byte’, ‘Cd-Rom’). For the evaluation of the pre-test, the similarity index algorithm of Goldsmith et al. (1991) was adopted. The similarity index may be viewed as an index of accuracy and completeness of the student concept map and as a valid indication of the quality of students’ knowledge (McClure et al., 1999; Chang et al., 2001). The performance score of the pre-test, presented in Table 1, corresponds to the similarity indices of students’ concept maps on a scale of 0-100 (the similarity index ranges from zero to one).

The post-test consisted of (i) a questions’ test, and (ii) a concept mapping activity. The questions’ test included 10 long answer items, in which each item scored 10 points. The questions’ test was constructed to measure students’ learning on the concept of ‘Peripheral Storage Units’ and included all the concepts that students learned either following COMPASS teaching method or traditional teaching. Two indicative items were: (i) ‘Which are the basic categories of peripheral storage units? Try to mention the storage units that belong to each category.’, (ii) ‘What is formatting of a storage unit?’. The questions’ test was scored by two informatics teachers. The Pearson correlation of raters was 0.953 (r=0.953, df=63, p<0.01). The scores rated by each teacher were summed and divided by 2, which was the performance score for the post-test (Table 1). The concept mapping activity included a construction task with paper-and-pencil for the central concept of ‘Peripheral Storage Units’, supported with a list of 25 concepts. For the construction of the map, students were asked to represent the appropriate concepts from the available list, ignoring the ones playing the role of distracters and relate them with their own defined relationships. The similarity indices of students’ concept maps were calculated (Table 2). The concept mapping activity aims at providing another measurement of students’ learning on the specific central concept and giving indications on how students’ concepts maps and subsequently students’ knowledge changed from pre-test to post-test.

3.3 Results

In order to investigate the effectiveness on learning of the teaching method followed, we examined students’ performance on pre-test and post-test. More specifically, we examined (i) students’ performance on pre-test activity as it was evaluated based on the similarity index and on various concept mapping measures (i.e. number of concepts/propositions represented on students’ maps and number of accurate concepts/propositions), (ii) students’ performance on questions’ test of the post-test, and (iii) students’ performance on post-test concept mapping activity and on the corresponding concept mapping measures. Descriptive statistics for pre-test and post-test performance by method of teaching are presented in Table 1. A t-test performed on pre-test performance revealed that the two groups were initially equivalent. Moreover, descriptive statistics for pre-test and post-test concept mapping measures by method of teaching are presented in Table 2.

Groups of Students – Method of Teaching	**Performance**	
	Pre-test	**Post-test**
Experimental Group – Working with COMPASS (n=33)	11.61 (8.11)	68.61 (17.22)
Control Group – Traditional Teaching (n=32)	12.13 (8.27)	48.63 (21.18)
Total (n=65)	11.86 (8.13)	58.77 (21.61)

Table 1: Means (and standard deviations) of the pre-test and post-test performance

The two-way mixed analysis of variance (ANOVA) with time (pre-test vs. post-test) as a within-subjects factor and method of teaching (working with COMPASS-experimental group vs. traditional teaching-control group) as a between-subjects factor was used to analyse the main effect of the method of teaching on students’ performance. The interaction between method of teaching and time is statistically significant ($F_{1,63}$= 22.7, p<0.001). Although the difference on pre-test performance is not significant, the average performance after the intervention for the experimental group (M=68.61, SD=17.22) was significantly higher (t=4.179, df=63, 2-tailed p<0.001) than that of the control group (M=48.63, SD=21.18). Moreover, for the experimental group as well as for the control group, the difference on the performance between the two time-conditions was significant (experimental: t=-24.035, df=32, p<0.001, control: t=-10.080, df=31, p<0.001). The results indicated that both groups improved their performance after following one of the teaching methods, but the participants of the experimental group working with COMPASS significantly outperformed the participants who followed the traditional teaching method. This provides an indication that the COMPASS environment had a better learning impact on students than the traditional teaching method.

Regarding the completeness and accuracy of students' concept maps (measured by the similarity index score) and consequently the students' performance, the results indicated significant two-way interactions between time and method of teaching ($F_{1,63}$= 17.032, p<0.001). The post-test score of the experimental group (M=58.45, SD=15.26) is higher than the score of the control group (M=43.63, SD=17.86). A *t*-test showed a significant difference (t=3.603, df=63, 2-tailed p=0.001). In line with the abovementioned results, in post-test, students working with COMPASS performed better and constructed more accurate and correct concept maps than those who followed the traditional teaching method. Insignificant differences were found comparing the concept mapping measures of the two groups on pre-test: (i) number of concepts (t=-0.741, df=63, p=0,461), (ii) number of propositions (t=-0.402, df=63, p=0,689), (iii) number of accurate concepts (t=-1.104, df=63, p=0,274), and (iv) number of accurate propositions (t=-0.532, df=63, p=0,596). This provides evidence supporting the abovementioned inference that the two groups were initially equivalent. As shown in Table 2, students' concept maps of both groups represented more concepts and propositions in post-test than in pre-test. Results indicated insignificant differences between the two groups for the number of concepts (t=1.713, df=47.498, p=0.093) and propositions (t=1.11, df=52.884, p=0.272) represented on post-test concept maps. However, results for the accuracy of the represented concepts (t=4.28, df=63, 2-tailed p<0.001) and propositions (t=3.54, df=63, 2-tailed p=0.001) indicated significant difference between the two groups. The students of the experimental group were able to represent more accurate concepts on their maps and construct more accurate relationships among these concepts. This provides evidence supporting the inference that experimental group students were able to achieve overall higher measures of performance than control group students.

Concept Mapping Measures	**Experimental Group (n=33) Working with COMPASS**		**Control Group (n=32) Traditional teaching**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Similarity Index	11.61 (8.11)	58.45 (15.26)	12.13 (8.27)	43.63 (17.86)
Number of represented concepts	9.27 (2.5)	18.45 (1.95)	9.75 (2.69)	17.22 (3.6)
Number of represented propositions	8.42 (2.49)	19.36 (3.1)	8.72 (3.36)	18.25 (4.79)
Number of accurate concepts	3.85 (2.33)	16.58 (3.01)	4.5 (2.42)	12.97 (3.75)
Number of accurate propositions	2.88 (2.19)	15.97 (4.1)	3.19 (2.48)	12.06 (4.78)

Table 2: Means (and standard deviations) of the pre-test and post-test concept mapping measures

Students' responses to open questions revealed that the students of the experimental group enjoyed their activity with COMPASS and found the process of constructing a concept map with COMPASS interesting. Also, 67% of the students asserted that all of the system's functions were well organized and useful, while 15% of them expressed their negative attitude towards the expert map facility. Most of the students (31 out of 33) reported that the provided feedback helped them to learn the concepts, understand their errors and construct their concept map. The tutoring feedback units for the concepts as well as the various types supported (description, example, definition, images etc.) were very useful for most of the students (94%) as students during the elaboration of the activity at any time had the opportunity to study the concepts that were unknown or they didn't remember. It is worthwhile mentioning that a considerable number of students started the construction of the concept map after studying the tutoring feedback units provided for a number of concepts. The available list of concepts, the structure/steps of the dialogue-based form of feedback and the tutoring feedback units stood high in most of the students favour. Among the facilities that were characterized as most useful were the explanation of the propositions, the tutoring feedback units and the reflective questions. Some of the students (8 out of 33) asserted that there was no reason to see the expert map, as the correct answer/proposition in dialogue-based form of feedback was always available. Moreover, a considerable number of students reported that although they had at their disposal the expert map, they tried to avoid seeing it and preferred to find alone their errors. It is interesting to mention that a number of students advised the expert map at the end after completing their activity. The performance feedback provided by COMPASS seems not to influence the performance of a number of students (13 out of 33), as they tried to focus on the representation of the concepts and their relationships and they selected to see their performance after a number of trials in correcting and re-examining their represented concepts/propositions. Indicative students' comments were: '*I like working with COMPASS because I have the opportunity to learn the unknown concepts through the available material*', '*It was a specially-interesting experience*', '*I favoured the dialogue-based form of feedback as the sequence of the steps gave me the chance to receive as much help as I needed*', '*I would like to work out more concept mapping activities with COMPASS in the future*', '*I was impressed by the feedback provided. During the activity, I felt that I had always at my disposal as much help as I needed*', '*It was an enjoyable and creative activity*', '*I would like to work with COMPASS in various subject matters as concept mapping activities and the feedback provided help me to comprehend the various concepts under consideration*'.

4 Summary and Further Research

In this paper, an overview of the main features of the COMPASS environment was given and the results of an experimental study were presented, focusing on the effectiveness of COMPASS in supporting teaching and learning. The results were positive and encouraging, indicating that the concept mapping task that students worked out as well as the facilities of the environment (e.g. alternative feedback forms and components, analysis and assessment of students' maps) helped students in learning the underlying concepts. COMPASS could be a useful tool of a teacher's toolbox and could be exploited as an effective alternative teaching and learning tool. Our future plans include the exploitation of COMPASS as an assessment tool, the analysis of students' interaction with COMPASS and their preferences with the different feedback forms and components, and the development of appropriate modules that would support the collaboration of students.

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EXPLORING ROOTS OF RIGOR: A PROPOSAL OF A METHODOLOGY FOR ANALYZING THE CONCEPTUAL CHANGE FROM A NOVICE TO AN EXPERT

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Abstract. During the course of science education one of the recognizable and desirable changes from a novice to an expert is in their language (knowledge representation). One noticeable change is that of weeding out ambiguous expressions bringing in clarity and rigor. However, this happens not by weeding out the concept names but by choosing more and more accurate linking words (relation names). By focusing on the relation names we report the results of a preliminary study that confirms that subject experts increasingly chose relation names (linking words) that come closer to formal descriptions. The significance of this observation to concept mapping community as well as to cognitive development is immense, for it provides a simple and effective method to study conceptual change, validates the use of refined concept maps in place of the traditional technique in science education, and also further strengthens the approach that relationship between nodes determine the semantics, and not the nodes per se.

1 Introduction

The context of the work is to analyze the transformations in knowledge representation from a novice to an expert. Several comparative studies were done by cognitive scientists, each of them focusing on some aspect. It is observed in one such study, that the expert's knowledge structure is coherent, economical and tightly integrated, while a novice's knowledge structure is often inconsistent, ambiguous, and loosely organized (Brewer & Samarapungavan 1991). Concepts in an expert's network are rich in interconnections than those of novice's network. Experts tends to focus on relations among concepts and while grouping of concepts, use the same relations criteria (Cooke, 1991. p. 38). Representations of expert's knowledge emerge over a period as a function of *repetitive refinements*. (Mack & Robinson, 1991, p. 265).

We focus in this work on the refinements that happen in the transformation of a novice to an expert in terms of the nature of changes in the knowledge representation. We use a variety of concept mapping technique for this analysis, focusing on the number and kinds of linking words used by novices and experts. Most significant focus of our study is on relations between the nodes (concepts), and not on the nodes per se. We follow the structuralist perspective that meaning of a node comes from the relations it has with other nodes. If meaning resides in the relations, as we assume, and given the fact that there occurs a change in meaning during the course of cognitive development, it is natural to look for the root of the change in the relations. We know that experts' knowledge is more rigorous and unambiguous than that of novices'. Can the roots of rigor and precision lie also in the nature of relations used by the experts? If so, what is that nature?

We hypothesize that during the cognitive development of a novice into an expert:

i. conceptual change happens due to re-writing the names of relations, and not due to re-writing the names of nodes,
ii. the number of relation names used progressively decrease,
iii. the same relation names are consistently used eliminating ambiguity and
iv. the number of relation names required for a formal representation in a given domain are not only finite but few. The lesser the relation names, the greater the formal character of the representation.

These proposals, if found to be true, will undoubtedly have a significant impact on cognitive development research, as well as implications to science education practice and research. They also have deeper epistemological implications. We must confess that we are neither providing conclusive verification to the proposal, nor are we examining the implications. That must wait for another occasion. Therefore, we are *not* attempting to provide a full empirical support in this paper, but we describe how a preliminary study was conducted, the nature of the analysis and how it can help to carry out a major study. The purpose of this paper therefore is to share our confidence in the strategy we are following, the details of the ongoing work, the methodology that we are following and some preliminary results. We welcome critical comments, falsifying cases, and possibly other methods of substantiating the above proposal.

2 The Method

The method constitutes in collecting the propositions of a member of a group, identifying the relation name (linking word) in a proposition, categorizing the relation names based on semantics, taking count of the number of relation names used in a fixed domain. The idea is to compare the sentences of a novice with that of the text book as well as subject experts for a given proposition selected from the same domain of knowledge.[1]

We collected the novice's sentences from a group of about 30 students of 9th grade eliciting their knowledge of a portion of cell biology (*structure and function of nucleus and mitochondria*), which is the domain for this comparative study. The student sample is a homogeneous group of 32 students, age 13-14 years, mixed gender from an urban school studying in English medium. The task given was to describe nucleus and mitochondria using simple sentences in about 45 minutes. The topic chosen was already covered in their school, and in addition to this the chapter was read out to the students before the responses were given. Their responses were compared with the sentences in the text book (NCERT, 2007) the students followed, by selecting the sentences stating the same proposition. We also took the sentences from two other text books (Campbell & Reece, 2005 and Taylor, et.al. 2003) prescribed for upto 12th grade, as an intermediary stage of the development. All these sentences were then compared with that of subject experts, by selecting the sentences from well known and authoritative books in the area of cell biology (DeRobertis & DeRobertis, 1995).

It is however possible to perform the study by several alternative ways. Our choices were mostly determined by what is possible within the time constraints. One distinct possibility is to do a cross age study collecting sentences from different groups exposed to increasingly greater exposure to a given subject domain. We are soon embarking on such a study. In this study however we took a rather complete sample for the novices, while a much shorter route for other stages by selecting sentences: (i) from two textbooks by authoritative undergraduate level books; (iii) from a standard advanced level book as representative of expert's stage, while considering the students of 9th grade as representative of the novices. The study can be further extended by collecting sentences from scientists, subject experts, researchers, science educationists, textbook writers, teachers, and students from different levels. Such a study may give highly granular picture of the process and verification or a falsification of the proposal.

We have also constructed sentences by following the relation names of the formal knowledge representation group (knowledge engineers), as a highly refined representation of the domain. When we create a concept map using the relation names suggested by the knowledge engineers we get, what we call, a *refined concept map* (RCM) (Refined Concept Map, 2006) as shown in Figures 1 & 2. The required relation names are selected from Relations Ontology (RO, 2006) to draw the RCM, with some exception as noted in the legend. Since, even subject experts often tolerate or commit non-rigorous expressions, particularly in biology (due to absence of formal representations), we consider the RCM, being a finer representation available, as a reference for the study and as a bridging tool for facilitating the transformation of a novice into an expert.

Dimension	Relation Names (Relation Types)
Part-Whole	• consists of • composed of • contained in
Class-inclusion	• includes
Spatial-inclusion	• surrounded by* • enveloped by* • covered by • located in • adjacent to • connected to • overlaps • wound around* • bound by* • occurs as*
Function	• has function
Attributes	• has nature • has size • has shape • has color • has property
Examples	• example • instance of

Table 1: Selected relation types recommended by the knowledge representation groups for the domain of cell biology. The names marked '*' do not yet have a formal semantic definition. A few of the relation names may be removed from the list, as and when some of them are defined in terms of the others. Also note that the list is not exhaustive.

3 The Analysis

The sentences written by the students to represent a proposition were selected, the nodes and the relation name used by them were marked. Then, we searched for the nodes and the relation names used by the text book and

1 We use the term 'sentence' for the various possible representations of a given assertion. And the term 'proposition' for the meaning of the several possible sentences.

by the subject expert (DeRobertis & DeRobertis, 1995), as shown in Table 1. For example, for the two nodes 'nucleus' and 'DNA' the relation names used are 'contains', 'comprised of', 'has', 'consists of', 'present inside' (inverse) by the students for the proposition 'nucleus contains DNA'. The textbook used the relation name 'contains'. The experts used 'contains' consistently. Our student sample however is large (n=32), while we considered only one subject expert. The text books of higher secondary level also used 'contains' consistently. This may be taken as an indication that experts completely weed out the other relation names. According to the knowledge representation experts, the relation name 'contains' is to be used only when expressing the relation between a material object with a region (such as a cavity or channel) (Smith, et.al., 2005).

The novice group used the relation names 'have', 'present in', 'consists of', and 'made of' for the two nodes 'chromosomes' and 'DNA'. The textbook used 'composed of', and the experts used 'made of', 'composed of' and 'complex of'. The incorrect relation names 'present in', and 'have' are considered weeded out in this case, with an additional relation name 'complex of' appearing in an expert's representation.

Dimension	Students	Textbooks		Experts
		Secondary level	**UnderGraduate level**	
Part-whole •nucleus contains chromosomes	• nucleus *is comprised of* DNA • nucleus *consists of* DNA • nucleus *contains* DNA • nuclues *has* DNA *present inside* • nucleus *has* DNA	• nucleus *contains* DNA	• nucleus *contains* DNA	• nuclei *contain* DNA
	• nucleus *contain* proteins and DNA • nucleus *consists of* chromosomes, DNA, proteins • nucleus *has* chromatin	• chromosomes *composed of* DNA, proteins	• Chromatin *is made of* proteins • Chromatin *is made of* DNA • Chromatin *composed of* coils of DNA	• chromatin *is a complex of* DNA and Histones
Spatial Inclusion • nucleus enveloped by nuclear membrane	• nuclues *contains* a nuclear membrane • nucleus *has* a nuclear membrane	• nucleus *is covered by* nuclear membrane	• nucleus is *enclosed by* nuclear envelope	• nucleus *is surrounded by* an envelope

Table 2: Sample propositions from various groups used for comparison and analysis.

The relation 'consists of' is indeed a part-whole relation, but does not specify the stronger constituent sense, that 'composed of' or 'made of' provide. Knowledge representation experts also recommend the use of 'composed of' when a whole constitutes parts materially (Keet, 2007). Mixing of spatial relations (containment) and parthood relations are often used interchangeably by the novices. This is noticed even among the experts. For example, in 'DNA is present in chromatin' and 'Chromosomes contain DNA', we see that containment relation is used in place of composition. However, such instances are found very sparingly.

The distinction between component and compartment is not noticed among the novices. Though the text books did not use relation names incorrectly, the novices tend to use 'consists of' and 'composed of' in a similar sense. No explicit mention of the distinction is found in text books, except among the subject experts. Historically, e.g. nucleus was considered a component, but as ultrastructure of the cell was revealed and dynamic aspects of cell cycle unraveled, nucleus becomes a compartment. This conceptual change that we witness in history can also be seen in the transformation of a novice to an expert.

In the proposition 'nucleus is enclosed by nuclear membrane' the concepts 'nucleus' and 'nuclear membrane' take part in a spatial and not part-whole relation. Therefore the more accurate linking word can be 'enclosed by' which we see was used by the experts. However the students' group used 'contains', 'has' and the textbook used 'covered by' which is similar to the expert's name. The usage of linking words 'contains' and 'has' can be said to be inaccurate in this context since the former is spatial and latter is ambiguous. The experts group has accurately used the linking word and the textbook group in this case is quite close to the proposition. Few more elaborated examples of comparison of the relation names used in a sentence by the novice (students) and an expert are depicted in Table 3.

Dimensions	Students	Expert
Part-whole	• nucleus is *comprised of* DNA • nucleus *consists of* DNA • nucleus *contains* DNA • nucleus *has* DNA present inside • nucleus *has* DNA	• nuclei *contain* DNA
	• nucleus *contains* chromatin • chromatin *is present inside* the nucleus • chromatin *is inside the* nucleus • nucleus *consists of* genetic material	• DNA *is present in* chromatin
	• chromosomes *have* DNA which *contain* the information	• chromosomes *contain* DNA
	• chromatin network *are made up of* DNA and protein • chromatin *contains* genes	• chromatin is a complex of DNA and Histones • chromatin *contains* DNA, RNA, basic proteins called histones, non-histone proteins
	• nucleus *contains* genetic material called genes • chromatin *contains* genes	• genes *present in the* chromosomes are found in pairs called alleles • genes *are made up of* DNA • genes *are located in* chromosomes
	• mitochondria *has its* own ribosomes and DNA • mitochondria *consists of its* own ribosome and DNA • mitochondria *have their* own DNA and ribosomes to produce proteins • mitochondria *have their* own genetic material like DNA and ribosomes • mitochondria *contains* its own DNA and ribosomes • mitochondria *has* its own ribosomes	• mitochondria *contain* DNA and ribosomes • *within the* mitochondrial matrix are small ribosomes and a circular DNA
Class-inclusion	• mitochondria *is a* double-layered cell organelle • mitochondria *is a* double layered organelle • mitochondria *is a* cylinder shaped important organelle • mitochondria *is a* cell organelle which is double layered membrane	• the inner membrane *divides the* mitochondrion into two chambers or compartments-outer and inner chamber
Spatial-inclusion	• nucleus *contains* chromosome which are visible as rod shpaed objects • nucleus *contains* entangled mass called chromosomes which become rod-like structures when the cell is about to divide	• nucleoli *can be observed inside* the nucleus • chromatin *associated with* nucleolus; nucleoplasm

Table 3: Comparison of Students and Experts Relations

Thus we see that experts, either tacitly or consciously, do use accurate relation names expressing the desired meaning. To fill the gaps in our study we need to include the groups of students, say of higher secondary, under graduate and graduate level. This kind of analysis though is time consuming, the method is simple and can be effectively carried out. We also think that the method can be used for studying conceptual change in all developmental studies, whether the development is ontogenic or phylogenic. By holding the relation names as constant, we can probe the kind of nodes that were used correctly and incorrectly by the agents, and similarly, by holding the nodes constant we can take notice of the kinds of relation names used. This preliminary study we carried out at least demonstrates that such a study is feasible and could throw more light on the changes, and possibly may become an effective methodology for understanding conceptual change and if the proposed hypotheses are proven we come close to the roots of rigor.

4 Discussion

The study if extended to a large number of groups along the course of cognitive development, we hope will provide more substantiation or may even falsify the claim. Instead of analyzing the text books, which are usually meticulously crafted before publication, it is worth studying either by interviewing the subject experts or by administering questionnaires. Since authors of text books do keep in mind the level of audience while writing the book, the language used can be used as a reasonable indicator of the group. We plan to repeat this study by selecting four to five text books of each grade, keeping the domain of knowledge constant.

We notice that, some experts whose focus is on the molecular biology did not even consider the need to assert a relation between "nucleus" and "DNA". Nucleus, being a transient structure the emphasis of the subject expert shifts to the basal components like "DNA", proteins and their assembly into nucleosomes. In the book on *Molecular Biology* by Watson (2004), there exists no entry for "nucleus" in the index. This indicates that some node names like "nucleus" so to speak pushed to the periphery. As already noted, several components eventually are recognized more aptly as compartments. Thus, the method suggested in this paper can provide such revealing observations that happen during the development.

Our claim that the nodes do not get replaced by others may be questioned on the ground that further nodes that get added haven't been considered, for the study systematically avoids them. Since, it is necessary to study how the same proposition is expressed by the experts, we did not consider other node names. However, even when we take them into account, we do see that very few relation names, often well defined, get in at later stages, while more nodes do get into the discourse as well. In a sense, the claim is that during the course of development process, knowledge gets added with just a few relation names but with more of nodes. As the knowledge gets represented in more formal terms, the relation names decrease progressively. Thus effectively all the nodes are handled by minimal relation names. Parsimony therefore can be redefined in terms of relation names.

These claims, we are aware, are little far fetched based on the current level of the study. We nevertheless make them to report the nature of implications a study like this may have. We report the partial results to elicit comments and suggestions and of course criticism. We plan to continue the study by adding more nodes into the knowledge base, and characterizing in greater detail the changing profiles during the development by including the groups of students, say of higher secondary, undergraduate and graduate level as well, and also performing analysis of at least five text books of each level keeping the domain constant.

Ever since, Thomas Kuhn (1960) highlighted the changes in the conceptual schemes occurring during the scientific revolutions, several scholars took notice of this to study the paradigm shifts. Paul Thagard (1992) used a crude form of concept maps to highlight the changes in the schema. Nancy Nersessian (1989) used concept maps to visually provide differences in the changes. These maps captured the network of ideas, shows the location, and exhibit changes throughout the network more clearly. Among the cognitive studies, Susan Carey (1986) carried out, by pointing out the transformation from a novice to an expert, the changes in knowledge structures from weak to strong restructuring. In the process, she points out, that the changes are not only *accretion* of concepts but also new concepts gets *subsumed* in a network. In the science education domain, concept maps have been used to explore the conceptual changes by demonstrating that students depict changes in the critical concepts, propositions and their maps become intricate and hierarchical in representation (Wallace & Mintzes, 1990, pg. 1038). Mintzes (2007) demonstrated a *punctuated model* of conceptual change with the use of concept maps, wherein the weak restructuring of the subsuming of concepts were punctured by strong restructuring involving integrating of concepts with relations. In another form of representation by Fisher used concept mapping to determine the processes of conceptual changes by focusing on the linking words in a semantic network (Fisher, 1990).

Thus, it is well known that conceptual change happens due to restructuring, and the structuralist approach that meaning of a concept emanates from the relations it has with other concepts, we further explore to operationalize this research using refined concept mapping by focusing on relation names. This is also in line with the observations made in the knowledge representation community that the regular or traditional concept map was not found to be apt for depicting scientific knowledge due to the presence of ambiguities, and inconsistencies in the usage of linking words (Kharatmal & Nagarjuna 2006, Sowa 2006, Kremer 1995).

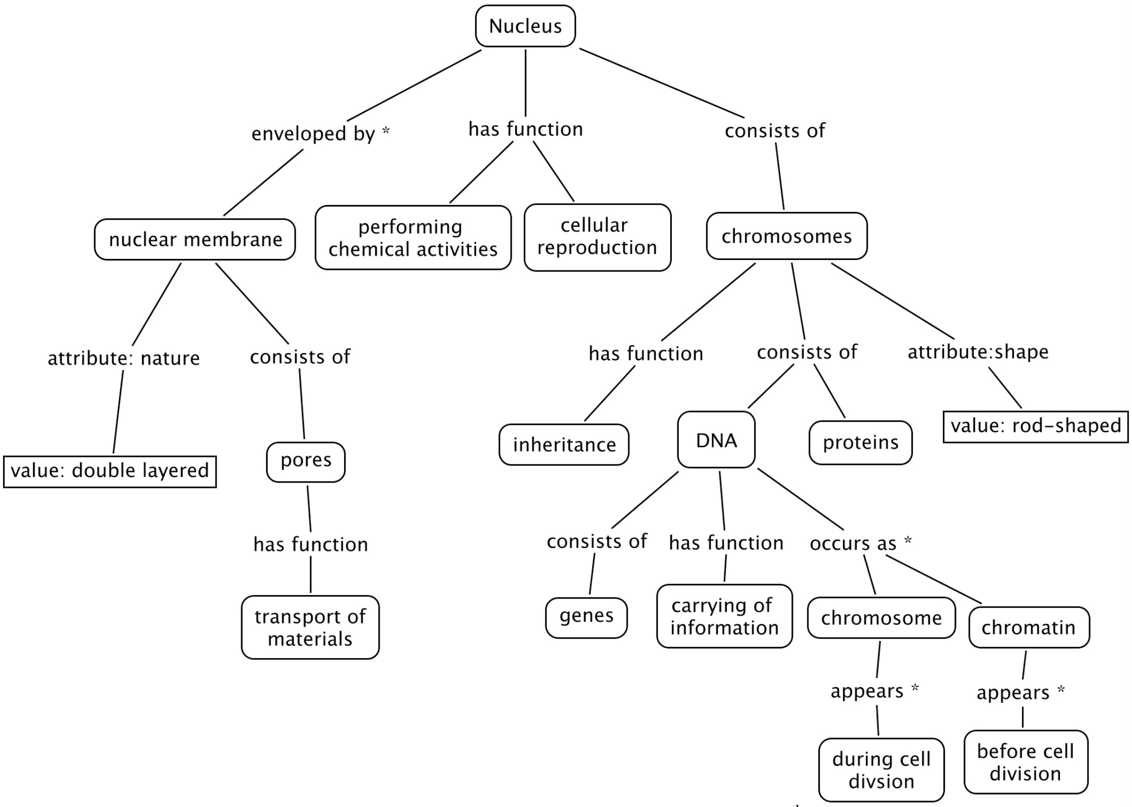

Figure 1: A refined concept map on *nucleus* drawn by the authors based on the 9th grade textbook (NCERT 2007). The relation names with * are not in the formal groups' relation vocabulary. Keeping in mind the level of the text, we used them based on the text to ensure proper mapping.

Accordingly, by identifying certain anomalies in the existing concept mapping methodology and by suggesting some refinements in the concept mapping methodology was proposed by Kharatmal & Nagarjuna (2006) to make concept maps effective for science education. By restricting the set of relation names, formally defined names provided for each domain more rigorous maps can be made without loss of knowledge (Kharatmal & Nagarjuna 2009). If we assume that the objective of science education can be best met by facilitating restructuring and re-representing of knowledge structure, then this disciplined method aids in such a transition.

In a more general theory, Karmilloff-Smith (1995) argues that during cognitive development the knowledge gets recursively *re-represented* and in the process implicit knowledge transforms into explicit knowledge. In these terms, it can be stated that well-defined relation names are the means of the transition from implicit to explicit. Formal knowledge being the most explicit consists of nothing other than the well-defined invariant relations keeping the nodes as variables. Thus the roots of rigor reside in relations. Given that meaning resides in relations, facilitating meaningful learning (Ausubel, 1978; Mintzes, et.al., 1997; Mintzes, et.al., 1998; Novak, 1984) must focus on the use of the few invariant relations while teaching science.

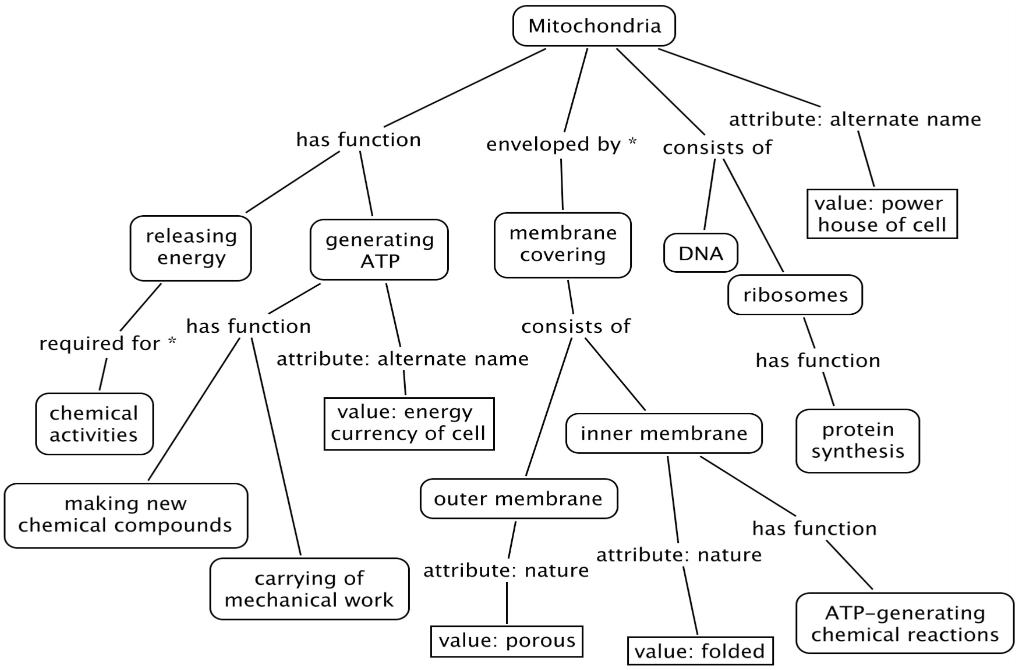

Figure 2: A refined concept map of mitochondria drawn by the authors based on the 9th grade text book (NCERT 2007). The relation names with * are explained in the legend of Figure 1.

To conclude, we submit that this preliminary study does not provide conclusive evidence to the hypotheses proposed, but the study does point to new possible methodology that can help us in studying the conceptual change from novice to an expert.

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FAULTS IN CONCEPT MAPPING: A MATTER OF TECHNIQUE OR SUBJECT?

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Abstract. Concept maps appear to reflect a user's knowledge achievement. For examining the impact of a subject's difficulty or rather Cognitive Load on concept mapping within an educational implementation, we developed a lesson about two differently complex subject matters. Furthermore, we intended to verify whether concept mapping is an acceptable knowledge test or not. A-level 6th graders produced individual concept maps with regard to a taught subject matter immediately after a computer-aided biology lesson. Each group produced a concept map about both implemented subject matters. Altogether 283 students participated by producing 138 concept maps about the subject matter "Polliwog to Frog" (A) and 136 about the "Ecosystem Lake" (B). We analysed the maps' complexity as well as the types of faults and we correlated the individual student's knowledge scores with his/her concept map's complexity. Students in general produced more complex concept maps about the easier subject matter (A), and they had difficulties to verbalize the appropriate connections of the complex subject matter (B). We found significant correlations between the knowledge scores and the actual complexity of a concept map: The actual complexity underestimates a student's knowledge in general. The conclusions for an implementation in a classroom will be specifically discussed.

1 Introduction NEW

Concept Mapping (CM) was frequently discussed as an appropriate method for knowledge testing (Novak 1984, Horn 2003, Schaal 2006). It represents a rather complex approach in assisting to develop visual presentations of complex coherences and in reflecting individually newly-acquired knowledge (Stracke 2004). It has some demand on the limited information capacity of the mental activity of working memory labelled as Cognitive Load (CL) (e.g. Baddeley 1992). Sweller, Merrienboer, Paas (1998) assume three CL components as (i) intrinsic load caused by the content complexity, (ii) extraneous load caused by the instructional mode, and (iii) germane load necessary for individually processing information towards long-term memory. As all three components are assumed to be additive (Sweller 2006) an increase of component (i) and/or (ii) without decrease of the other would cause a Cognitive *Over*load. Capacity for (iii) germane load would be reduced and consequently cognitive learning of the subject matter. Applied to the CL theory (i) intrinsic load is the subject matter and (ii) extraneous load is referring to the lesson within the consolidation phase, e.g. concept mapping.

In our study, concept mapping was spontaneously introduced to the students as a consolidation phase in a 6th grade computer-supported biology lesson. In order to check the hypothesis that CM provides an appropriate knowledge test we correlated post-test knowledge scores and actual complexity (AC) of concept maps. To investigate the effect of CL we altered (i) intrinsic load with two differently difficulty subject matters and compared students' achievement. Therefore we designed a lesson about two differently difficulty subject matters. CM was introduced to the novice students as a consolidation phase. For a reduction of cognitive overload (e.g. Baddeley 1992; Scharfenberg, Bogner, Klautke 2007) component (ii) we simplified the design by implementing specific pre-structures with pre-defined items (Nückles 2004) (Table 1). None of the linking phrases were pre-defined.

2 Data collection

Altogether 283 6th graders participated in our study, a total of ten Bavarian high school classes (highest stratification level [=Gymnasium]). The concept mapping was introduced to the students as a knowledge consolidation phase after a completion of a computer-supported lesson. Students were novices with regard to the method itself and that is why we introduced the concept mapping with a separate ten-minute preface: for this purpose the teacher functioned as a tutor by presenting an example unrelated to our subject content. We selected two subject matters for its implementation; students had 35 minutes to complete the poster in dyads. Both subject contents differed in term of its content and its quantity. The first subject (A) dealt with "Polliwog to Frog" consisting of 18 pre-defined items; the second (B) was more complex and dealt with the "Ecosystem Lake" consisting of 24 items (Table 1). Students were free to add more items. Linking phrases were not specified. For the afterwards analysis all hand-written concept map posters were digitised with MaNet® 1.6.1. (© MaResCom GmbH) (Figure 1). Previous knowledge and changes in standard of knowledge were measured by means of pre-test (K1) two weeks before and post-test (K2) immediately after the lesson.

(A) Polliwog to Frog	polliwog	larva of frogs	spawn	eggs	cluster	brood care
	march	metamorphosis	gills	lung	insects	algae
	foreleg	hind leg	singing	frog	mating	tail
(B) Ecosystem Lake	cohabitat	biocoenosis	temperature	biotope	oxygen	consumer
	herbivore	abiotic factors	biotic factors	bacteria	biomass	producer
	carnivore	photosynthesis	decomposer	animals	light	destruents
	1^{st} order	2^{nd} order	ecosystem	plants	habitat	user

Table 1: Pre-defined Items of subject (A) “Polliwog to Frog” and (B) “Ecosystem Lake”

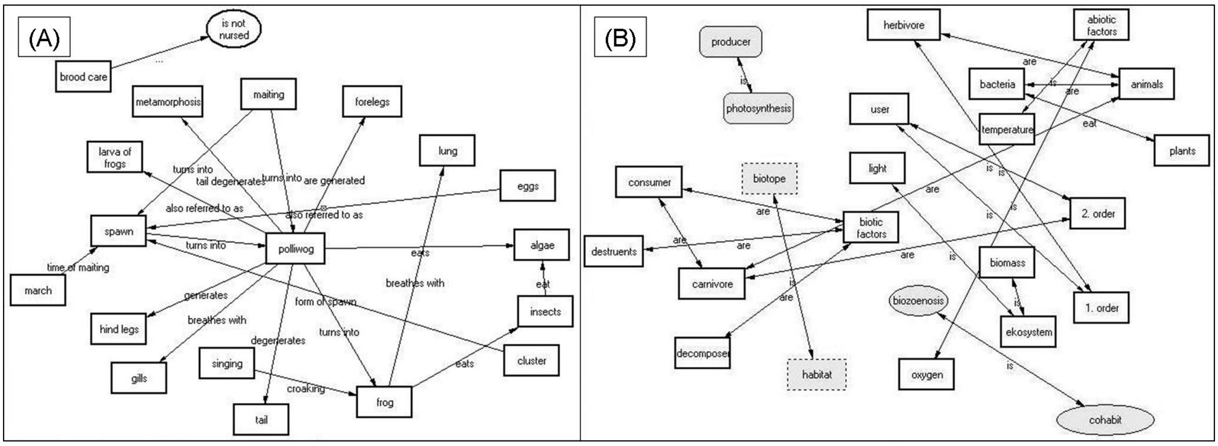


Figure 1. Examples for digitised, not corrected concept maps about subject (A) “Polliwog to Frog” and (B) “Ecosystem Lake” annotation: in (A) round frame marks not pre-defined item, added by student; in (B) different frames mark different subnets

3 Analysis of concept maps

3.1 Analysis of objectivity

The objectivity of analysis is guaranteed, if its test analysis is not influenced by the analyzer. This is taken for granted, if different persons come to same results of correction (Bortz, Döring 1995). Therefore, the correctors analyzed 10% of the concept maps a second time after four weeks as well as a second corrector analyzed the same 10% independently. The comparison of the results of two correctors tests the objectivity of the interpretation of the connections (Ingenkamp 1992). The results of all correctors were compared to calculate objectivity by Cohen’s kappa- coefficient of the cross tabulation (Zöfel 2002) (Table 2).

$$\text{kappa} = \frac{n \cdot \sum_{i=1}^{k} d_i - \sum_{i=1}^{k} z_i \cdot s_i}{n^2 \cdot \sum_{i=1}^{k} z_i \cdot s_i}$$

Table 2: Objectivity of interpretation of errors by calculation of Cohen’s kappa-Coeffizient;
k = number of row/column; n = overall frequency; zi = sum of rows; si = sum of columns; di = frequency in diagonal

3.2 Quantitative analysis

We analyzed following parameters: 1) the maximal complexity (MC) which is the number of all connections the student created; 2) the actual complexity (AC), is the complexity of the concept map after all incorrect relations were deleted; 3) the corrected actual complexity (CAC), is the AC after all relations, that are incorrect with regard to the content but not in respect of technique were deleted; 4) the number of all mistakes; 5) the number of subnets are nets without connection to each other within the concept map (fig. 1(B)). In this study a perfect concept map has only one net.

3.3 Qualitative analysis - Comparison between the subject matters

We considered six error types made while constructing the concept maps. In our opinion there are three reasons why students made errors: they did not understand the method of concept mapping (1), the content (2), or both

(3) (Table 3). We followed the classification of Schmucker (2007). We differed in the estimate of the reason of error F5 *(SG3)*. In our opinion this is not a problem of the method, but of the students' knowledge.

The pre-test attests previous knowledge about subject (A) (mean score 58%) but hardly any about subject (B) (mean score 41%). Students had already hands-on experience with subject (A), but not with subject (B) which was abstract including many Latin terms. Due to these findings we distinguish between the subjects as (A) easy and (B) complex. To evaluate under which circumstances concept mapping may provide a useful method to get a general idea of a topic we compared the concept maps about the two subject matters. Furthermore, we analysed whether concept mapping can match with conventional knowledge tests, we correlated both the actual complexity AC and the corrected actual complexity CAC of the concept maps with knowledge scores.

error types	***possible reasons for errors***	***example***
F1: *right linking phrase – wrong direction of arrow (S5)*	*method not apprehended*	Frog ← breaths with — lung
F2: *right linking phrase – no direction of arrow (S4)*		Frog breaths with lung
F3: *wrong linking phrase – direction of arrow indicated (S6)*	*content not apprehended*	Frog — breaths with → gills
F5: *wrong linking phrase – no direction of arrow (S3)*		Frog breaths with gills
F4: *no linking phrase – direction of arrow indicated (S1)*	*method and content not apprehended*	Frog .. → lung
F6: *no linking phrase – no direction of arrow (S2)*		Frog .. lung

Table 3: Error types and possible reasons for errors *(S = definition of Schmucker2007)*

3.4 Correlation between Concept Maps and knowledge post-test

In order to check whether concept maps represent students' content knowledge, we correlated the complexity of the concept maps with students' knowledge scores of the post-test. In doing so we distinguished the actual complexity AC without errors in respect of both content and method and the corrected actual complexity CAC without mistakes in respect of content. The correlation was tested by a bivariate correlation with Spearman's Rho and two-tailed significance.

4 Results

4.1 Analysis of objectivity

The analysis of objectivity according to Zöfel (2002) revealed for both analyzers a coincidence of 82% for subject (A) "Polliwog to Frog" and 70% for the subject (B) "Ecosystem Lake", respectively. The coincidence of the 1st and 2nd analysis of the same analyzer is 83 % (subject (A)) and 97% (subject (B)).

4.2 Quantitative analysis

Due to our data' non-normal distribution we used non-parametric analysis. 58.6% of our concept maps about subject (A) embodied less than 6 mistakes, the median is 5 mistakes. Only 27% of the concept maps about subject (B) contain just small mistakes. In 62.7% of them about 6 to 25 mistakes were found. The median is 8 mistakes (Figure 2). The median of the actual complexity AC of the concept maps about subject (A) is 13, about subject (B) 11 (Figure 3). The corrected actual complexity CAC is higher with a median of 14 about subject (A) and 14.5 about subject (2) (Figure 7). The median of subnets per concept map is 5 about subject (A) and enormous 13 about subject (B) (Figure 5).

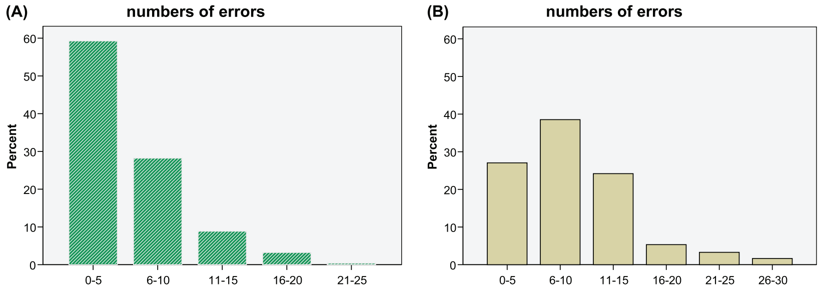


Figure 2. Number of errors per cmap (A) "Polliwog to Frog" (B) "Ecosystem Lake"

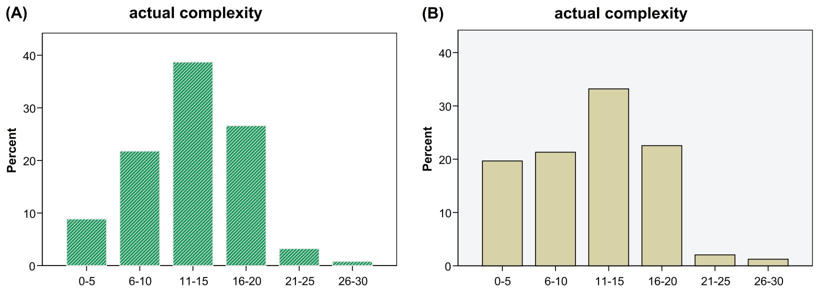


Figure 3. Actual complexity (A) "Polliwog to Frog" (B) "Ecosystem Lake"

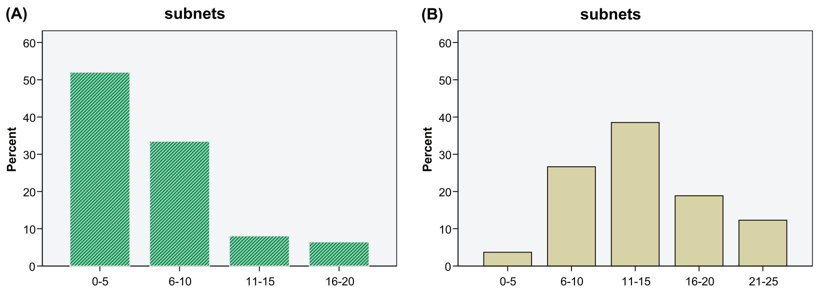


Figure 4. Numbers of subnets per cmap (A) "Polliwog to Frog" (B) "Ecosystem Lake"

4.3 Qualitative analysis - Comparison between the subject matters

In both subjects, it matters the percentage of mistakes F1, F2 and F4 which is shown to be equivalent (Figure 5). F1 and F2 are technical errors just as F4: the connection was mislabelled without any direction. There are substantial quality differences between the two subject matters with regard to the content errors and the content & method errors (Figure 5). The easier, less complicate subject (A) contained more than 51% mistakes F3, doubtless with respect to the content. But the more difficult and complex subject matter (B) produced only 29% of F3 mistakes. Instead of F3 errors F5 and F6 increased substantially in percentage.

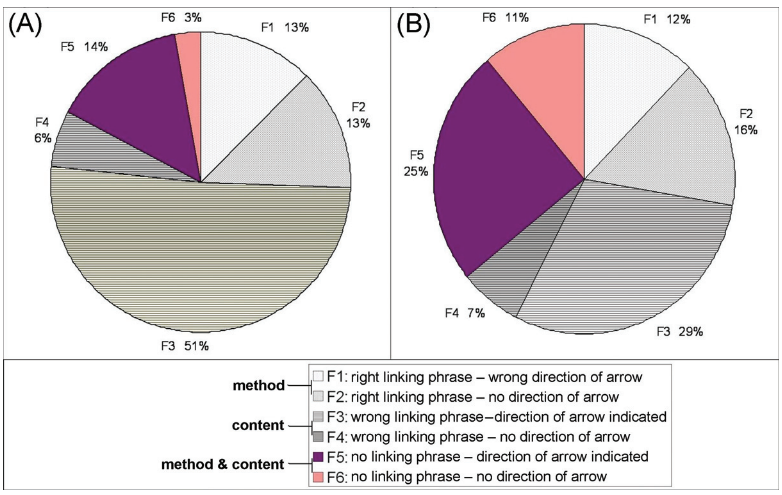


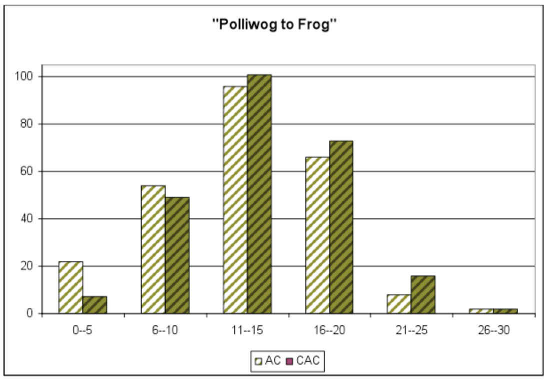
Figure 5. Distribution in percentage of error types (A) "Polliwog to Frog" (B) "Ecosystem Lake"

4.4 *Correlation between Concept Maps and knowledge post-test*

Cognitive knowledge tested by pre- and post-tests increased in both subject matters (tab.4 p=0.000). Figure 6 shows the CAC in comparison with AC for both subjects. The number of concept maps with high complexity increases especially for subject (B). The correlation AC of concept maps and knowledge tests are highly significant. The CAC without deletion of technical errors correlates even better (Table 5). However, the correlations with the post-tests are weak with coefficients about 0.2 (tab. 5).

Subject Matter	*Test*	*sum score*	*SD*	*Wilcoxon*	
				Z	*asymp. Sig. (2-tailed)*
(A) Polliwog to Frog	prae-test	5.9	1.91	-12.662	0.000
	post-test	8.5	1.32		
(B) Ecosystem Lake	prae-test	2.9	1.13	-11.579	0.000
	post-test	4.4	1.36		

Table 4: Sum scores of pre-test and post-test of subject (A) and (B) and Wilcoxon test



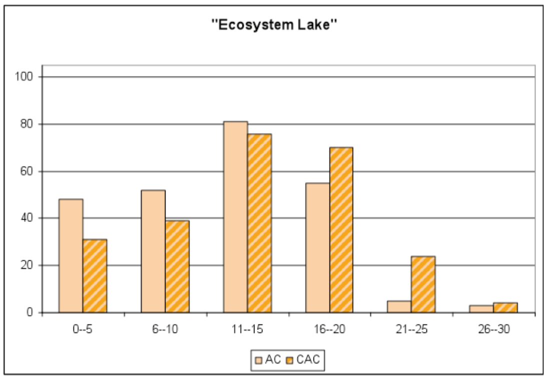


Figure 6. Actual Complexity AC and Corrected Actual Complexity CAC for (A) "Polliwog to Frog" and (B) "Ecosystem Lake"

Subject Matter	*Complexity*	*Correlation Coefficient*	*Sig. (2-tailed)*
(A) Polliwog to Frog	actual complexity AC	,195	0.002
	corrected actual complexity CAC	,208	0.001
(B) Ecosystem Lake	actual complexity AC	,271	0.000
	corrected actual complexity CAC	,297	0.000

Table 5: Spearman's Rho of knowledge post-test and AC / CAC of concept maps

5 Discussion

5.1 *Analysis of objectivity*

Objectivity of analysis of the concept maps is given in both subject matters according to Zöfel (2002). In Subject (B) there is a relatively low coincidence of 70% between the two correctors with the high coincidence of 97% of the self-testing. This indicates the complexity of the subject (B) with a high firmness of the corrector.

5.2 *Quantitative analysis*

To sum up, the more difficult the subject matter, the more mistakes and thereby the more subnets and low AC were produced in the concept map. The easier the subject, the fewer mistakes and subnets and higher AC were produced. The CAC indicates an overestimation of errors or rather an underestimation of the student's illustrated knowledge.

5.3 *Qualitative analysis*

Because of the lack of monitoring feedback about the errors in the 1st concept map (A) students could not eliminate these technical mistakes. Thus students need a second corrective introduction into the method of concept mapping, but as it seems to come naturally to them good concept maps are not necessarily an effect of more training.

Evidence suggests that the reduction of F3 errors in concept maps about subject (B) in comparison with subject (A) is because of the increase of F5. We cannot exclude that all students had enough time to finish their concept map, but the majority had. We suggest students may have been overburdened with the complexity of subject (B) and they may have tried to jot vague retention down. As this knowledge was weak students were not able to verbalize it in form of correct labelling of the relations. Cognitive overload is also possible as subject (B) was much more complicate including Latin terms and the number of items high (Scharfenberg, Bogner, Klautke 2007; Nückles 2004).

5.4 Correlation between Concept Maps and knowledge post-test

Concept maps could represent students' knowledge; however under the conditions of the present study concept maps could not be a substitution for knowledge tests. Difficult subject matters appear to cause an overestimation of errors. The correlation AC of concept maps and knowledge tests are highly significant, but weak. This is consistent with Novak, Gowin and Johansen (1983). A concept map reflects its draughtsman's knowledge. However, too many factors exist aside from the subject knowledge such as someone's ability in verbalisation. This is supported by the findings with CAC, which correlates better than the AC (Table 4). The CAC without deletion of technical errors suggests representing cognitive knowledge of the subject whereas the AC represents the ability of concept mapping, too.

6 Summary

Young students are able to handle concept mapping very well although the technique is absolutely new to them. This is true if the subject matter is easy. On the other hand, students failed to do so with a complicate subject matter. This is completely in line with Slotte & Lonka (1999).

Student made similar percentage of mistakes F1, F2 and F4 in both concept maps. Due to the lack of feedback after the construction of their 1st concept map, students could not eliminate these mistakes. This needs a 2nd explanation by the teacher. More training is not necessary as concept mapping seems to come naturally to children.

In spite of the successful practice with the first concept map (subject (A)) which achieved good results, students failed with the second subject (B), mainly caused by an increase in number of mistake F5 and F6 with simultaneous decrease in percentage of mistake F3. As the majority of the students could finish the concept map in time we suppose these mistakes reveal specific knowledge gaps. Students may have been overburdened with the complex subject and they may have tried to jot vague retention down. As this knowledge was weak students might not been able to verbalize it in form of correct labelling of the connections. Cognitive overload is also possible as subject (B) was much more complicate and the number of items high (Scharfenberg, Bogner, Klautke 2007; Nückles 2004).

We found a significant correlation between knowledge test scores of students and the complexity of their constructed concept maps. For the AC we did not different between methodical error and in respect of content. This could have caused an underestimation of the mapped knowledge. The CAC ignores methodical mistakes. The correlation of CAC with the knowledge test scores is higher then with the AC, but both are weak. In spite of the high variance a concept map could provide an indication of the student knowledge. So concept mapping application could be an adequate consolidation phase revealing specific knowledge gaps additionally. This could give teachers a guideline for the further schedule close to the students' needs.

Evaluation Programme

Mannheimer Netzwerk Elaborations Technik MaNet Version 1.6.1.

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FLEXIBLE CONCEPT MAPPING

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Abstract. In this paper we want to analyze some real cases of concept mapping and evaluate the necessity of accepting forms that are non-orthodox, both in the normal language and in a rigorous model of concept mapping syntax, provided that these forms are aimed at facilitating dynamic change of cognition and integration of new knowledge. In other words we believe that if the concept map maker is pushed to create her/his concept map within an excess of constraints, we would be at risk, as educators and mediators, for losing the main opportunity, given by this tool, to know, sustain and evaluate the learning process that is having place. The overload of working memory due to the constraining effect of the so called "rules for good concept mapping", has a very different role for children and for adults, as well as for concept map makers in agglutinative languages, as the Basque one. We want initiate a progressive and aware release of an excess of rigorousness, finalized to a better adaption of mother language to the necessities of concept mapping and vice versa, in every case.

1 Introduction

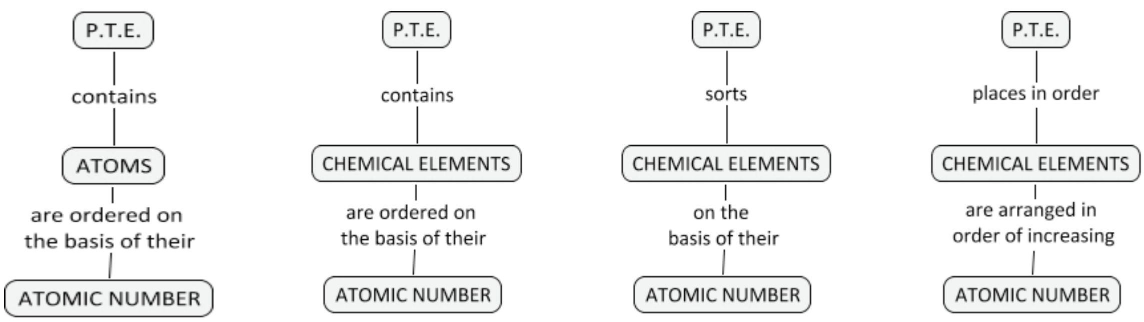
This research is aimed at both: a) explaining the rejection of concept mapping by adults and of some secondary school students as partially due to the highly elemental character of the ternary propositional structure of concept maps, compared to the complexity of relations that are managed by the adults in their natural language, and *b)* to show how these limits can be (partially) overcome by approaching further the language of concept mapping to the natural language, by enriching the variety of admitted forms for linking phrases and concept labels, by admitting exceptions to some syntax rules of both languages, reducing to the essential minimum the rules that are really mandatory. For example, nouns and pronouns are not advised in linking phrases, and some authors claims for single-word links (Kharatmal & Nagarjuna, 2006). If we want the students to construct accurate and unambiguous propositions, then the rules and conventions that are *not* strictly and explicitly related to Ausubel's background of concept mapping, should be released. For the same theoretical reasons we are convinced that the basic core of concept mapping is the most privileged code to interface with the processes of meaningful learning construction in every field, as described by Ausubel's, therefore it would be an error to interchange among various forms of knowledge representation, maybe downstreaming the specificity of each knowledge domain, if the main task is not the representative, but the metacognitive one, and if we want to give the teacher a proper tool for mediating learning.

2 Analysis of simple - but troubled - cases of concept mapping

Let's start from this example, reported from a chemistry class with fifteen years old students of one of the Authors. The following sentence was read in class from Italian Wikipedia and translated here:

> "The periodic table of elements is the key by which atoms are ordered on the basis of their atomic number Z. Conceived by chemical Russian Dimitrij Mendeleev in 1869, the PTE..."

The first three subsequent versions of the initial part of the C-map show how the plain text was decoded, recoded in a Cmap and restructured by the students that were at the very beginning practice of concept mapping.



In this first step three concepts were elicited from the text and were properly ranked. This step combines the major efforts in decoding and recoding in concept mapping.	An error, from the original text, leaped out and was corrected in #2.	The teacher focused upon the first proposition in #2 and suggested that a better verb than “contains” had to be found, because those elements aren’t "thrown in" randomly in the PTE.	This change would restore independence between the two propositions. But the first independent proposition don't answer to the question "which kind of order?", whereas the second doesn't tell "where".

Fig. 1. Three stages in the construction of the first C-map for 15 years old learners, and a try to create two independent ternary propositions.

The passage from plain text to #1-2 implies the recognition of concepts, of their role and rank in the first sentence of the c-map. Passing From #2 to #3, the first proposition has gained more precision, but the students avoided the repeated reference to the ordering in the second proposition. As a matter of fact, the first linking phrase, “sorts”, has a conceptual meaning that get complete with a sorting parameter, i.e. the concept in the second proposition. So #3 is viewed as a single coherent proposition by the students, formed by three concepts and two linking phrases (quinary). This isn’t orthodox as a form in concept mapping. In fact, if we read the second proposition in #3, [Chemical Elements on the basis of their Atomic Number], we admit that it doesn’t make sense for its incompleteness. If we further add a verb in the second link (as in #4) we could gain independence for the second phrase. But looking at #4, we introduce an element of ambiguity: there is not an explicit way, for the inexpert reader, to infer that the “elements are ordered...” inside the periodic table, and not elsewhere. The extended proposition in #3 hasn’t this drawback.

We ask ourselves to what extent and for what end should we further rearrange this map to gain both explicative capability and strict ternary structure and independence of every proposition.

We maintain that #3 is a good compromise between orthodoxy and meta-cognitive restructuring of knowledge. So #4 doesn’t add nothing to the cognitive work of the student, but it just would defer to an a priori tie of rigid rules commanded by orthodox concept mapping.

Moreover we cannot ascribe the difficulty in reproducing the correct meaning in the C-map to an intrinsic complexity of the original text. The example phrases is ubiquitous in normal texts, and we cannot renounce to the advantages of concept mapping due to a few cases like this one. Rather than evaluate formal observance of the rules in the finished C-map, we should appreciate what a work of conceptual re-modelling and refining takes place *during the process* of concept mapping.

Finally, let’s image what a psychological impact would we have if we would say: “no, it doesn’t work because the second proposition has not a complete meaning”, addressing to the student that elaborated #3 C-map.

We should remember that the “living entity” we must respect, help and encourage to grow, is the cognition of that student, not the representation of it.

Let’s examine the next example showing a typical situation, where the full meaning within a knowledge domain, results from a larger scale of the “atomic” propositions, that is from the “relations among relations”.

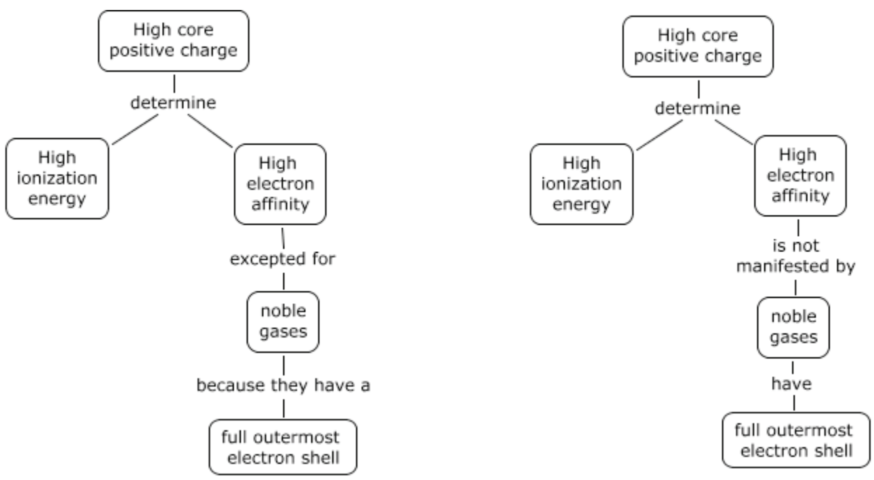


Fig. 2: the left c-map is the original one. The right one has been modified for the purpose of this paper to show the consequences of rendering all the propositions independent.

The following two propositions could be written as independent claims, but renouncing to the completeness of correlated meaning:

1. [High electron affinity] is not manifested by [Noble gases]
2. [Noble gases] have [full outermost electron shell]

A complete sense of the correlation is displayed by the complete –original- sentence:

[High core positive charge] determine [high electron affinity] excepted for [noble gases] because they have a [full outermost electron shell]

The sentence is of a "chain text" type; nevertheless it has a well distinct conceptual structure.

It is worth to notice that this sentence was not based on a text source, but on the knowledge of the student, under the synchronous reviewing - mediation of the teacher, who reminded him that a high core-charge doesn't always correspond to a high electron affinity.

If a c-map is the result of a mediation process, it is always a good one. Furthermore, The dynamic – explicative character of the C-map is given by the use of meaningful linking words as "*excepted for*" and the explanatory "*because*". If we renounce to these words for the purpose of adhering to an abstract rigorousness, we get a c-map whose real meaning need to be inferred by an expert reader. On the contrary, we believe that a C-map that aims at being a representational resource, should respect the priority of reducing the extent of implicit content for a generic reader. This can be obtained by resorting to articulated linking phrases and composed concept labels, as we can see in the next section dedicated to Euskara language.

We can see that often in the language *the relation* between two concepts *is related* to a third concept. This relation is not of a binary type and we won't renounce to make a C-map of a certain subject only because it contains some such "Y" type of relation.

Let's see an example of this case, arisen while mapping the following text in a collaborative reading of a book (Le Couter & Burreson, 2004, pag. 234), among seventeen years old teammated students:

"Combined with morphine , scopolamine is used as the anesthetic known as "Twilight sleep..."

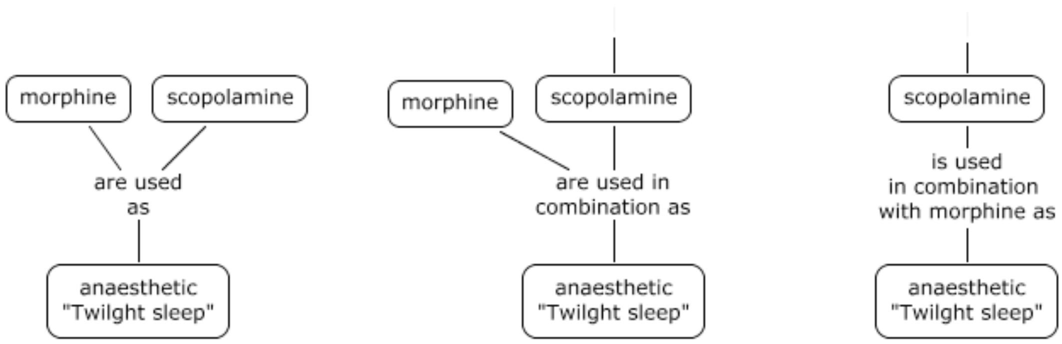


Fig. 3. How to solve a "Y" relation by "embedding" a secondary concept in the linking phrase.

The first arrangement assigns the same logical role to the concepts of [scopolamine] and [morphine]. But that solution was modified because it gave the false belief that each substance could be used separately as an anaesthetic. So the linking phrase "are used as" was properly changed by the students to give the second arrangement. However the C-map concerned hallucinatory alkaloids, so that scopolamine was the in-context concept, whereas morphine, being a drug, had an ancillary role, as pointed out by the "dead side entry", to the left of the "main stream" in the middle C-map. In these cases we propose that an exception to the rule that prohibits the use of concepts in the linking phrase could be tolerated, as in the third arrangement in Fig. 3.

A different occurrence of concepts added in linking phrases arises often when we need a classificatory word (a "is a" kind of word) to characterize (and disambiguate) a concept. Examples drawn from students and from various c-maps from the 2nd CMC proceedings, are the followings.

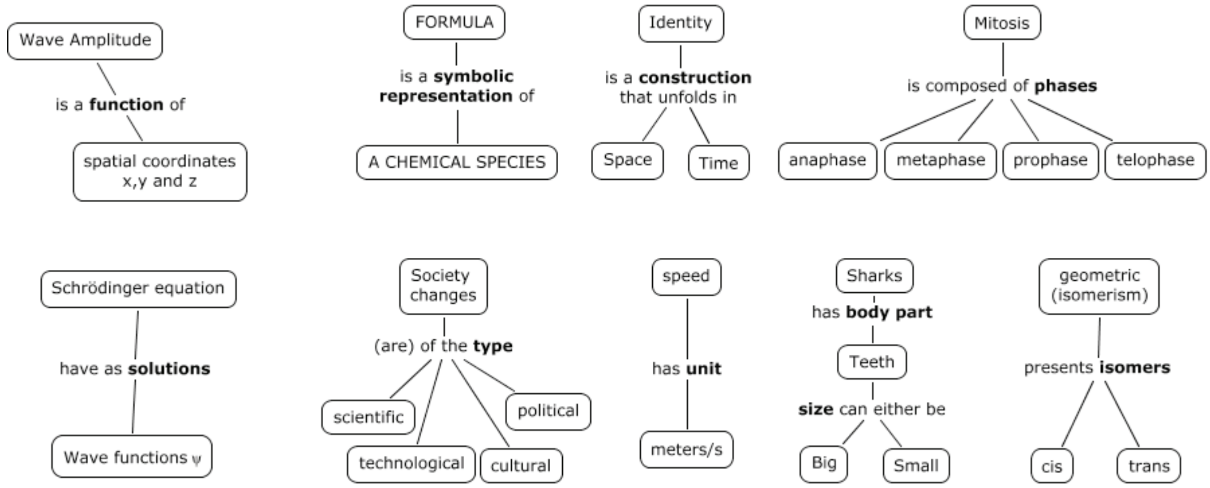


Fig. 4 Bold words in linking phrases are category terms, i.e. very general concepts that are out of context. (these excerpts were adapted from students' C-maps and from the 2nd CMC proceedings: Vol 1, pp. 213, 426, 500, 557, 3; Vol 2, pp. 72)

It is manifest that those words, as *construction*, *phase*, *solution*, *type* etc., have a role as categories and not as relevant concepts in the domain of these C-maps. Sometimes these *category nouns* are used also as root or first level concepts in the same C-map, as in the case of isomers, in the last fragment of a C-map about chemical isomers. So these nouns can be properly admitted in linking phrases, permitting also a considerable help in the construction of linking phrases in Basque language.

Another degree of freedom is due to the use of simple conjunctions and prepositions, without verbs (e.g.. *with*, *either*, *or*, *through*, *such as*, *by*, *from*, etc.), while one of the (non-written) advices in concept mapping training, claims that a linking phrases should always be a *verbal* predicate, as: *includes*, *can be*, *have*, etc. Frequently these linking word have a [verb] that remains understood, as in: [*are] either – or*; *[are associated] with*; *[are made] through*; etc. Or maybe the verbal predicate is part of the first concept – event, so that the linking phrase serves only to complete the proposition. But conjunctions, prepositions or articles, serve sometimes to separate two parts of the same concept, as in Fig. 5 (from 2nd CMC Proceedings, pag. 238 vol.I).

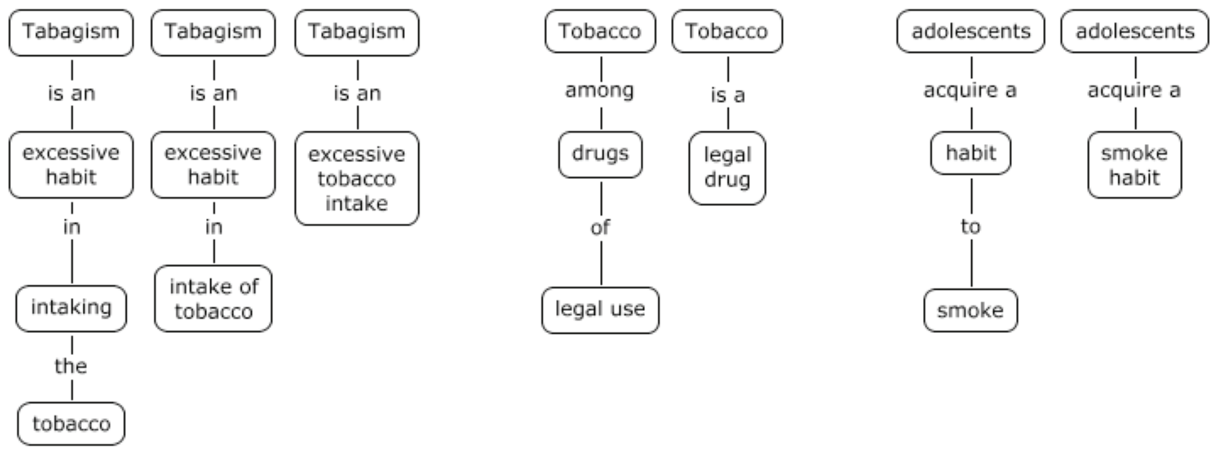


Fig. 5 Concepts that were divided by linking word has been recomposed in each of three fragments of the same C-map of a 13 years old student. The original sequence is the first on the left of each group. The middle one has an implicit verb "are" that accompanies the preposition "among", but the lower "of" in the same chain has only the role of separating two parts of the same concept.

This kind of concept mapping often indicates a poor metacognition or a verbatim concatenation of words from textual sequences. In other words, the capability to group words to generate articulated concept labels, relies on the recognition of the logic role of each term, therefore this grouping is a key factor in meaningful learning. Furthermore, if grouping requires more than putting words together, i.e. substitution with single terms having the same meaning (e.g. "drugs of legal use" = "legal drugs"), it is required also a lexical experience to the learner.

This grouping of concepts can be a very serious issue when it is asked by the excessive complexity of a text or of a thought. As an example let's take these two statements (Le Couter & Burreson, 2004, pagg. 247, 239):

> "*Tobacco changed the role of opium in Chinese society, from a medicinal herb (that was swallowed as pellets or drunk as infusion) to an addictive forbidden drug to be smoked*";
>
> "*This level of poverty would have saved (such) a (elderly herbalist healer) woman from ergotism (because of being unable to purchase contaminated flour) but ironically, as maybe the only person untouched by the ergot poisons, she became even more vulnerable to the accusation of witchcraft*".

The first complex statement (left part in Fig. 6) requires the adoption of *flexible strategies* of reconstruction as *a)* articulated concepts, *b)* quinary propositions and *c)* implicit verbs (to avoid the repetition of the verb "changed" three times). The second one (right part in Fig. 6) requires an harder work of restructuring and choice of composed concepts, the elicitation of an implicit causal effect (of immunity as due to magical arts) sustained by the *flexible* grouping of concept labels and the ungrouping (through the preposition "of") of the single concept of [accusation of witchcraft] that was split to give the word-concept of [witchcraft] and the slanting link.

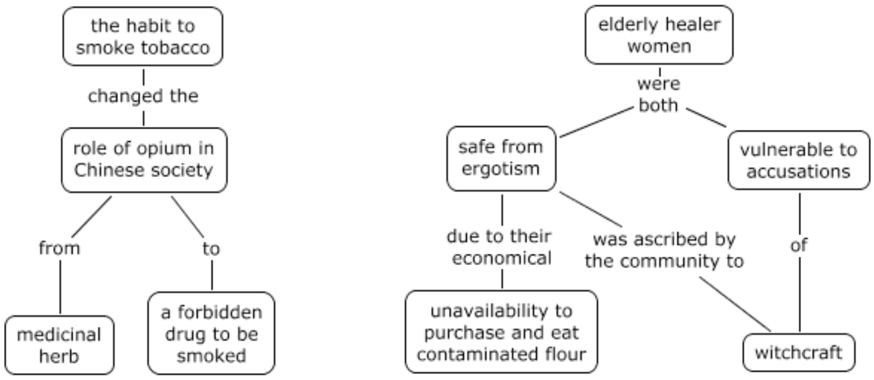


Fig. 6 Fragment of concept maps of very complicated texts. The concepts are "constructed" in such a way to highlight the smallest number of fundamental relations, avoiding to "atomize" concept labels.

We maintain that such rearrangements (that have taken several attempts in changing the rank and the organization of the concepts and of the C-map) could demonstrate a metacognitive insight of the learner, although these fragments of C-maps are not very good instances of orthodox forms.

There is a sharp difference between the excessive grouping or - on the opposite side - "atomizating" of concept and linking phrase labels, whether these actions result from the lack of restructuration of the plain text and of the "thinking stream", or when they derive from an intrinsic complexity of the knowledge domain. Complexity is characterized by the presence of several "scales of observation" or levels and it is a hard and valuable job for the learner to choose the most proper ones when "circling" concept labels in closed shapes, if she/he wants to map both the details and the main ideas of her/his complex natural language.

The last example was spurred to us from a different concern (application of logics in concept maps) by M. Kharatmal (personal communication). It illustrates how - even in simple statements - we are compelled to use articulated linking phrases. This seemingly clear statement: "*Plastids are found in plant cells only*" could be easily transformed in a concept map proposition if we could consider [Plastids] as the more inclusive concept, as in the first proposition Fig. 7 (even in that case the linking phrase must be articulated because of the logic role of "only").

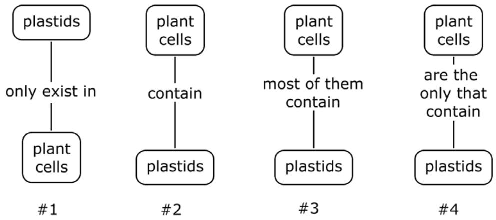


Fig. 7 A problem of logic in a (apparently) simple statement. If the concept of plant cell has to be used as being the most inclusive, there is an intrinsic irreversibility of the logical meaning of the term "only" that prevents us to shorten the linking phrase in #4.

But, as it would be very likely in a C-map about plants, the issue becomes more complicated if the [plant cell] concept claims to be the more inclusive one. We must notice that the C-map fragment should make explicit *only* the information that is contained in the statement, nothing less and, above all, nothing more that could be already part of our knowledge, as the awareness that root cells in a plant haven't plastids, as an example. In this case the claim about plastids informs us that these objects are findable *only* in cell plants, whereas it don't say whether *all* the plant cells contain plastids or not. So the proposition in the C-map should express for sure that if a cell contains a plastid, that cell must to be a plant cell. Instead the #2 proposition gives us extra (and untrue) information that *all* plant cells have plastids, while the #3 gives the (true) *extra* information that there are plant cells without plastids. Finally, #4 logically revert the original statement with its articulated (and non-orthodox) linking phrase. We are free to use *plastids* or *plant cells* as the subject in natural languages sentences, and generally our choice is the one that transmits the most correct meaning in the simplest form. Generally speaking, in concept maps, right inclusive relations are determined by the context, and the awareness of the rank between concepts in each couple is a point of force of concept mapping, but it constitutes also a binding constraint to our expressive capability. That is to say that concept maps are not a "natural" language, and often we can only approximate the complexity of the text elements - parts that we have decided to restructure as a C-map. The quality of the approximation, in such cases, depends strongly by the use of flexible criteria.

3 Concept mapping in Euskara

The Basque language, (native: Euskara) is an *agglutinative* language, i.e. most words are formed by joining morphemes together. Moreover, Euskara is a Subject-Object-Verb (SOV) type language (de Rijk, 1969). As an example, the sentence "The Water is in the Sea" is written: *Ura (water) itsasoan (in the Sea) aurkitzen (found in) da (is)*. Evidently the structure of Basque language is very far from the [subject]—verbal predicate + preposition → [object] form of analytical languages, as the English or the concept maps ones, and this difference generates problems that can be solved through a flexible - generalized use of propositional structure and through some slight license in the grammar.

3.1 Construction of propositions

There are two ways to solve this problem. The first one (Fig. 8*a*) is not to observe the grammatical order asked by Basque sentences; we do not think that it could be a right solution because it would decrease communicative effectiveness. In the second solution, we can divide the sentence into two parts and link them by special words like "zera", "ondoko" or "honako" (They can translate in English in this way: "the following one:" or "this one:"). This is somewhat equivalent to the addition of pronouns or category nouns in English linking phrases.

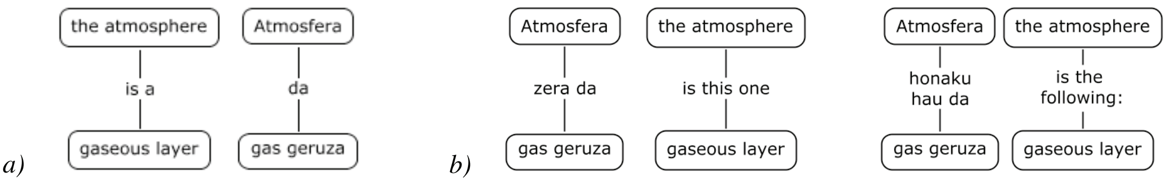


Fig. 8 *a)* Unacceptable proposition obtained by verbatim translation; *b)* Two alternative solutions obtained with pronouns.

The insertion of a pronoun in articulated linking phrases helps also in those cases of nouns that are modified by a suffix that is requested by the verbal predicate, as can be a preposition. If a Basque object noun has such a suffix, it becomes unsuitable as a subject of a derived proposition (Fig. 9*a*). On the contrary, the prepositions are part of verbal predicates in English, where nouns remain unchanged and usable for other propositions. If the subordinated concept is preceded by a pronoun in the linking phrase, we make only a tiny error in Basque grammar by leaving off the –*n* suffix (Fig. 9*b*).

Fig. 9 *a)* Incorrect derived proposition caused by –*n* (in) suffix. *b) honako* pronoun dispenses us from using the –*n* suffix in the noun. Notice that "naked" nouns (as itsaso = sea) are never used in Basque, because the articles (-a, -ak,) are always merged with the nouns.

3.2 Use of prefixes

The second problem is that in Basque language are needed suffixes, for example "*-k"*, to mark the subject of a transitive predicate. Let's take into consideration the following two sentences: "*The atmosphere is a gaseous layer*" (and) "*The atmosphere has water*". In Basque these sentences can be translated as "*Atmosfera gas geruza da*" (eta) "*atmosfera**k** ura du*". How to build up concept maps if the same concept changes from *Atmosfera* to *Atmosferak* in the two branches? Here (Fig. 10) is our solution.

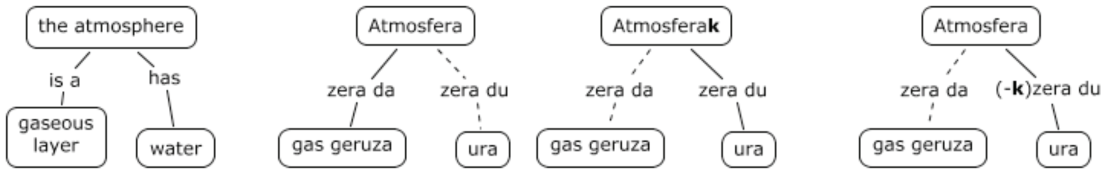


Fig. 10 The dashed lines indicate incorrect sentences. The solution is to move the transitive prefix (**-k**) from the subject to the linking phrase.

A rich collection of math and science c-maps in Basque language can be accessed from the University of the Basque Country Folder in IHMC Public Cmaps (3) server (web shortcut in references).

4 Generalized rules for "easy" concept mapping

Concept mapping is never an easy task for a learner of a new subject. But there are nevertheless some simplifications that should be allowed to concentrate the efforts upon the metacognitive task.

4.1 Construction of concepts

Once that the Focus Question has been identified (this doesn't means that the focus cannot be changed later on), the first task is the *construction of concepts*. The term "construction" implies that concepts aren't somewhere in texts or in our mind, but that - in every not-elemental knowledge domain - they have to be chosen, assembled from words and (if possible) transformed with nominalization actions (Guastavigna 2004). These *nominalization* operations (reducing a group of words to a single term) are not always possible for the learner, whereas the individuation of evocable and aware units of experience in the structure of her/his cognition–affection, constitutes a priority for meaningful learning. Therefore we allow concept labels to be formed by an *indefinite number of words*. In our experience we don't say to our students: "there are too many words in that node", but: "if you re-read those words, are you sure that you are still viewing them as a single concept, and that they cannot be divided in two or more related units?" This question hasn't always an absolute answer. In very complex knowledge domains there are margins of subjectivity and may be favorable to subdivide the fundamental relations in a few well-articulated concepts, in such a way to highlight a few fundamental relations (Fig. 6), rather than "atomize" the network as made of single-word concept labels.

We can realize that the real criteria for good "concept designing" is indeed a criterion of individuation of the minimum number of the most fundamental relations and of placing them in a central position of the structure.

4.2 Flexible construction of propositions

As we have seen in *2.1*, concepts can be constructed, or individuated, only having an idea of their involvement in the reciprocal relationships. It means that even the inclusivity relation is determined by the initial choice of the most fundamental relationships in the knowledge domain. The asymmetry of the inclusion between two concepts is not negotiated here, as being a basic component of metacognition. But it should be remembered that this inclusion relation has to be interpreted as a "local" type (it doesn't imply a hierarchical or pyramidal C-map on larger scale) and *relative* to the context, determined by the focus question and by the root concept, as Joseph Novak has pointed out (Novak & Gowin, 1984). On the other hand, an important element of flexibility is that "*propositions contain two **or more** concepts connected using linking words or phrases to form a meaningful statement*" (Novak & Cañas 2008). As we have seen in several examples of the second paragraph, the construction of quinary propositions (formed by three concepts and two linking phrases) is not always a symptom of insufficient restructuration of the C-map by the learner. Therefore we accept generalized and extended propositions, provided these can be perceived as "*units of meaning*" (Novak & Cañas 2008). In the main C-map of the latter reference we can see some propositions with non verbal linking phrases that we have classified of the type with *implicit* verb, as in:

[Perceived Regularity or Patterns] — in → [Events (Happenings)], [Objects (Things)]

[Interrelationships] — between → [different Map Segments]   (this one could be merged in a single concept)

[Organized Knowledge] — necessary for → [Effective Teaching], [Effective Learning] (verb "is", implicit)

As there are extended (quinary) propositions, as the followings:

[Concepts], [Propositions] — are → [Hierarchically Structured] —in→ [Cognitive Structure]

[Concepts], [Propositions] — are → [Hierarchically Structured] —especially with→ [Experts]

[Concepts] —are→ [Labeled] — with → [Symbols], [Words].

In the latter statement the Authors presumably wanted to highlight the role of *Labeling* as an event-concept, rather than to use the simpler form [Concepts]—are labeled with →[Symbols], [Words], this being another form of flexibility in proposition construction.

We want to remember again that all forms of grouping, of using nouns in linking phrases, are very advantageous in agglutinative languages as in the Basque one.

5 Summary

We have reflected enough on the relations between mother-tongue language and concept mapping as a pedagogical language, to draw the following conclusions. Language and its logic develop as the cognitions of individuals develop. For the younger, children at primary school, the oral or written language has a strict resemblance with the propositional – simple – structure of concept maps (minimal phrases, single word labels for concepts and linking phrases). In that developmental age, as we and many other educators have verified, the systematic use of concept maps (making, reading as narrations) has, among other advantages, the potentiality to help the growth and refinement of language. But with the older and the adult learners, the most part of whom haven't got trained with concept maps, the written and oral language, as their cognitive performance, have been developed along independent ways. In this case the impact of concept mapping, forced with the same elementary criteria, if restrictively applied, can represent a sort of overloading constraint that can discourage older students and adults and keep them far from concept maps. To fill the gap between the natural language and the concept mapping language in adults, and to engage them in concept mapping, a wider acceptance of conventionality and subjectivity in their elaborations as learners is required, provided that some basic criteria – the ones that are correlated to metacognitive activity - are respected. We also need a more flexible managing of the basic criteria of concept mapping, to fit complex and sophisticated knowledge claims that arise in the natural language, provided that main relations and conceptual nodes are well defined-chosen anyway in the c-maps.

It is worth noting, agreeing with one of our reviewers, that certain settings, e.g. a teacher generated concept maps used for instruction, might call for more formalized concept mapping techniques to allow for a greater precision and rigor of expression, and also for a model of well made structured concept maps to imitate.

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FROM THEORY TO PRACTICE: THE FOUNDATIONS FOR TRAINING STUDENTS TO MAKE COLLABORATIVE CONCEPT MAPS

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Abstract. Training beginners is critical to avoid the naive use of concept maps (Cmaps) in the classroom. The rewards for using concept mapping can be achieved in the context of appropriate, rather than frivolous, didactic activities. Using the theoretical background of concept mapping, educational methodology and classroom management, we devised a four-session activity for training beginners. Moreover, to foster deep changes in the traditional classroom dynamics, we explored the role of Cmaps as visualization tools for enhancing collaborative knowledge construction. Collaborative Cmaps respond to some of the new educational demands posed by post-industrial society and should be present in the 21st-century classroom. We devised three innovative methodological strategies (half-structured Cmaps, expanded collaborative learning and propositional clarity table) to boost the training session. The favorable result shows that previously naive students could produce acceptable Cmaps after a short period of training (four classes).

1 Introduction

Concept mapping is a well-established technique that allows explicit the description of idiosyncratic mental models. It has been widely used for educational and corporate purposes with a broad variety of goals, including assessing prior knowledge as well as eliciting, archiving and sharing expert knowledge, and fostering collaboration (Novak, 1998; Fischer et al., 2002; Coffey et al., 2004; Coffey, 2006; Novak & Cañas, 2006). The apparent ease of production of concept maps (Cmaps) is attractive for beginners and explains the popularity of Cmaps. However, naive use of concept mapping may produce few (or none!) of the expected benefits, and such experiences may be playful and funny at best. During the closing talk of our last conference in Costa Rica, Cañas and Novak (2006) proposed the re-examination of the foundations for the effective use of Cmaps. They pointed out that many of the difficulties observed with the use of Cmaps derive at least in part from inappropriate use of the technique, inadequate training for users and trainers, and a general failure to recognize the importance of the tool's theoretical foundations.

Mature use of concept mapping in the classroom setting requires a solid methodological background. Insufficient theoretical knowledge makes implementation a troublesome task for the teacher. Naive use of Cmaps may result from the following events (which are generally related to the teacher's classroom routine):

1. The teacher uses the Cmaps to change the classroom dynamics.
2. The students produce various Cmaps in a short period of time because they are fascinated with the new classroom climate.
3. The teacher has difficulties handling the large amount of Cmaps because the textbook does not provide a correct answer for grading.
4. The teacher stops providing feedback to the students authoring Cmaps and Cmaps evaluation is restricted to simple verification of Cmaps production.
5. The teacher does not realize the benefits of concept mapping, makes unfavorable judgments about it, and avoids future use.

This undesirable sequence arises from the inadequate balance between the theoretical and practical aspects that must be considered to allow a mature use of concept mapping in the classroom. Experienced teachers pay less attention to the Cmap underlying theory but their own experiences may be inadequate for successful implementation. Moreover, the complex social interactions and dynamics of the classroom necessitate teaching skills independent of the understanding of the theories supporting Cmaps. Suitable use of concept mapping in classroom also requires familiarity with educational methodology and classroom management (Jones & Jones, 2003; McLeod et al., 2003), as schematically shown in Figure 1.

Training is the critical aspect to guaranteeing rewards from concept mapping. As a trainer, the teacher should be a skilled mapmaker in order to support the students during the training period. Moreover, training must be intentionally designed with a basis in the triple theoretical foundation presented in Figure 1. Appropriate training is fundamental for creating a safe path for introducing Cmaps in the classroom and for overcoming implementation challenges. In response to the warning posed two years ago, we propose a four-session activity sequence specially designed for training beginners to make collaborative Cmaps.

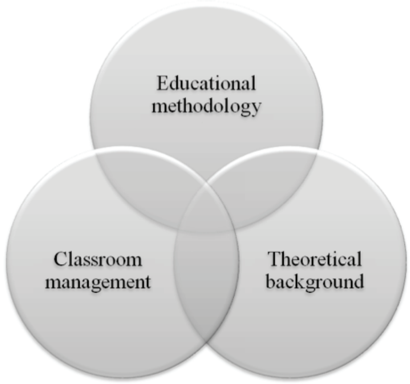


Figure 1. Triple theoretical foundation required for avoiding a naive use of concept mapping in classroom.

2 New educational demands and collaborative Cmaps

The knowledge explosion, information technology development and globalization have dramatically affected our society (Hobsbawn, 1996; Friedman, 2007). As a result, new social paradigms have emerged and attested the end of industrial society. The new society that has shaped our contemporary way of life is identified with such labels as knowledge, post-modern and post-industrial. While industrial society was based on work and goods manufacturing, post-industrial society is centered in free time, creative idleness, and service production in the form of symbols, information, values and esthetics (De Masi, 2000). The power in industrial society depended on the possession of manufacturing resources (e. g., factories). In contrast, the power in post-industrial society depends on the possession of information (e. g., mass media) and ideation resources such as research labs.

In contrast with the pronounced social changes involved in the transition to a post-industrial society, schools have not changed at all. The education designed for industrial society still prevails at most schools. Schools resemble an industrial factory in that all classrooms are identical, their teachers have a standardized discourse, and all students are expected to answer the same questions in the same way (Menezes, 2000). Such standardization, one of the industrial society's main features, affected the educational system by allowing only one model to satisfy teachers' and students' diverse expectations.

Traditional schools were formed under industrial paradigms, and their methodological procedures must be revised to respond to the new demands of post-industrial society. In addition to transmitting disciplinary knowledge, 21st century education requires the development of skills related to life-long learning, teamwork, creative thinking, and collaborative knowledge construction (Fischer et al., 2002; Sawyer, 2006). The powerful combination of these cognitive and communicative skills with confidence, which is related to emotional behavior, can foster students' empowerment in classrooms. The new educational demands can be described as follows:

1. Life-long learning = metacognition + self-evaluation.
2. Confidence = self-evaluation + motivation.
3. Teamwork skills = motivation + creativity.
4. Creative thinking = creativity + metacognition.

Any methodological change in classroom activities in order to fit the needs of post-industrial society must pursue a truly collaborative and empowering environment that involves both teachers and students (Mintzes et al., 1998). The ultimate lesson to be taught in post-industrial classrooms is to learn how to learn (Georghiades, 2004; Novak & Gowin, 1984). In this context, collaborative concept mapping can be considered a methodological strategy capable of adapting traditional classroom dynamics to the new educational demands of the 21st century.

2.1 Creation, collaboration and concept mapping

Creation is a central value for the post-industrial society. The increasing demand for innovation and creative thinking can be addressed more easily when a collaborative group is formed. As collaboration and creation require extensive practice, students should work together and collaborate in creative groups throughout their formal education. Opportunities for practicing creativity and collaboration in schools must be devised by teachers using innovative methodological strategies.

The creative process that takes place in collaborative groups can be described in three steps. Externalization and elicitation of task-relevant knowledge precede consensus building, which can be conflict- or integration-oriented (Fischer et al., 2002). As visualization tools, Cmaps foster the collaborative knowledge construction process by making idiosyncratic mental models explicit for revising (intrapersonal activity) and sharing ideas (interpersonal activity). Both purposes are important during collaborative knowledge construction because all participants can visualize, interpret and organize their own ideas (intrapersonal) before beginning conflict-oriented and/or integration-oriented consensus building (interpersonal). Figure 2 shows the role of visualization tools (Cmaps) at each step of collaborative knowledge construction.

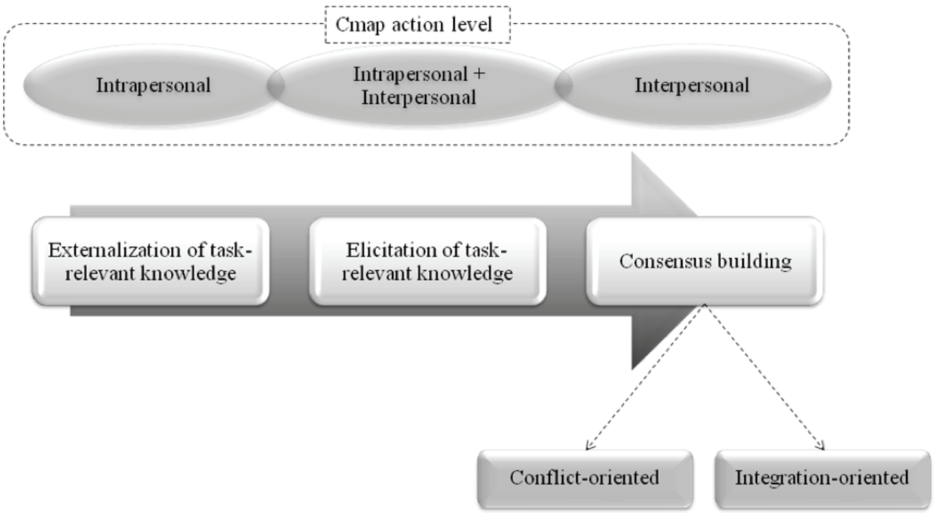


Figure 2. Visualization tools (Cmaps) and their relationship with the collaborative knowledge construction process.

Collaborative concept mapping is an interesting methodological strategy that responds to some of the educational demands posed by post-industrial society. Recent findings presented in the literature confirm that this technique is effective when students have been trained appropriately and can use Cmaps in a mature rather than naive way (Basque & Lavoie, 2006; Novak & Cañas, 2008). In our contemporary context, collaborative concept mapping allows the development of synthesizing and creating minds (Gardner, 2006), as well as teamwork skills, which are formative requisites for 21st-century citizens (De Masi, 2000; Sawyer, 2006). Thus, training activities must include collaborative Cmaps instead of exclusively focusing on individual concept mapping.

3 Half-structured Cmap (HSCmap), expanded collaborative learning (ECL) and propositional clarity table (PCT) for training beginners

We designed and tested a four-session activity based on the theoretical foundations involving concept mapping, educational methodology and classroom management, to train beginners to make collaborative Cmaps (Table 1). The first step in training a student to make maps proficiently was to ensure understanding of Cmap structural aspects. For this purpose, the following central concepts were selected:

1. Proposition: Cmap building block. This must be understood as a semantic unit formed by *"initial concept + linking phrase + final concept"*.
2. Focal question: ultimate goal to be addressed by the propositional network. This must be understood as the critical element for selecting the most relevant propositions and maintaining Cmap clarity.
3. Revision: dynamic characteristic of any Cmap, which is never finished. It must be stressed that the "right" answer is no longer available; on the contrary, it is continuously pursued.
4. Hierarchy: structural fine-tuning of Cmap. It must be stressed that this helps to organize concepts according to their inclusiveness and make the overall Cmap clear for a reader.

The training period was enhanced with three strategies: half-structured Cmap (HSCmap), expanded collaborative learning (ECL) and the propositional clarity table (PCT). HSCmap was inspired by the cyclic Cmap and the experiments on dynamic thinking described in the literature (Safayeni et al., 2005; Derbentseva et al., 2007). The HSCmap demands summarizing capabilities because it restrains the number of concepts used during the Cmap construction. On the other hand, since the HSCmap does not define the maps structure, the author(s) is (are) free to build concept relationships without restrictions. Figure 3 shows the HSCmap adopted in our training activities. The author(s) can reach any of the following structures: linear, hierarchical tree, hierarchical cross-link and cyclic (we will later show that cyclic structures reveal whether the Cmap has a static or dynamic nature).

Table 1: Description of the four-session activity for training beginners ("X" indicates the work's features developed in each class).

Class #	Activity description	Where?		Who?		Structural parameters			
		Classroom	**Home work**	**Individual**	**Collaborative**	**Proposition**	**Focal question**	**Revision**	**Hierarchy**
1	• Presentation of a Cmap to students (model) • Discussion about the proposition structure • Discussion about the role of focal question • Negotiation of the focal question for Cmap#1	X	-	X	-	X	X	-	-
2	• Teacher's feedback of Cmap#1 • Preparatory reading assigned: *"Good and bad reasons for believing" (Dawkins, 2004)* • Selection of key concepts from a text • Classroom discussion • Negotiation of the focal question for Cmap#2 • Cmap#2 revision at home	X	X	X	-	X	X	X	-
3	• Preparatory reading assigned: *"The immovable Earth" (Brody & Brody, 1997)* • Cmap#3a preparation ready for classroom discussion • Classroom discussion • Collaborative and half-structured Cmap#3b for sharing ideas and discussing in pairs	X	X	X	X	X	X	X	X
4	• Preparatory reading assigned *"The cosmic egg" (Brody & Brody, 1997)* • Classroom discussion • Peer review and propositional clarity revision of the Cmap#3b • Expansion of the Cmap#3b from the text ideas (preparation for the discipline exam)	X	-	-	X	X	X	X	X

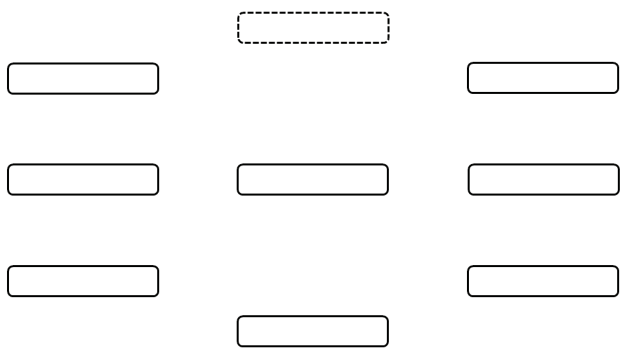


Figure 3. HSCmap with nine concepts used during our training activities. The dashed box highlights the root concept of the HSCmap and the author(s) knows that this is the starting point for the readers.

Expanded collaborative learning (ECL) is characterized by activities that involve the students' peer review of any material collaboratively produced by them. Peer review is rarely explored as a means of changing traditional assessment procedures; the challenge of students' self-evaluation breaks a paradigm in the classroom and reduces the power asymmetry between teacher and students. Furthermore, since students inhabit a relatively consistent zone of proximal development, peer review offers an opportunity for them to share knowledge with each other; this experience is distinct from interactions with the teacher, who is not in the same zone of proximal development (Novak, 2002; Vygotsky, 1978). Peer review expands the collaborative activities developed by small groups of students, and for this reason, we expect ECL to distinctly shift learning experience and outcomes. This activity can increase the students' awareness of their achievements and failures during the Cmap training period. Moreover, ECL is an assessment exercise that offers a safe road towards the self-evaluation that allows mapmakers to continuously revise their Cmaps.

The propositional clarity table (PCT) was designed to reinforce the Cmap structure, which is based on semantic units. The PCT asks the author(s) to do more than read and check the Cmap as a whole, as the author(s) is (are) asked to pay close attention to each proposition in the map network. A 4-column table is prepared and each row contains one proposition from the Cmap. The first three columns allow the description of the elementary components of the propositions (initial concept, linking phrase and final concept), while the last column is for ranking the clarity of each proposition using a Likert-scale approach varying from 1 to 5 (extreme values: 1= low semantic clarity and 5=high semantic clarity).

The combination of the HSCmap, ECL and PCT allow emphasizing the role of the main aspects related to concept mapping throughout the training session (Table 2).

Table 2: Matching the central concepts (proposition, focal question, revision and hierarchy) and the proposed training booster strategies (HSCmap, ECL and PCT). Plus signals indicate the importance of each strategy to deal with the selected central concepts.

	Proposition	Focal question	Revision	Hierarchy
HSCmap	+ +	+ +	+	+ + +
ECL	+	+	+ + +	+
PCT	+ + +	+ +	+ + +	+

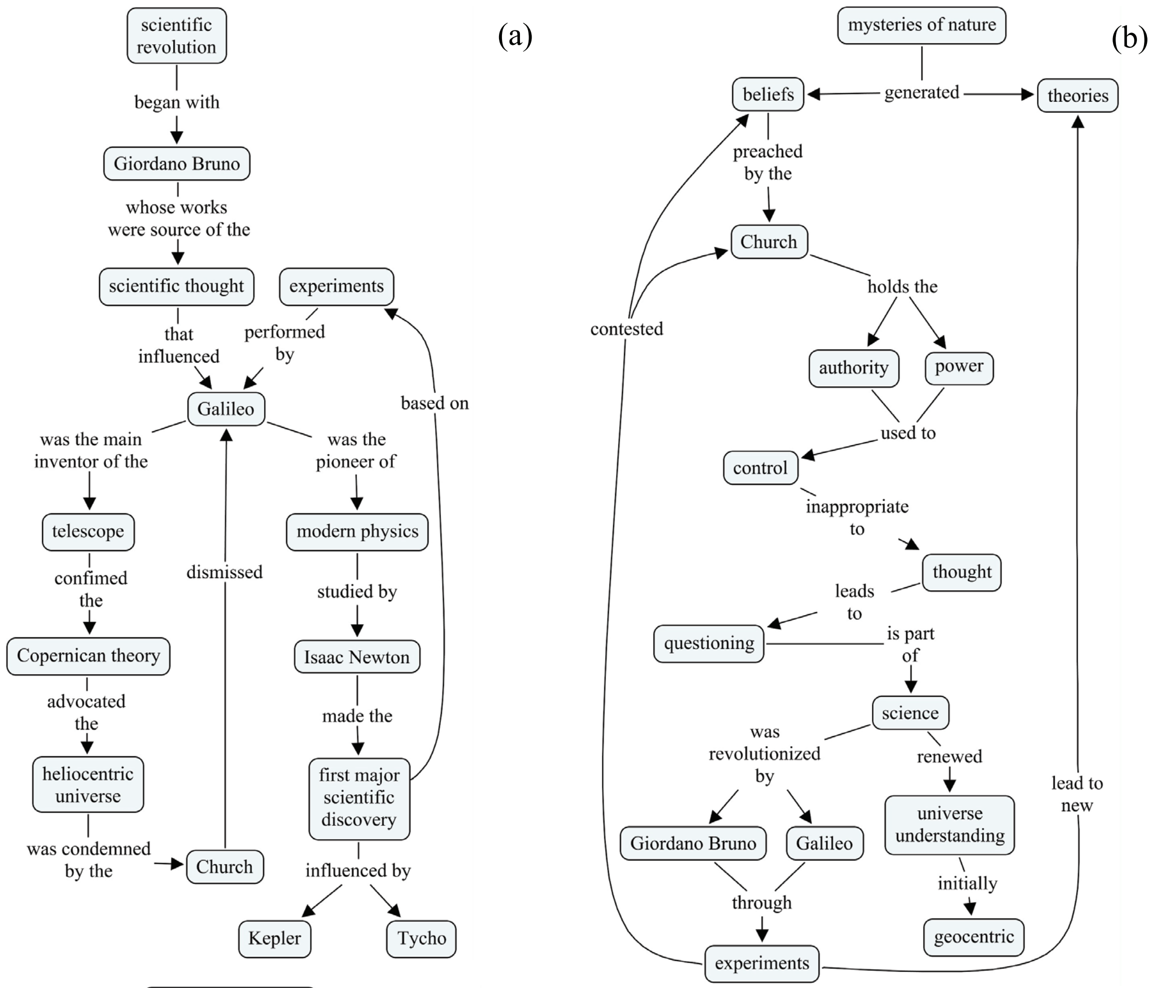
4 Training first-year undergraduate students

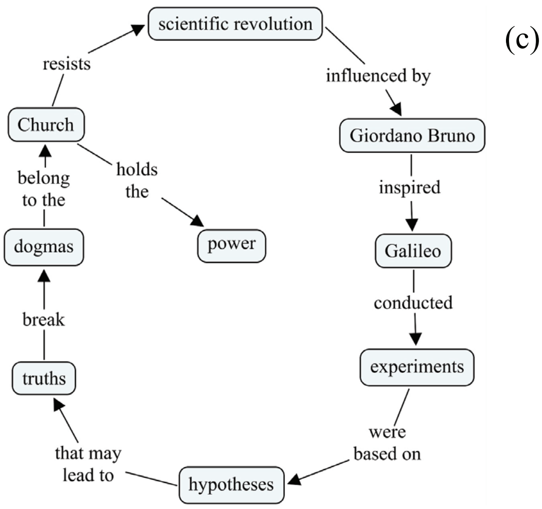
The application of the four-session activity shown in Table 1 occurred during the discipline ACH 0011 Natural Sciences, which is offered for all first-year undergraduate students at Escola de Artes, Ciências e Humanidades (School of Arts, Science and Humanities at São Paulo University). The main goal of this discipline is to provide a broad view of the impact caused by scientific and technological development in our society. Scientific literacy, a new post-industrial demand, is a requisite for an autonomous citizenship. A new contract involving society and science is under negotiation and all citizens must have the right to make their own judgments about ethical aspects of scientific and technological issues (Fourez, 1997; Unesco, 2005). Therefore, scientific literacy needs to be nurtured throughout formal education.

The first part of the 2008 edition of ACH 0011 Natural Sciences discipline was used to apply the devised training sequence for introducing the students to concept mapping and to prepare them for using Cmaps during the final part of the course. The material produced by a three-student group is presented in Figure 4 to support the most relevant findings that were verified throughout the training period. For this reason, our preliminary comments are focused on the activities developed during classes #3 and #4 (Table 1).

Individual Cmaps were prepared by the students after reading the preparatory text entitled "The immovable Earth" (Brody & Brody, 1997), assigned as homework. This text discusses the scientific revolution from a historical perspective and highlights the impact of Galileo's investigative work during the 16^{th} century. This activity prepares students for the classroom discussion, because they can make their idiosyncratic mental models explicit through a visualization tool (Cmaps). Therefore, they can visualize, interpret and revise their own ideas before starting a discussion with their counterparts in the classroom. Figures 4a and 4b show two individual Cmaps, in which authors' idiosyncratic features can be verified. Two different approaches were used to address the proposed focal question (How can we relate the main events that led to scientific revolution?). One student focused on the philosophers who were responsible for this endeavor and used information from the assigned text (Figure 4a). The other student also included information provided by the assigned reading for class #2, entitled "Good and bad reasons for believing" (Dawkins, 2004), which discusses the differences between scientific and religious thinking (Figure 4b). The latter student developed a broader approach, while the former focused on the scientific domain.

These individual Cmaps show beginner fingerprints and both can be improved. There is a big concept (first major scientific discovery) and a conceptual imprecision involving the beginning of the scientific revolution (see the proposition: scientific revolution began with Giordano Bruno) in Figure 4a. The proposition “universe understanding initially geocentric” in Figure 4b presents structural and conceptual problems. On the other hand, it should be stressed that each of these students had previously produced only two Cmaps each. The Cmaps are well organized and present an interesting overall structure. Moreover, these Cmaps prepared the students for the collaborative concept mapping using half-structured Cmap (Figure 4c).





(d)

Initial concept	Linking phrase	Final concept	
scientific revolution	influenced by	Giordano Bruno	4
Giordano Bruno	inspired	Galileo	2
Galileo	conducted	experiments	5
Experiments	were based on	hypotheses	4
Hypotheses	that may lead to	truths	4
Truths	break	dogmas	3
Dogmas	belong to the	Church	3
Church	resists	scientific revolution	5
Church	holds the	power	4

Figure 4. Material produced by a three-student group during the training activity. Individual maps (Cmap#4a) prepared before the classroom discussion during class #3 (Fig 4a and Fig 4b). Collaborative half-structured map (Cmap#4b) prepared after the classroom discussion during class #3 (Fig 4c). Propositional clarity table and students’ evaluation (made during the class #4) using a Likert-scale approach (Fig 4d). Focal question for the presented Cmaps: How can we relate the main events that led to scientific revolution?

After discussing the assigned text in the classroom, the students were organized in groups to prepare a collaborative version of their individual Cmaps. In addition to collaborating between pairs, they must synthesize their ideas because the HSCmap required the use of nine concepts as a challenging boundary condition. The intrapersonal activities required for the collaborative knowledge construction (Figure 2) intensified the group discussion and the result was a clear Cmap (Figure 4c) that offered a direct response to the focal question. The interpersonal elicitation and consensus building developed from the idiosyncratic contributions of prepared participants, confirming the importance of the visualization tools for supporting collaborative knowledge construction. Some groups spontaneously used cyclic structure; this structure usually highlights cause and effect relationships among the concepts. In these cases, students made a more dynamic Cmap than those kept at a descriptive level (static Cmaps).

The fourth class was reserved for revising the collaborative Cmaps. The propositional clarity table (PCT) was used to let the authors check the clarity of each proposition in order to be sure that the Cmap clearly presented the authors' ideas. The PCT for the collaborative Cmap shown in Figure 4c is presented in Figure 4d. The authors ranked each proposition using a Likert-scale approach (extreme values: 1= low semantic clarity and 5= high semantic clarity). The students noted both the importance of revising their Cmaps and the absence of the right answer that is frequently present in the traditional strategies used for evaluation purposes.

5 Summary

This work proposes a response to the re-examination of the foundations for the effective use of Cmaps (Cañas and Novak, 2006). To ensure experience of the rewards of concept mapping, training is critical and intentional activities should be designed for this aim. A four-session activity for training beginners was set up and applied in the higher education context. Half-structured Cmaps (HSCmaps), expanded collaborative learning (ECL) and propositional clarity table (PCT) are innovative approaches that enhance the training period. Their effects on Cmaps may highlight the key structural features of concept mapping (proposition, focal question role, revision and hierarchy) that allow beginners to make acceptable Cmaps in a short period of time (four classes). The training activities may avoid the naive use of concept mapping and take advantage of the theoretical background available in the literature to overcome the difficulties that arise during the process of changing the classroom environment. After this first pilot trial, the authors will keep evaluating the results to refine and adjust the training procedures until 2010. More practical interventions during the ACH 0011 Natural Science discipline are scheduled to 2009, 2010 and 2011.

Despite the preliminary results seem positive, there is room for further investigation into the development of methodological strategies that ensure effective training. Different contexts may require different solutions that can be developed from the triple theoretical foundations discussed here.

6 Acknowledgements

The authors thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, 553710/2006-0) and Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for funding our research projects. We are also in debt to the students responsible for the concept maps presented in this work (Bruna Mayara Cremon, Figures 4a/4c; Andrea de Souza Aguiar, Figures 4b/4c; and Rodrigo do Prado, Figure 4c).

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HEALTHY HABITS THROUGH LITERACY: A CONCEPT MAPPING AND HEALTH CURRICULUM FOR PRESCHOOL AND PREKINDERGARTEN CHILDREN

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Abstract. The purpose of this paper is to report on the development and implementation of the *Healthy Habits through Literacy* curriculum and to extend our knowledge of the utility of concept maps to assess the complexity of preschool and prekindergarten children's knowledge structures. *Healthy Habits through Literacy* was designed to combat the rise in childhood obesity by building the background knowledge and concept development of health related topics. The curriculum supports the goal of improving readiness outcomes for preschool children by utilizing strategies that help children develop visible thinking strategies including concept mapping. Implementation of *Healthy Habits through Literacy* afforded researchers the opportunity to develop and test a protocol for constructing concept maps from transcribed interviews of young preschool children, estimate the associations of concept map scores and measures of vocabulary development and school readiness, and to extend our knowledge of the utility of concept map scores to quantify the represented knowledge structures of 3-year-old preschool children. The estimated reliability for mapping and scoring the transcribed interviews was .95. The children's concept map scores were positively associated with their standardized achievement scores on the EVT-2 (.29) and the BBCS-3:R Self-/Social Awareness scores (.49).

1 Introduction

Concept mapping has been successfully used to assess science curricula and in particular to assess science curricula implemented in preschool settings. The purpose of this paper is to extend the investigations of the use of concept mapping with young children and the reliability and validity of the use of concept map scores to quantify the complexity of young children's knowledge reported in the work of Figueiredo, Lopes, Firmina, and de Sousa (2004) and Wehry, Algina, Hunter, and Monroe-Ossi (2008). Figueiredo et al. used concept mapping in a rural setting in Spain to assess young children's knowledge of cows. Wehry et al. developed and investigated the reliability of a scoring system used to quantify concept maps constructed from transcribed oral responses to interviews of the young children experiencing the *Young Florida Naturalists* curriculum. This study will extend their work to the *Healthy Habits through Literacy* preschool curriculum which focuses on nutrition and physical fitness. We evaluated a protocol for use when constructing concept maps from children's transcribed interviews, extended the reliability study of the scoring system to the new curriculum, investigated associations of concept map scores and achievement, and extended our knowledge of the utility of concept maps to even younger preschool children.

Neuman (2006) pointed out the importance of children's knowledge relative to their early literacy achievement, but noted there has been little discussion of the differences in children's content knowledge as it relates to that achievement. She posited that this lack of knowledge leads to reading comprehension difficulties because the gap existing between the knowledge of children who live in poverty and those who do not widens as the children become older. Moreover, many current efforts to close the achievement gap focus on skill development in isolation from meaningful content. Siegler (2001) emphasized that the central connection between instruction and cognition is learning and, furthermore, that we can teach children to pursue meaning thereby increasing the probability that they will seek meaning. Advances in cognitive science show that learning to learn is a skill that can be learned.

The more one knows about a topic the better one understands, learns, and remembers new information about that topic. The *Healthy Habits through Literacy* curriculum proposes that the development of intentional thinking requires that teachers provide learning opportunities that introduce ambiguity in the content. Through this type of instruction, learning possibilities are open and lead to *mindfulness*, a thinking disposition with three components: ability, inclination, and sensitivity (Langer, 1989, as cited in Perkins, Tishman, Ritchhart, Donis, & Andrade, 2000).

Thinking routines are "simple patterns used over and over again that support and scaffold specific thinking moves or actions" (Ritchhart, Palmer, Church, & Tishman, 2006). Thinking routines make thinking visible, promote mindfulness, and are critical for identifying students' misconceptions. Routines include questioning students when they describe their ideas. For example, asking, "*What makes you say that*?" provides children with a useful structure to support their ideas and enables teachers to learn what children are thinking about a particular topic. Increases in students' inclination toward thinking, their awareness of opportunities for thinking, and their use of specific thinking skills help foster better understanding (Perkins, 2003).

Developing non-linguistic representation strategies such as graphic organizers, pictographs, and concept mapping relates to the importance of Paivio's (1990) *dual-coding* theory of knowledge storage. Knowledge is stored two ways, in linguistic and non-linguistic (imagery) forms. Marzano, Pickering, and Pollock (2001) found that students who used both ways to store information were more able to recall and apply knowledge. Concept maps, help children see relationships among concepts and provide a visual representation for hierarchical concepts (Novak & Gowin, 1984). The *Healthy Habits through Literacy* curriculum, designed to strengthen children's background knowledge and cognitive development, embeds explicit thinking routines. The curriculum calls for the use of concept mapping to document growth in the complexity of the children's knowledge structures. Figure 1 shows a concept map depicting the tenets of the *Healthy Habits through Literacy* curriculum.

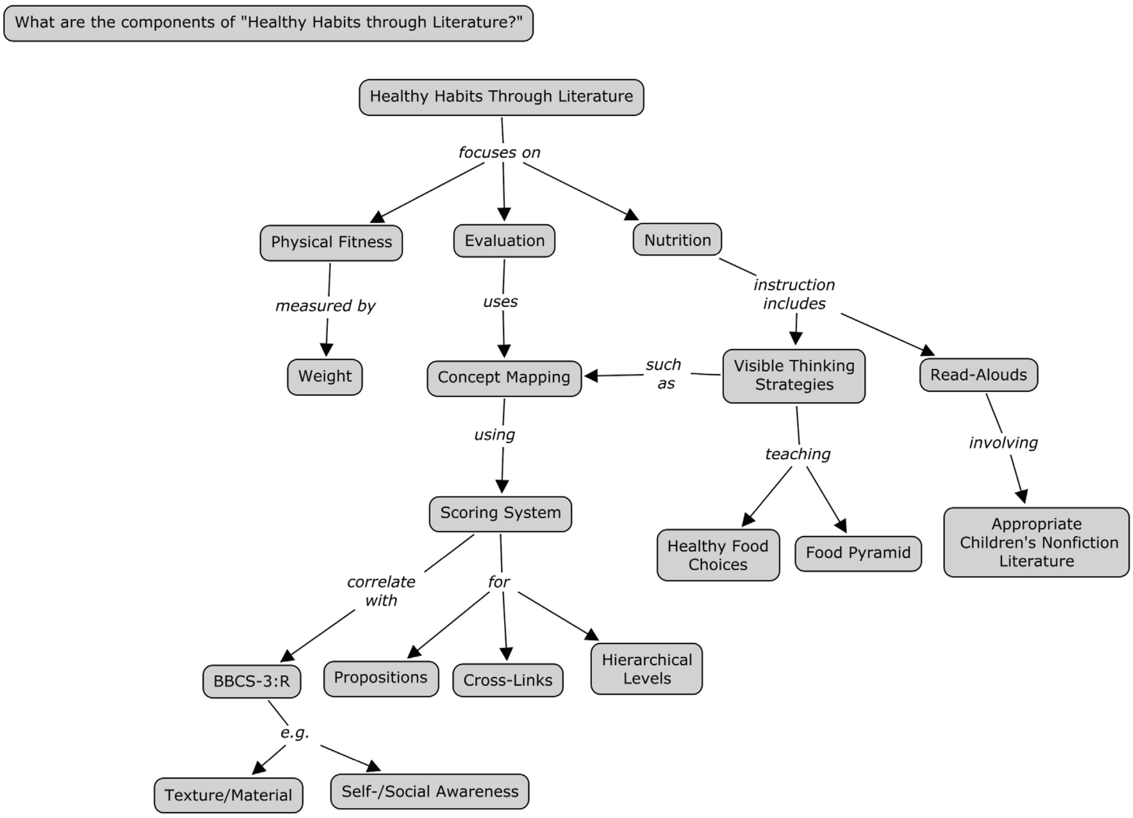

Figure 1. A concept map depicting the *Healthy Habits through Literacy* curriculum.

2 Intervention: *Healthy Habits through Literacy*

The *Healthy Habits through Literacy* curriculum focused on four goals. The first goal was to increase young children's knowledge of the food pyramid, food groups, and healthy food choices through the implementation of the embedded *Color Me Healthy* curriculum (Dunn, Thomas, & Pegram, 2001). The second goal was to increase teachers' use of explicit instructional strategies that promote cognitive development. A third goal was to increase teachers' consistent use of non-linguistic representations that demonstrate relationships among topics through concept mapping. Finally, the fourth goal was to provide children with daily physical activities that are appropriate for preschool children.

The research team provided weekly, ongoing support to teachers through on-site coaching and professional development sessions. Prior to implementation, teachers attended a concept mapping workshop that included an overview of concept mapping, making a concept map having the focus question, "*What makes a healthy body?*" and viewing videos of preschool teachers completing a concept map with preschool children. Following the initial session, a project researcher modeled how to complete a class concept map with teachers from the participating classrooms.

Implementation of *Healthy Habits through Literacy* lessons began March 2008 and continued through May 2008. Instructional strategies included using children's literature to identify vocabulary and concept words linked to health content. Questioning strategies were used to encourage discussion among children before, during, and after readings. Visible thinking strategies such as "*What do you see, what do you think, what do you wonder?*" were embedded in the teacher-child dialogue to strengthen mindful thought. Each teacher completed an initial class concept map that visually represented the preschool children's knowledge of healthy habits prior to the implementation of the curriculum. Class concept maps were continually updated to reflect the knowledge children gained throughout the curriculum implementation.

2.1 Participants and Context

The *Healthy Habits through Literacy* curriculum was implemented at a local preschool center, serving some of the most vulnerable children who reside in a high-need, high-crime, urban neighborhood. Almost all of the enrolled children are low-SES, African-American children. The teachers of three classes enrolling approximately 55, 3-year old preschool and 4-year-old prekindergarten children implemented *Healthy Habits through Literacy* during spring 2008.

2.2 Assessing Healthy Habits through Literacy

The *Healthy Habits through Literacy* project included a pre-assessment and three additional assessments. In the pre-assessment, after listening to their teachers read a book about fitness and nutrition, the children were asked to use pictures to construct a class concept map having "*What makes a healthy body?*" as its focus question. The class concept map was displayed in the classroom and updated to reflect the children's increased knowledge structure as they progressed through the lessons.

In Assessment 1, the children were given a blank organizer for the class concept map, pictures representing the concepts on the class map, and scripted directions for completing the assessment, (*"Over the past few weeks, you have been learning about being healthy. You and your classmates organized pictures into a class concept map that showed what you have learned. I have pictures that look like the ones used on your class concept map. Let's look at the pictures I have here. This is …(identify each of the pictures). Try to remember how the pictures were connected on the concept map you made with your class. Use the pictures to show me where you think they go and how they are connected."*) Assessment 1 occurred March 19-27, 2008. Figure 2 shows the concept maps transcribed from Assessment 1 interviews of a prekindergarten child who participated in a concept mapping curriculum as a 3-year-old preschooler during the 2006-2007 academic year and the concept map of a prekindergarten child who was a novice mapper. The concept map on the left was developed from the interview of the child experienced in concept mapping. The child sorted the concepts by categories in a top to bottom fashion, provided linking words, and used all concept pictures provided. The concept map on the right was developed from the interview of the child who was a novice mapper. The novice mapper also sorted the concepts but used a horizontal display following the conventions of print in a left-to-right fashion, provided no linking words, and used only seven concepts.

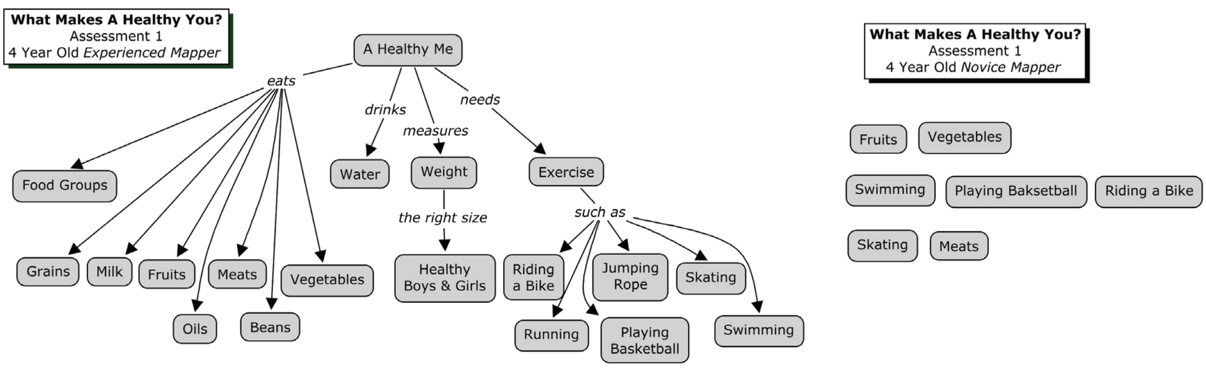

Figure 2. Concepts maps of two prekindergarten children formed as part of *Healthy Habits through Literacy* Assessment 1.

Assessment 2 was conducted April 21-29, 2008 by project researchers using a structured interview. Interview transcripts were transformed into concept maps using a mapping protocol and individual concept maps were scored using a concept map scoring system which assigns values to propositions, cross-links, and hierarchical levels. (See Wehry et al., 2008.)

Figure 3 shows the Assessment 2 concept maps of the same children featured in Figure 2. The experienced mapper's interview resulted in a fairly complex concept map structure. The novice mapper demonstrated the well-known quirkiness of children this age by not being in the mood to elaborate on being healthy.

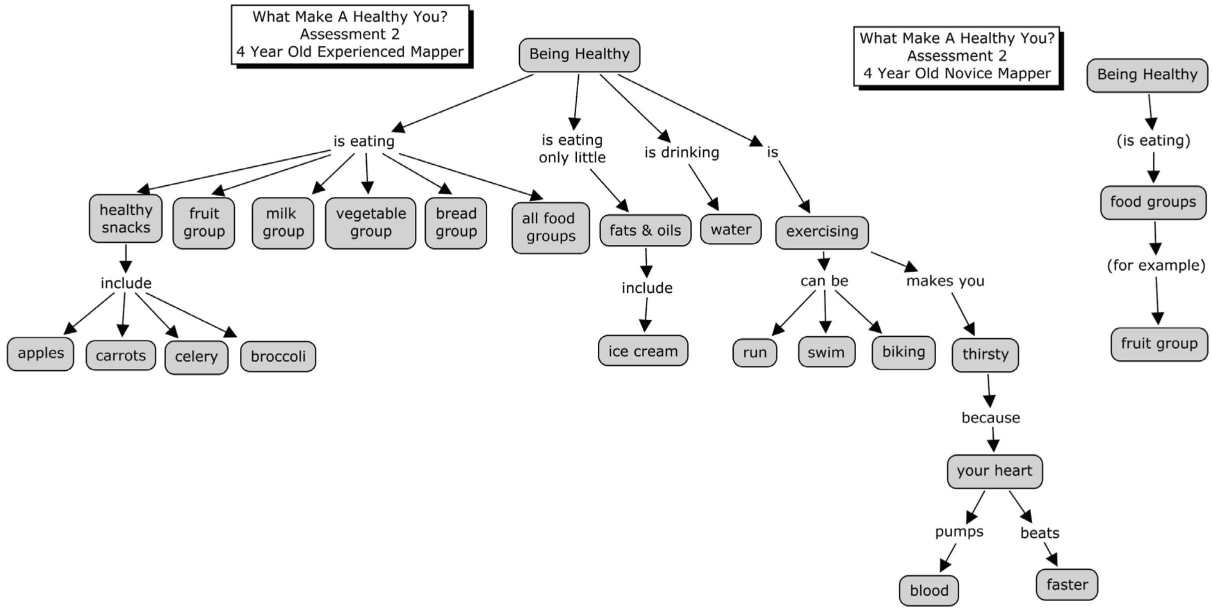

Figure 3. Concepts maps of two prekindergarten children formed as part of *Healthy Habits through Literacy* Assessment 2.

Assessment 3 was completed May 12-16, 2008 to assess children's understanding of the *Healthy Habits through Literacy* content as represented on the final, updated class concept map. Children were shown the class concept map and asked "*What do these pictures represent? This is the class concept map you did with Ms.* _______. *What do the pictures tell you about being healthy?*" Children were assessed individually, responses were transcribed, concept maps constructed, and scored to evaluate the complexity of the children's knowledge about nutrition and fitness.

3 Research Questions, Data Collection, and Analyses

The purpose of this study is to report the development and implementation of the *Healthy Habits through Literacy* curriculum and use results from the implementation to extend the work of Wehry, Algina, Hunter, and Monroe-Ossi (2008) which investigated the utility of young children's concept maps to quantify the complexity of their knowledge structures. Data used in this study included concept maps constructed from the Assessment 2 interviews, children's demographic information, and vocabulary and school readiness achievement test scores. Research questions include

Research Question 1: How much of the total variance in preschool children's concept map scores was accounted for by the person who constructed the concept maps from the children's transcribed interviews?

Research Question 2: Are preschool children's concept map scores differentiated by class assignment (age), and gender?

Research Question 3: Is the complexity of prekindergarten children's knowledge structures as represented on the Assessment 2 concept maps greater for children who previously experienced a curriculum that included concept mapping than for children who were experiencing concept mapping for the first time?

Research Question 4: Are measures of preschool and prekindergarten children's language development (receptive and expressive) associated with their Assessment 2 concept map scores? Are measures of preschool and prekindergarten children's school readiness (receptive and expressive) associated with their Assessment 2 concept map scores?

3.1 Data Collection and Analyses

Data used included the transcribed Assessment 2 interviews. The project research team developed a concept mapping protocol and trained three mappers to use it to form concept maps from the transcribed interviews. Concept map raters, trained to use a previously developed scoring system, scored the concept maps. Data also included children's demographic information, an indicator of whether or not the prekindergarten children experienced the *Young Florida Naturalists* curriculum as 3-year-old preschoolers, and achievement scores. In early spring 2008, the participating children (with informed consent) were administered the Peabody Picture Vocabulary Test, Fourth Edition (PPVT-4; Dunn & Dunn, 2007) and Expressive Vocabulary Test, Second Edition (EVT-2; Williams, 2007), Bracken Basic Concept Scale Revised: Expressive (BBCS:E; Bracken, 2006a) and Bracken Basic Concept Scale-Third Edition: Receptive (BBCS-3:R; Bracken, 2006b) as a part of a related study investigating potential differences in the expressive and receptive vocabulary measures of low-SES, African-American children. The PPVT-4 assesses children's receptive vocabulary and listening ability while the EVT2 assesses children's expressive vocabulary and word retrieval. The BBCS-3:R uses a receptive format to assess children's basic concept development—concepts which are considered necessary to early formal education, and the BBCS:E uses an expressive format to assess children's basic concept development.

4 Results

4.1 Interrater Reliability

Training in the use of the mapping protocol was provided to three researchers and training to use the scoring system was provided to three other researchers. Each of the 48 transcribed interviews was mapped by each mapper producing 144 concept maps. These maps were then each scored by the three raters. Altogether, each interview had nine concept map scores for each component and nine total scores. To examine the generalizibility of scores across raters, four person (p) by mapper (m) by rater (r) G studies were conducted for three components of the concept map score and the total score. The results of the G studies are presented in Table 1.

	Concept Map Score Types							
	Proposition Score		Cross-Link Scores		Hierarchy Score		Total Score	
Source of Variation	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability
Person (p)	47.35	95.94	7.35	85.91	3.50	82.66	14.30	94.71
Mapper m)	0.06	0.12	0.00	0.00	0.00	0.04	0.02	0.16
Rater (r)	0.08	0.15	0.00	0.00	0.02	0.55	0.04	0.26
p*m	1.25	2.52	0.98	11.50	0.40	9.52	0.03	0.20
p*r	0.33	0.67	0.10	1.19	0.17	4.00	0.00	0.00
m*r	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p*m*r	0.29	1.40	0.12	1.40	0.14	3.22	0.70	4.67
$\hat{\rho}^2$ relative	.96		.85		.83		.95	
$\hat{\phi}$ absolute	.96		.86		.83		.95	

Table 1: Generalizibility Study Results

The G studies indicated the interrater reliability is .96, .86, .83, and .95 for the propositions, cross-link, hierarchy, and total score, respectively. The raters contributed very little to the total variance of the concept map component scores and the total score, and the mappers contributed little to the total variance of the proposition score and the total concept map score. However, the interaction of the mappers and person (interview) accounted for roughly 10% of the variance of the cross-link and hierarchy scores. Any variation in the mapping of these aspects of the concept map results in a minimum of a 5-point difference because of the scoring system (see Wehry et al., 2008). Even though the total score has high reliability, researchers intend to review the mapping protocol to obtain better consistency across mappers. The concept map scores were averaged across mappers and raters and the resulting mean concept map score was used in the remaining analyses.

4.2 Concept Map Scores Differences by Population Subclasses

Thirty children (15 boys and 15 girls) were prekindergarteners and 18 children (11 boys and 7 girls) were 3-year-old preschoolers. Gender and class were tested in a regression to determine if there were differences in the children's concept map scores by class (age) or gender. Results of the regression are presented in Table 2.

Source of Variance	*df*	Mean Square	F ratio	*p*-value
Class	2	10.11	0.11	.8990
Gender	1	175.51	1.85	.1802

Table 2: Regression Results for Class and Gender

The children's concept map scores were not differentiated by gender or class. The adjusted mean score for girls was 21.71 and for boys was 18.00 indicating that the structure of the girls' knowledge represented on the concept maps might be more complex than the boys, but this difference was not statistically significant. The mean score of the prekindergarten children (20.39) was also slightly higher than that of the preschoolers (19.22), but, again, this difference was not statistically significant.

The 30 prekindergarteners consisted of 16 children who experienced the *Young Florida Naturalists* curriculum as 3-year-old preschoolers the previous year. A possible difference between the mean scores of these two groups of children was tested using regression. Table 3 shows the results of the regression. The scores of the prekindergarten children were not differentiated by their mapping experience; however, the experienced mappers' mean score was 21.12 and the novice mappers' mean score was 19.55.

Source of Variance	*df*	Mean Square	F ratio	*p*-value
Experience	1	18.50	0.14	.7112

Table 3: Regression Results for Concept Mapping Experience of the Child

4.3 Correlations of Concept Map and Achievement Scores

The mean concept map scores of the children were used in conjunction with the available PPVT-4, EVT-2, BBCS-3:R, and BBCS:E scores to investigate associations between concept map and achievement scores. Table 4 shows the estimated correlations between the children's concept map and achievement scores.

Test	Subtest/Score	Mean	Correlation	*p*-value
PPVT-4	standardized	91.26	.19	.26
	raw	66.63	.17	.32
EVT-2	standardized	94.54	.29	.09*
	raw	53.86	.28	.10*
Bracken Receptive	School Readiness Composite (standardized)	8.91	.19	.27
	School Readiness Composite (raw)	52.83	.19	.28
	Self-/Social Awareness (standardized)	8.34	.49	.00**
	Self-/Social Awareness (raw)	20.74	.40	.02**
	Texture/Material (standardized)	7.63	.25	.14
	Texture/Material (raw)	11.17	.20	.25
Bracken Expressive	School Readiness Composite (standardized)	10.31	.20	.24
	School Readiness Composite (raw)	42.49	.28	.11
	Self-/Social Awareness (standardized)	7.94	.23	.18
	Self-/Social Awareness (raw)	9.54	.25	.15
	Texture/Material (standardized)	7.83	.23	.18
	Texture/Material (raw)	5.20	.21	.23

Note. * indicates statistical significance at α=.10 and ** indicates statistical significance at α=.05; *n*=35.

Table 4: Correlations of Achievement Test and Concept Map Scores

Both the standardized and raw EVT-2 and BBCS-3:R Self-/Social Awareness scores were positively correlated with the children's total concept maps scores.

5 Discussion

The *Healthy Habits through Literacy* project was successfully implemented in three classes at one child care center. The children's knowledge of the food pyramid, food groups and healthy choices increased. The *Healthy Habits through Literacy* curriculum did not involve the level of hands-on experiences found in the *Young Florida Naturalists* project and the focus topic of *Healthy Habits through Literacy* was more abstract for the children than in the *Young Florida Naturalists* project. The average concept map score, 19.91, for *Healthy Habits through Literacy* was also lower than the average score for *Young Florida Naturalists*, 22.55. The *Healthy Habits through Literacy* interviews were more often than not lists of healthy foods the children liked to eat. The research team plans to revise the curriculum to include more hands-on experiences that will hopefully allow the children to make more cross-links.

The research team is working to develop a mapping protocol and scoring system that can be used for both formative and summative evaluation across curricula in preschool settings. Therefore, the mapping protocol needs revision to strengthen the consistency among mappers. The simple interviews involving lists of food were mapped with consistency; however, consistency was less apparent as the complexity of the interview increased. Since complexity shows up in the cross-links and hierarchy levels, it is not surprising that the mapper by interview (person) interaction variance was large. The research team plans to refine the mapping protocol and conduct a new generalizibility study. The use of the scoring system contributed little to the total variance in the map scores across both the *Healthy Habits through Literacy* and the *Young Florida Naturalists* projects.

Differences found in the concept map scores of boys and girls in the *Young Florida Naturalists* project were not replicated in this study; however, the point estimate of the girls' mean score was higher than the boys'. What was more surprising is the finding of no difference in the concept map scores of the 3-year-old preschoolers and the prekindergarten children who were a year older. One possible explanation for this is the abstract nature of the focus and that interviews from both groups of children consisted mostly of lists of food.

Similarity to *Young Florida Naturalists* findings, the BBCS-3:R Self-/Social Awareness scores were positively correlated with the children's total concept map scores. However, the BBCS-3:R Texture/Material scores were not associated with the children's concept map scores. The Self-/Social Awareness scale assesses person-oriented knowledge. Inspection of the scale items shows that children were asked to select pictures that correspond to named attributes of people and/or relationships among people. The Texture/Material scale assesses children's knowledge about the attributes of objects in their environment. *Healthy Habits through Literacy* focused on self rather than objects, so this finding was not surprising.

Given that a goal of the project was to promote cognitive development, the positive correlation between the children's vocabulary measure, EVT-2, and concept map score is important. Note, however, the children's scores on the PPVT-4, the more widely used measure of vocabulary, were not associated with their concept map scores. But the reverse was found for the Bracken scales where scores from the receptive and not the expressive scale were correlated with the children's concept map scores. More research is needed on the use of receptive and expressive measures when assessing young, low-SES, African-American children.

5.1 Implication for Practice

Novak and Musonda (1991), in a study that constructed concept maps from young children's transcribed interviews, found that rating the interviews did not provide clarity when determining the structure of the children's knowledge relative to the entire domain. However, construction of concept maps allowed the respondent's propositions to be arranged in a hierarchical form and cross-links illustrated. Our experiences with preschool children's concept maps similarly showed that their maps could be useful as formative assessments. It was through constructing concept maps from the children's interviews that we first noticed the children had knowledge of the food pyramid and the food groups and could list healthy foods they liked to eat. However, most of the children did not place their list of healthy foods within food groups. Most complexity of the maps was expressed as hierarchical levels not cross-links. A suggestion for curriculum revision might be to develop sorting tasks where children sort pictures of foods into food groups.

5.2 Further Research

Avenues for future research include redesigning *Healthy Habits through Literacy* to develop hands-on activities for the children and developing more curricula designed to promote children's cognitive development. The concept mapping protocol needs to be refined to obtain more consistency when mapping cross-links and hierarchical levels. This study demonstrated concept mapping curricula, scoring, and associations with achievement could be extended downward to include 3-year-old preschoolers—the next steps will extend concept mapping curricula upward to include prekindergarten and kindergarten children.

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HOW THE DIALOGUE BETWEEN COGNITIVE, CONATIVE AND AFFECTIVE CONSTRUCTS IN ENTREPRENEURIAL AND ENTERPRISING LEARNING PROCESS IS EXPLICATED THROUGH CONCEPT MAPPING?

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Abstract The question of how to learn entrepreneurial and enterprising behavior has recently became one of the core questions in entrepreneurship education. Our approach to entrepreneurial and enterprising learning allows us investigate "how the cognitive, conative and affective self-regulating abilities interplay in entrepreneurial and enterprising learning process?" To contribute to this stream of research this paper adopts the three-partite constructs of the personality and intelligence originally introduced by Snow, Corno and Jackson (1996) and further applied to entrepreneurship education by Ruohotie and Koiranen (2000). This research consists of the two year follow-up reflections of 18 university students who participated in two consecutive study programmes of entrepreneurship education during years 2003-2006. The programme adopted entrepreneurial and enterprising pedagogy. Textual data consisted of 400 pages of reflections. Research methods and data analysis followed a two-part progression: 1) The application of Straussian Grounded Theory with the coding proceeds through open, axial and selective phases, 2) the concept map method. The results indicate that all constructs appeared in these entrepreneurship education learning interventions as well and transitions between them. However, the disappearance of affective construct in meta-level reflections emerged. The focus of this article is to present the aims and the results of this study. Although, we want to stress the methodological aspect of concept mapping. The article gives some views to develop 'pattern matching' and reliability of concept mapping.

1 Introduction

The question of how to learn entrepreneurial and enterprising behavior has recently became one of the core questions in entrepreneurship education. Our approach to entrepreneurial and enterprising learning allows us investigate "how the cognitive, conative and affective self-regulating abilities interplay in entrepreneurial and enterprising learning process?" This paper is organised according to our research question. First we have a slight insight into entrepreneurship, and entrepreneurial and enterprising learning; and the dynamics of cognitive, conative and affective constructs and meta-level self-regulating abilities. This is followed by a description of the research design and methodological approach. After that we report the results, discussion and ideas for future research. Even though our aim is to describe a research the main focus of this article is to present the methodological aspect of concept mapping and its utility in research.

2 Concepts and Theoretical framework

Entrepreneurship is a complex idea and entails a wide range of beliefs. Some believe that entrepreneurship must involve risk-taking individuals who start new ventures that are innovative and experience rapid growth. Others may only focus on the idea that entrepreneurship is about starting new ventures. When we talk about entrepreneurship we should recognize that it has many different meanings attached to it (Gartner 1990). To define entrepreneurship we also invoke the terms *enterprising and entrepreneurial*. Considering the differences between these terms the only major distinction that can be made is that an entrepreneur is traditionally associated with business activity (Gibb 1993). To avoid confusion and be exact, in this article are used explicitly both concepts, entrepreneurial (referring to the business context) and enterprising (referring general education and learning processes). The self-regulation and its future orientation aspects are focal elements in entrepreneurial and enterprising learning and behaviour (Linnakylä & Välijärvi 2005, PISA). *Self-regulation* enables goal-setting, strategy development and creative thinking which as a consequence enable motivation development and goal achievement. Self-regulation plays a major role in high level achievements and performances (Tiedemann 2000).

The question of how to learn entrepreneurial and enterprising behavior has recently became one of the core questions in entrepreneurship education. Our approach to entrepreneurial and enterprising learning allows us investigate "how the cognitive, conative and affective self-regulating abilities interplay in entrepreneurial and enterprising learning process?" To contribute to this stream of research this paper adopts the three-partite constructs of the personality and intelligence originally introduced by Snow, Corno and Jackson (1996) and further applied to entrepreneurship education by Ruohotie and Koiranen (2000). As Snow, Corno and Jackson (1996, p. 243) argue, these three modes of mental functioning have been historically distinguished but are still regarded as interactive elements in human intelligence and personality. The following Figure 1 indicates the interplay between constructs and metaconstructs of personality and intelligence.

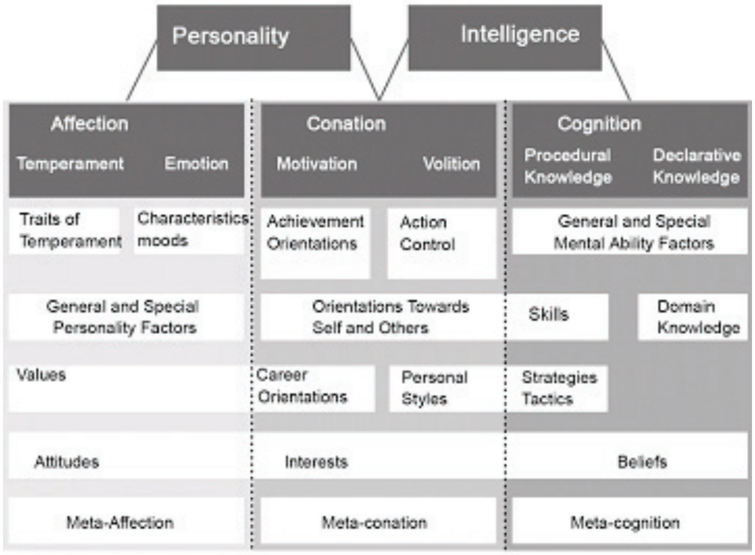


Figure 1: Constructs and metaconstructs of personality and intelligence (Combined: Snow, Corno & Jackson 1996, p. 247; Koiranen & Ruohotie, 2000, p. 104) and complemented with Metal-level construction

The cognitive construct contains declarative and procedural knowledge. The distinction between these is that the former refers to the way we link concepts together and the latter to our abilities to apply this knowledge. *Conation* is divided into two parts: motivation and volition. The motivational factor includes among other things internal and external goal-orientation, fear of failure, need for achievement, self-esteem, belief in one's own abilities and prospects, all of which are at the core of enterprising learning. Volitional structure entails among others, persistence, the will to learn, endeavour or effort, mindfulness in learning, intrinsic regulation and evaluation processes as well as different control strategies. (Ruohotie and Koiranen 2000.) Motivation precedes volitional processes to formulate the goals, but volition guides in setting clear goals as well as in the enactment and realisation of the decision. Thus both of these factors are essential in entrepreneurial and enterprising learning. *Affection* is divided into temperament and emotion. Temperament is more lasting and hardly dependent on individual situational factors, while an emotion may be strongly linked to a situation. If affection is embedded in all situations and each individual has his/her own temperament, it is hard to see that we can isolate these from a learning situation. For example, research in the field of fear of failure is deeply embedded in the concept of emotion and also temperament. A need for achievement can also be seen from an affective perspective. At a deeper level the affective construct relates to our values and attitudes. To put this simply, what we regard as valuable guides our willingness and interest to learn. Thus the affective construct is as fundamental to our learning as the conative construct.

These propositions finalise our approach to entrepreneurial and enterprising learning and allows us investigate "how the cognitive, conative and affective self-regulating abilities interplay in entrepreneurial and enterprising learning process?" This approach consists of three categories of self-regulatory abilities; meta-cognitive ability referring to the cognitive construct, conative meta-ability referring to the conative construct and affective meta-ability referring to the affective construct. We are aware that this proposition is open to criticism, especially considering that the dynamics of these meta-level processes are drawn from and developed by cognitive psychology. However, we also argue that perhaps the role of affective self-regulatory processes is neglected aspect in this debate and thus provides an opportunity to contribute into research in this field. This complexity also gives us methodological challenges. How to find methodological solutions for investigating this kind of dynamics? The solution we decided to adopt was a combination of Straussian grounded theory and concept mapping approach and technique.

3 Methodology

The textual data consisted of the two year follow-up reflections of 18 university students who participated in two consecutive study programmes of entrepreneurship education during years 2003-2006. The programme adopted entrepreneurial and enterprising pedagogy. The data consisted of 400 pages of reflections from seven modules, altogether 90 documents, out of which 36 were group documents (18 students * 7 modules = 126-90=36). The reflection instructions to gather students' experiences were same in all modules. The reflection format was based on action research studies. It guided towards three levels reflection; technical, practical and critical levels and to focus on the learning of an individual, the group and the course as well as an organisation and society.

The coding scheme was carried out within NVivo 7 qualitative data analysis software (QSR NVivo 7.0.281.0 SP4, 2007), while the construction and analysis of map representations expands NVivo's modelling functionalities by utilizing IHMC CmapTools concept mapping and knowledge modelling software (IHMC CmapTools 4.11, 2007; see e.g. Cañas et al, 2004). The resulting matrices were exported from the software to be processed further in spreadsheet and concept mapping software to summarize the results in meaningful representations.

Research methods and data analysis followed a two-part progression:

1) The application of Straussian Grounded Theory with the coding proceeds through open, axial and selective phases: The method of Grounded Theory has been recommended for those fields with few established theories, lacking sufficient knowledge or concepts or when new perspectives are of special interest. It is suitable for this research from all these three perspectives, since we know very little about the dynamics of how the cognitive, conative and affective self-regulating abilities interplay in the entrepreneurial and enterprising learning process. Influenced by pragmatism and social interactionism, Glaser and Strauss suggested that there was a need on the one hand to respect and reveal how the actors perceive phenomena and on the other hand to develop methodological tools for that. (Glaser & Strauss, 1967).

2) The concept map method: Concept mapping as defined by Novak (1998) and further developed by Åhlberg (2001) was applied as the basis for representations of research findings. By its' definition concept mapping provided a meaningful way of representing relational structure of the results of analysis.

As Jackson and Trochim (2002) argue this methodology is well suited for open-ended survey text data (or like we consider for reflection data as well) because it combines the strengths of word-based and code-based methodologies while mitigating some of their weaknesses. Through the word based approach it is possible to recognize reoccurring patterns or words, and on the other hand, retaining the context of these concepts and a desire to analyze the responses as a set representing the whole sample make code-based analyses also a very appropriate basis for concept mapping. Therefore, this mixture of thematic and word-mapping approaches in concept mapping has been seen us a very appropriate way to make interpretations about students' reflections. For example the following example may illustrate the mixture of these approaches in this research:

"*I **received** theoretical substance among other things about the parameters related to computation and economics in the starting phase of an enterprise. I **learned** that from the parameters it is quite easily to deduct the viability and economical stability of an enterprise. The process of constructing a business plan from a give model took form through the good material and the instruction from the entrepreneurship center.*" (The words which were regarded to refer cognitive construct are in the text with bold style – on the other hand, the example as a whole represents a good sample of cognition expression.)

The data collection in concept mapping is an ongoing, iterative basis, and where the researcher keeps on adding to the sample until there is enough data to describe what is going on in the context or situation under study. This process goes on until "theoretical" saturation is reached. As a consequence of theoretical sampling, coding, constant comparison, the identification of the core variable, and the saturation of data, categories and codes, the grounded theory emerges from a data in an unforced manner (Cohen, Manion & Morrison 2007, p. 491 - 495). Therefore the coding process of this study, building towards the grounded theory, included "operations by which data are broken down, conceptualised, and put back together in new ways" (Strauss & Corbin1990, p. 57).

In the *open coding phase* the topical content of the reflections and their related meta-level expressions were identified. In *the axial coding phase* first the references and meta-references were identified and organised according to the three constructs as a mini frame work. Then, by further adopting the three-partite constructs of personality and intelligence, these were organised according to different elements of each construct and presented as a concept map. Finally the transitions between these constructs were analysed. (see e.g. Åhlberg, 2004). In the *selective coding phase* core categories are chosen and systematically related to other categories validating those relationships. This provides a tentative model or a theory for further development.

However, the concept map itself does not constitute a theory regarding the effect of our program of learning entrepreneurial and enterprising readiness which we assume is structured on three-partite constructs. As

Trochim (1989) points out to achieve such a theory we need to state how the independent variable (for example our intervention) is related to the concepts on map. For instance, after reviewing the intervention in detail, we might conclude that some aspects of this three-partite constructs of personality and intelligence on the map will be most likely strongly affected than others. Specifically, we have overlaid our expectations about intervention effects onto conceptual structure, presenting where it will affect some concepts and not others. Thus, the concept maps in this study can act as the framework for a statement of theory, but can not be considered as a theory in and of themselves. Like Trochim (1985; 1989) suggests the further use of "pattern matching" could appropriate for us which works best when there is a clearly articulated, detailed theoretical pattern. These detailed patterns are more likely to be unique and a match will, consequently, be attributable to this unique theoretical "fingerprint". This research takes first steps towards this approach.

The reliability and validity of concept mapping was considered in the study according to and Jackson and Trochim (2002) who constructed their ideas on Krippendorff (1980) work: a) some units are more difficult to code than the others; b) some categories are harder to understand than others; c) subsets of categories can sometimes be confused with larger categories; and d) individual coders may be subjective.

4 Results

Open coding: First 1686 expressions were coded and then categorised according to their topics. All together 25 topics were identified and out of these 72 percent focused on seven categories. 242 meta-level expressions were identified among these 1686 references. From these 239 (99 percent) were identified in seven topical categories. Thus since our research question concerns self-regulating abilities these are most valid to us. Table 1 presents these frequencies.

Table 1. Topical categories and their references and meta-level expressions

Topical categories	Documents / category		Documents with Meta-level expressions		References/ category		References with Meta-level expressions	
	Number	%	Number	%	Number	%	Number	%
Learning and change	80	89	43	48	117	6,9	70	28,9
Collaboration, group dynamics	90	100	35	39	125	7,4	60	24,8
Studies and praxis	67	74	26	29	287	17,0	36	14,9
Individual work and processing	58	64	22	24	326	19,3	34	14,0
Time as resource	49	54	15	17	146	8,7	21	8,7
Joy, positive experiences	49	54	7	8	88	5,2	8	3,3
Teaching and pedagogy	48	53	9	10	117	6,9	10	4,1
Others 18 different categories					480	28,5	3	1,2
Documents N=90					1686	100	242	100

The meta-level reflection was defined by criteria, which allows taking into particular account the temporally regular nature of producing the reflection texts over a lengthy period of time. This is performed in explicit order to control and/or understand the relevant factors affecting own studying action and its' conditions. Expressions can also serve as foundation for planning or anticipation of future events and action explicated in text. Thus the inherent *meta-levelness* of the category refers to learning as reflected through explicating observations of how things keep changing, as different phases, activities and conditions of the path sequentially become active.

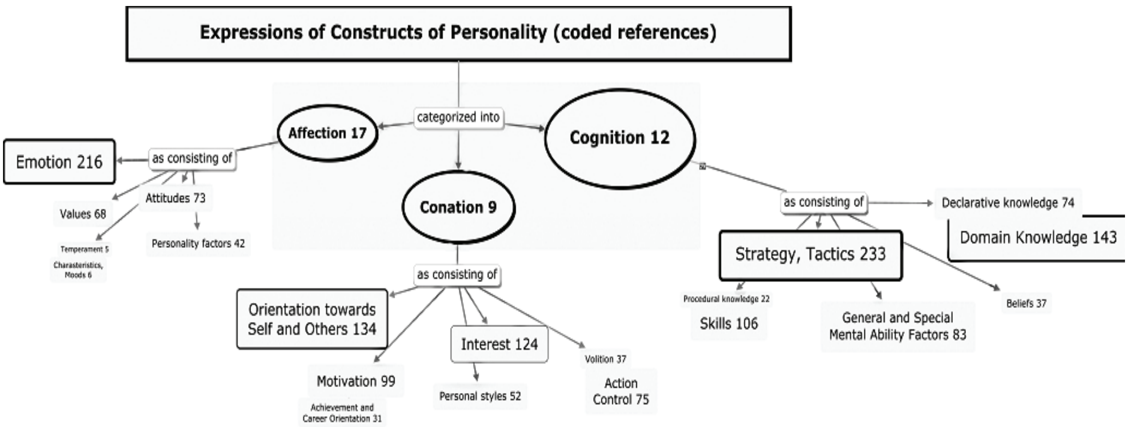
Topical category	Examples of expressions
1.Learning and change **Expression**	My view on entrepreneurship and entrepreneurial education expanded. I read quite a lot of new material that was mainly interesting. Hence, learning took place …
Meta-level expression	On the other hand, the recognition of also this deficiency is an essential thing for my own developement because for my own action as an educator of adults in the context of entrepreneurial education to evolve I must understand the diversity of the learners' starting points.

Axial coding: The distributions of the 1686 references and 242 related meta-level references are presented in Table 4 and examples of their expressions in Table 5.

Table 3. References and meta-level references according to the three-partite constructs of personality and intelligence

Construct	References		Meta-level References		Meta-level as % of total references
	Number	%	Number	%	
Cognition	698	41,4	169	69,7	24,2
Conation	561	33,3	57	23,6	10,2
Affection	427	25,3	16	6,7	3,7
Total	1686	100	242	100	

To look into these in more detail we constructed a concept map describing the relationships inside each construct.



(size of a sub-category relates to the frequency of coded references, size of the main construct to the relative size summed from the frequency of references in the sub-categories)

Figure 3. Expressions of constructs of personality with their associated sub-categories.

Construct	Examples of expressions/references
Cognition **Expression**	Domain knowledge: "*I received theoretical substance among other things about the parameters related to computation and economics in the starting phase of an enterprise.*"
Example of meta-level expression	Domain knowledge: "*[...]My knowledge on countryside travelling business is also too shallow. For this there is literature available, but a training session by an institute would be in order.*"
Conation **Expression**	Action control: *"Nobody has to be dragged along with the group but everyone strives to do one's best and invest in the effort."*
Example of meta-level expression	Action control: *"I felt myself receiving something else in exchange. I was the first to announce that "I'm allowed to do what I want". This was the element of freedom that also the research indicates entrepreneurhip to bring."*
Affection **Expression**	* *"I felt truly happy. [The beginning of the 15 credits unit suited me well timing wise.]"*
Example of meta-level expression	*"[...]Also it was obvious from observing the peer-group activity, how it had evolved. Most of the groups had truly examined their peer-group's work and considered the possible improvements to be implemented. In this sense, the peer-group activity should be first and foremost consoling, seeking for the positive and good qualities and aimed at improving the products, sustaining not that much focus on the negative or failed things."*

Within the cognitive category's sub-categories the reflection focuses on the areas of strategy and domain knowledge. This is largely due to the students' tendency to reflect on the decisions done in order to solve different kinds of problems mainly related to coordinating collaboration and organizing own action accordingly. The understanding of the strategic reflection being connected with collaborative operations gets support even on this level of representation, while viewed in context with the results from the open coding stage and especially when observing stress being received by the 'Orientation towards Self and Others' sub-category within the conative content.

The second large sub-category within cognition labeled 'Domain knowledge' should also be investigated in close contact with the previous two. At the same time it is instructive to view it alongside with the understanding of the prominent weight that comparative reflection on studies and praxis represents within the results of open coding. Here, looking at the open coding category, 'Studies' are seen as both the content and materials used in teaching, and also the pedagogically grounded action of the task setting. 'Praxis' in turn is the professional and everyday experience of the student related to the subject of teaching and studying.

In addition to the interplay between cognitive and conative constructs within the reflected content, the main finding at this point of analysis is the apparent significance of the amount and quality of action for the processes being accessible to reflection. The strong presence of the elements of 'Procedural knowledge' presented by the reflection on *how to act* gets even stronger, when taking into account the amount of reflection on skills. Skills can be reflected as either being learned as a result of studying or as operating as resource or limitation for the variety of strategies being available for application.

Secondly the aforementioned generally positive nature of the reflection reveals itself here, too. The content related to the construct of affection holds within the second largest, single theoretical category of 'Emotion'. This is due to students' notable tendency to eagerly name and point out positive feelings and emotion throughout and across the reflection on different themes – to say, events, activities, and stages of the study path.

At this stage we can say that all three constructs are present and also that action and positive emotions are extremely visible within these constructs and also that the reflections are written as interplay between these three constructs. However, to look more deeply into their interplay we still identified the transitions between different constructs. Transition is defined as a distinct, sequential passage within text from reflecting one construct to reflecting another, throughout which the narrative and thematic focus remains unbroken. The analysis of such transitions was done to understand the dynamics of reflecting constructs of personality in more detail, e.g. in which kinds of sequences do constructs get reflected in context with one another. Among 1686 references 238 transitions were identified.Their relationships are presented as a concept map in Figure 4.

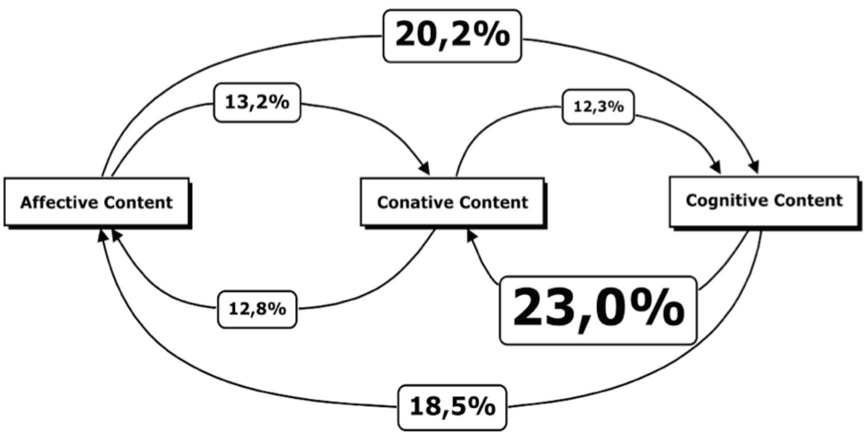


Figure 4. Transitions between the constructs (N 238)

Transitions	Examples of expressions
From cognitive to conative	Will the assignment fail, if the references aren't the "correct ones"? When searching for the idea of the entrepreurship education, from the perspective of the subject, this is in turn an "academic" conflict which is the evaluation criteria used for not ending up "murdering souls" once again? On the other hand, there emerged an idea, that we definitely won't be content with ourselves receiving "less than two" [for a grade]… …this to notify [teacher], even though we're not promoting rivalry for it's own sake.
From affective to cognitive	* I experienced a sensation of insight each time I started to work on a new paper; yet again I'd learned to think about things from another perspective.
From cognitive to affective	* During the 15 credits at hand, I've aimed at extracting as much as possible out of the subject. Even though the studies have taken time –meetings, emails, reading, writing- studying has been in general rewarding and good for self esteem.

Now looking at the relationships between three constructs, it becomes obvious that all of them are important in learning interventions. Cognitive related relationships cover 74 percent of transitions, conative related 61.3 and affective related 64.7 percent. The transitions between the three constructs take place in all directions. The most coded transition is from reflecting cognitive to conative content and the second-most coded transition is from affective to cognitive construct. It is a very common pattern within the data for the reflective writing sequences to initiate from recollection of having distinct emotions connected to different stages of the studying path and the related actions.This can be seen as an indication of how the catalyst nature of affective construct manifests itself also within reflection.

Selective coding: Now, as the selective coding assumes, we can select the core categories and relate them to other categories thus compiling a tentative model for further development. As Strauss and Corbin (1990, 116-142) express it "put the data back in new ways" check quote

The open coding indicates that action orientated pedagogy stimulates reflections and meta-abilities. Collaboration seems to be the key element of the learning and meta-learning of entrepreneurial and enterprising readiness. The research design of this study enhanced entrepreneurial and enterprising learning process.

Axial coding shows how all three constructs; affective, conative and cognitive, are present and involved in the three construct dynamics, although metalevel affective reflections are missing. Conation orientation towards others and self are reflected the most which is presumably grounded on the fact that courses designed were based on the collaborative pedagogy.

5 Discussion and ideas for future research

These results indicate that all constructs emerged in these entrepreneurship education learning interventions as well and transitions between them. The study indicates how affective meta-abilities, affective, conative and cognitive, constructs determine our learning processes. Thus to take into account more this interplay might help to enhance entrepreneurship in general.

However the disappearance of affective construct in meta-level reflections might reflect our poor ability to enhance entrepreneurial attitudes and values both found important for example in research of intentions. Strengthening these underrepresented elements might enhance students' reflection and self-regulation processes and as a consequence empower entrepreneurial and enterprising learning. Such ideas encourage us to suggest that this stream of research should get more emphasis in entrepreneurship education research.

However, it should noted that even the key concepts and their relationship are defined this research still is a very tentative and thus need a lot of efforts to reach the state of theory. Our tentative model as a suggestion for further explorative research in authentic settings to be developed towards theory is that: affection stimulates action in the cognitive construct and collaborative learning stimulates action and affection. Conative construct is stimulated by action.

Thus, in the future, the use of 'pattern matching' in concept matching (Trochim 1985) could be valuable since it could generate and scale our theoretical expectations, relationships and outcomes, in more detail. Hence, the questions of reliability and validity in concept mapping (Jackson & Trochim 2002; Krippendorff 1980) should be considered more precisely, since we overcame with all these difficulties: a) some units are more difficult to code than the others; b) some categories are harder to understand than others; c) subsets of categories can sometimes be confused with larger categories; and d) individual coders may be subjective. Therefore, we would see that in the future research we could develop a) *criteria reliability* for units and categories and b) *inter-rater reliability* referring to the fact of using more than one researcher in coding of same data.

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IMPACT CONCEPT MAPPING HAS ON PRE-SERVICE TEACHERS UNDERSTANDING OF SCIENCE CONTENT KNOWLEDGE AND DEVELOPMENT OF THEIR SCIENCE PEDAGOGY

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Abstract. The focus of this study is to support and improve the quality of teaching and learning of elementary teacher candidates in the physical and life sciences. Concept Mapping and Peer-Instruction (using ConcepTests) were used to model best practices in enhancing science concepts and processes at a conceptual level and to provide teacher candidates with a tool to enhance the learning environment and formative assessment of teaching and learning in their classrooms. Research indicates that an understanding of how students learn (or fail to learn) combined with appropriate cognitive tools, such as concept mapping, can create learning environments that produce improvements both in teacher preparation and their attitude toward teaching. The project aims to develop both an improved understanding of barriers to elementary teacher candidates learning physical and life science concepts as well as providing tools to help them surmount those barriers. The participants were pre-service candidates enrolled in the Macon State College (MSC) Early Childhood Education Program. The elementary schools where they conducted their field internships are in the neighboring school districts in Bibb and Houston counties. The use of ConcepTests and Concept Mapping provided a peer-supportive environment for pre-service candidates in which to develop a deeper knowledge of science concepts. Comparison of initial and final student concept maps suggests a moderate correlation between learning approach, development of concept knowledge and quality of knowledge organization.

1 Introduction

The objectives of the study were to: (1) allow teacher candidates to see concept mapping and peer-instruction practices proven to increase their conceptual understanding of physical and life science; (2) give teacher candidates the opportunity to use concept mapping as an organizing tool to engage in conversation in tandem with an expert, providing a deeper understanding of the implementation and use of this cognitive tool; and (3) provide teacher candidates the opportunity to apply concept mapping techniques to what they have learned and to receive immediate feedback while initially implementing the practice.

In the last two decades within all disciplines in science there has been an unequivocal shift in the goals of science teaching from helping students merely create a knowledge base of scientific facts to developing deeper understandings of major concepts within a particular discipline/domain of knowledge. This emphasis on conceptual understanding in science education reform has guided the development of standards and permeates all major science education reform policy (AAAS, 1989, 2001; NRC, 1996). However, this transition to teaching towards conceptual understanding presents a host of challenges both in theory and practice. More crucial is the fact that few if any students come to the study of physical and life science in college, without significant prior knowledge of the topic. Yet there is often little time invested by instructors in finding out the depth of their prior understanding, and more specifically any misconceptions and lack of understanding that might effect how they fit the new information they learn into their current cognitive framework.

Research has repeatedly pointed to teachers and the teaching environment as the key to improving student achievement. According to Darling-Hammond and colleagues (2001), studies have concluded that teacher qualifications (e.g. knowledge and expertise, education, and experience) "account for a larger share of the variance in students' achievement than any other single factor, including poverty, race, and parent education" (p. 10). One overriding feature that re-occurs throughout the literature as a paramount component of quality teacher preparation is the ability of teachers to "learn *about* practice *in* practice" (Darling-Hammond et al., 2001, p. 20). While theoretical instruction is important in building a foundation for teaching, adequate opportunities for teachers to apply the knowledge that they have learned is critical (Darling-Hammond et al., 2001; Gersten, Chard, & Baker, 2000). Critics accuse teacher preparation programs of not providing teachers with enough knowledge and practice with research-based strategies, hence the reason for a lack of implementation. One of six factors that Gersten and colleagues (2000) claim determines a teacher's sustained use of a practice is the teacher's ability to "understand and think through the instructional approach" and how it can be used. Given this framework, it becomes apparent that a teacher's level of knowledge about and experience with a given practice is directly related to his or her future implementation of that practice in the classroom.

Teaching methods, based on a careful consideration of constructivism in its epistemological, psychological and educational aspects, contrast with traditional ones. Gil-Perez (2002) indicates that it is not possible to change this behavior of the traditional teacher unless they change their epistemology, their ideas about how scientific knowledge is built, and their viewpoints about science. A constructivist learning environment is, according to Wilson (1996, p.194) "a place learners work together and support each other as they are using a variety of tools and sources of information, following the orientation of the learning purposes and the activities of problem solving". Building such an environment has a lot to do with the way the teacher approaches teaching and learning.

One of the important requisites of such constructivist environments is that students cooperate with each other for the solution of the tasks, which are proposed to them. These tasks should be stimulating challenges for their learning and cognitive development. Having cooperative activities, when it takes place in an adequate environment, is enriching as it often leads to students' meaningful learning (Soares, 2006). A concept map is a graphic organizer which uses visual representation to hierarchically organize a set of concepts, connected by descriptive words in order to build meaningful statements. Expressing meaningful relationships between concepts through a concept map reveals each student's comprehension and knowledge structure (Novak & Gowin, 1984). The negotiation of ideas among students, on the basis of concept mapping individually and/or by groups, particularly, when monitored by the teacher, helps them deepen the knowledge upon which the maps are based. This allows students and teachers being able to glean the meanings of course materials (Novak & Gowin, 1984).

At Macon State College (MSC) we are designing and developing a new teacher preparation program with certification in elementary and special education. The science course content is aligned to the Georgia Performance Standards (GPS) for physical and life science for K-5. Our attempt is to provide a content-rich background for our Early Childhood majors in order for them to become conceptually engaged and be able to acquire critical thinking skills as they progress onto becoming teacher candidates in our program. This is crucial for our students especially with respect to Science, Technology, Engineering, and Mathematics (STEM) education. MSC is an open enrollment college, part of the University System of Georgia that historically, has a rather depressed academic profile especially with respect to the public schools and STEM education. Although teacher education coursework often use constructivist teaching strategies that are student-centered and model best practice, lack of prior preparation in science and content connection to the real-world often lead to a disengagement with science course content (Anagnostopoulos, Smith, & Basmadjian, 2007; Putnam & Borko, 2000). By integrating concept mapping within standards based curriculum, teacher candidates can learn course content and immediately see its application within the K-5 setting, providing them a strong foundation of how to apply knowledge learned in their coursework to unique and realistic instructional settings.

2 Theoretical Background

Conceptual understanding denotes a complex, multidimensional integration of information into a learner's existing conceptual framework. Marzano and Kendall (2007) describe concepts to be synonymous with generalizations pertaining to disciplinary knowledge. In understanding science concepts this requires the organizing of ideas into principles and processes that are guided by these principles. This suggests that the acquisition of new knowledge and enriched understanding requires a balance between students' prior and new understandings. In addition, it requires varied instruction and ongoing assessment during the course of instruction. The following four teaching strategies lend themselves to teaching towards knowledge enrichment based on conceptual understanding: (1) using different instructional strategies regarding topics chosen and time involved in teaching those concepts; (2) different approaches used to help students identify their prior understanding; (3) use of misconceptions as a diagnostic tool for assessment; and (4) using assessments designed to detect change in understanding.

The use of alternative conceptions and/or misconceptions to promote conceptual understanding has a long history in the teaching of science (Hestenes, Wells & Sawackhamer, 1992). Pintrich and colleagues (1993) indicate that the motivation to persist in the difficult process of constructing and organizing knowledge is related to the value of the task and to the student's belief in the likelihood of success in internalizing knowledge. The value of a task can also be influenced by classroom contextual factors in the form of peer interactions that help create an environment of commitment to understanding. This can be achieved by integrating cooperative peer instruction in the form of ConcepTest, and class wide discussions through collaborative concept mapping.

ConcepTests (CT) were developed by Eric Mazur (1997) to help students confront misconceptions, and develop conceptual skills by defending their understanding about concepts in physics. The very nature of peer-guided discussions allows students to explore and confront their understanding and/or misconception. ConcepTests are designed to promote debate between peers thereby providing a safe scenario for conceptual shifts to occur in the relative absence of a grade.

The theoretical foundation of concept mapping rests upon the constructivist view of education and Ausubel's theory of meaningful learning (versus rote learning) (Heinze-Fry, 2004). Concept maps (CM) were developed as a metacognitive tool that help students understand the science they study by revealing gaps in understanding, identifying misconceptions, promoting reflective thinking, and facilitating shared understanding (Iuli & Hellden, 2004). Concept maps visually represent an individual's knowledge within a framework of concept relationships thereby allowing assessment of an individual's understanding. An instructional format with these components will provide teacher candidates with the opportunity to reflect on their own misconceptions, and to refine their own understanding by listening to one another's ideas and justifications and seeking clarifications. Pre-service teachers can construct concept maps that identify and define structural concepts based on their individual understanding and knowledge about curriculum and pedagogy. Concept mapping can be used to make explicit the relationship between principles, processes, and their conceptual content. Research on the current status of US elementary science curricula reveals considerable mismatch between science instruction and science concepts. Concept mapping can be used to bridge this gap by revealing to the teacher whether or not their students grasp both the concepts and procedures as an integrated whole. CT and CM techniques were used to identify teacher candidates' prior knowledge and provide them with a safe environment and the flexibility to probe, monitor, control, and reflect on their own learning

The Learning and Studying Questionnaire (LSQ) (Entwistle et. al., 2002) is a well-established survey instrument that examines students' approaches to learning and studying. Previous research by Iuli and Himangshu (2007) suggests the efficacy of using student approaches to learning to correlate concept-mapping data in undergraduate science. Improved map organization representing a more coherent understanding of relationships between concepts strongly correlates with a conceptual approach to learning. For most items on the LSQ, students respond on a 1-5 Likert scale (5=high). Subscales result from adding together the responses on the items in that subscale. Because change in conceptual understanding can be influenced by individual differences in approaches to learning as well as peer-interaction, LSQ scores were obtained to provide a measure of individual learning approaches. The differential between Deep versus Surface approach scores was used to group students as Deep, Surface or Mixed learners. Scoring was done using EXCEL 10.0.

3 Methodology and Materials

This pilot study was designed to provide an environment in which to test the impact of interactive teaching strategies on enhancing student conceptual understanding in an undergraduate science course designed for pre-service teacher training. The experimental design involved the use of CT and individual CM for teaching physical science concepts in a course designed for elementary science teachers based on GPS for elementary science. Development of conceptual understanding was compared between individual pre-service teacher concept maps at two different points, beginning (initial cmap), and end of semester (final cmap) and compared to a collaborative unit map which addresses a science theme using different disciplinary lenses for example physical science and earth science. The criteria for analysis of concept maps included number of accurately linked concepts, hierarchy and organization, presence of examples, and removal of misconceptions. In addition, the Learning and Studying Questionnaire (LSQ) was administered in order to group students as Deep, Surface, or Mixed (using both Deep and Surface methods) and data from ConcepTests was used to triangulate analysis of concept maps.

A base line of pre-service teacher candidates' understanding regarding physical science concepts was assessed pre-instruction by designing reading quizzes used to evaluate prior understanding. Change in pre-service teacher candidates' conceptual understanding was assessed at several points post-instruction by designing questions based on application of concepts. An item-analysis of questions missed by 50% or more of each group of students was used to design ConcepTests. In addition, sub-groups consisting of 2 pre-service candidates each were engaged in creating collaborative unit map regarding a science theme viewing concepts, processes and their applications from 2 disciplinary lenses, for example teaching Habitats of Georgia blending life science and earth science. Peer-instruction and guidance during both the ConcepTest and collaborative concept mapping activities provided a venue for addressing misconceptions and clarifying concept confusion.

Using this design, all pre-service candidates were trained in the use of concept mapping as well as provided with immediate feedback support. This design provided the potential to identify an effective method for impacting teacher preparation. The total number of pre-service teacher participants was 65 with $\alpha = .05$ and power = .80 the required sample size is about 28 participants per group. This was necessary for the observation of a moderate effect size ($\omega^2 = .06$; Cohen, 1988). As the intention of this pilot study was to generate a model for replication, a moderate effect size was required in order for the project to merit replication and further implementation of these teaching strategies.

4 Data Analyses

The sample population consisted of a total of 65 pre-service teachers, (59 females and 6 males), enrolled in the General Science for Elementary Teachers course at MSC. The LSQ distribution for this population is, 20% deep learners, 52% mixed learners, and 27% surface learners (Figure 1). ConceptTests correlated strongly (r (2) = 0.76, $p<0.01$) with concept maps of deep learners, and moderately (r (2) = 0.56, $p<0.01$) with concept maps of mixed and (r (2) = 0.52, $p<0.01$) surface learners.

LSQ Type	Concepts (% increase) (> 4 linkages)	Hierarchical (% increase)	Misconception (% decrease)
DEEP (n=13)	38	30	0
MIXED (n=35)	51	45	23
SURFACE (n=17)	35	53	29

Figure 1. Comparison between initial and final concept maps based on student approaches to learning.

For the majority of pre-service teachers in this study analysis of initial and final student maps reflected gains in number of concepts as well as depth of understanding (represented by linkages between concepts). Irrespective of the approach to learning, 75% of pre-service teachers demonstrated gains in conceptual understanding as measured by the end-of-semester maps (Figure 2). Moderate gains in increased number of linkages and hierarchical organization were observed in the concept maps from mixed (51%, 45%) and surface learners (35%, 53%), respectively. Deep learners showed a minimal increase of 38% with respect to number of linkages and 30% increase in hierarchical organization. With respect to absence of misconceptions, none of the concept maps constructed by deep learners had an misconceptions while maps from mixed and surface learners showed a 23% and 29% decrease in misconceptions, respectively, Figure 1. Overall analysis of individual student concept maps between the beginning (initial Cmap) and end of the semester (final Cmap) suggests: (1) Gains in understanding as denoted by 63% increase in hierarchical linkages, 75% increase in number of concept linkages (> 4) and 46% increase in examples provided to explain concept relationships and (2) Misconceptions and inaccuracies were reduced and clarified by 25%, (Figure 2).

Criteria	Initial Cmap (n=65)	Final Cmap (n=65)	% Gain (+)/ Loss (-)
Concepts Accurately Linked	2 linked concepts = 65 3 linked concepts = 52 4 linked concepts = 32 >4 linked concepts = 8	2 linked concepts = 65 3 linked concepts = 65 4 linked concepts = 54 >4 linked concepts = 57	2 linked concepts = 0% 3 linked concepts = + 46 4 linked concepts = +34 >4 linked concepts = +75
Hierarchical	16	57	+ 63
Examples Included	40	53	+ 46
Presence of Misconceptions/ Inaccuracies	35	8	- 25

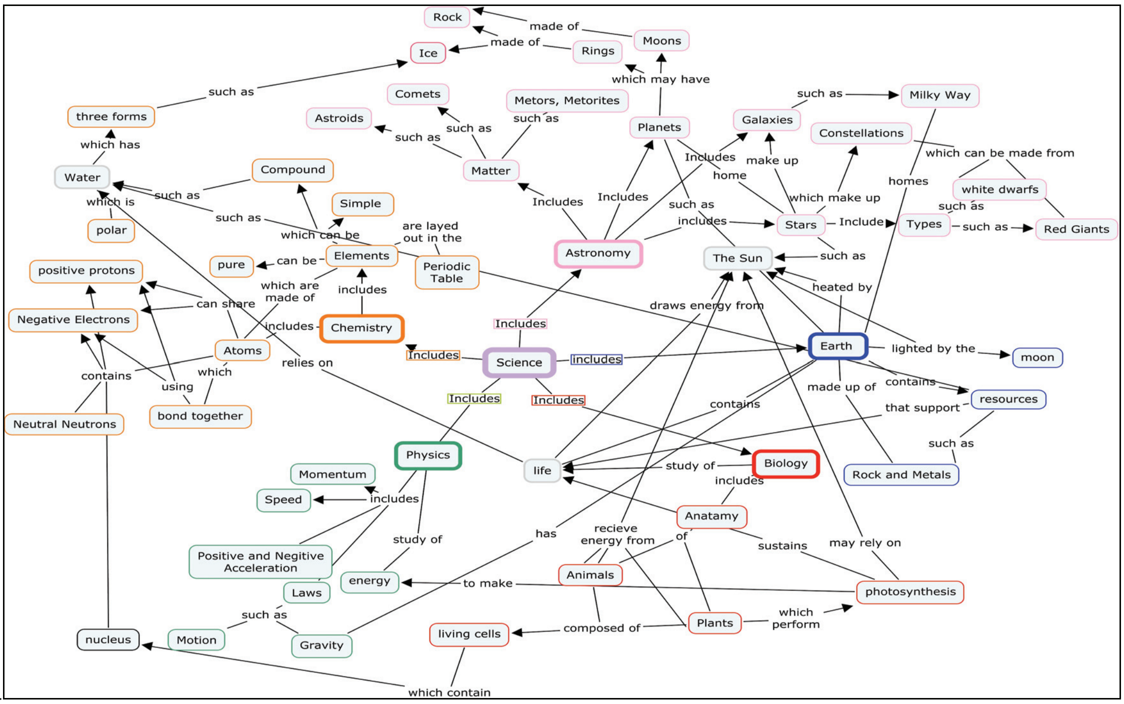
Figure 2. Overall comparison between initial and final concept maps (n = 65).

Figures 3a. & 3b. provide an example of one pre-service teacher candidate's initial and final concept maps to show the progression of concept and hierarchy development. The following observation by this student is included as she described her attempts to create a concept map about motion and energy.

Being able to actually see the concepts arranged visually and being able to re-organize and link them again and again I realized I was trying to put too much that I was finding hard to link. I needed to revise my map and actually re-did it four or five times before I could use only the big ideas to connect motion and energy …. I think we try to link too many terms and that would be very difficult to teach especially to third graders. The concept map helped me understand what I was missing and how to connect the terms. It was also useful and less scary to work along my classmates as I continued to make my map better.

The above student transcript indicates that being able to visualize the organization of concepts provided a useful means of learning about her own understanding and that the refining process was important in identifying key concepts regarding motion and energy that helped her connect these concepts from both a physical science and a life science perspective. This pattern is apparent in the structure of the concept maps constructed by the mixed and surface learners.

3a



3b

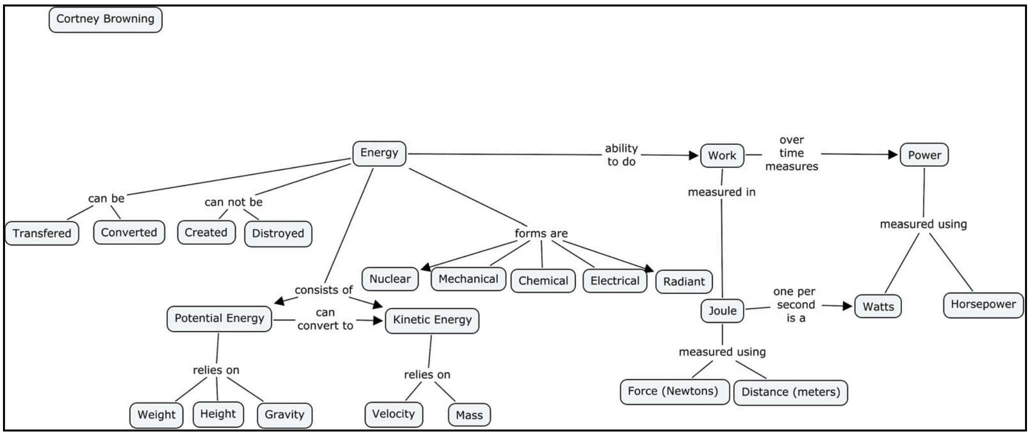


Figure 3. Maps a & b depict one pre-service teacher's development in hierarchy and concept accuracy between the beginning (a) and towards the end of the semester (b).

5 Results and Conclusion

Data analysis indicated a moderate correlation between individual approaches to learning and the growth observed in concept understanding in pre-service candidate maps between the beginning and end of semester. The moderate correlation between approaches to learning and the responses on the ConcepTests analysis for both mixed and surface learners correlates with the fact that only 3 pre-service candidates had any High School Physical Science prior to entering the EC program. Initially these student teachers were hesitant to defend their understanding of concepts but their discussions became more robust as they used the concept mapping process to guide their understanding or lack thereof. An overall increase in student confidence on an individual basis and classroom level as expected was represented in gains in conceptual understanding between the individual initial and final maps. In addition, end-of-term collaborative unit maps (data not included) each constructed by a pair of teacher candidates, for student teaching in a third grade classroom, indicated integrated content understanding, accuracy, and hierarchy not observed in initial individual concept maps.

6 Significance of Results

This is a first attempt to use different meta-cognitive strategies in concert to enhance student conceptual understanding in science in a standards-based Early Childhood teacher-training program. An overall increase in teaching confidence on an individual and classroom level basis was represented in gains in conceptual understanding between initial and final concept maps and the collaborative unit map. The use of peer-instruction through ConcepTests and collaborative concept mapping provided an environment that nurtured student engagement and enhanced conceptual understanding for the pre-service teacher candidates.

The broader impact of this project is the ability to change how pre-service teachers are prepared to teach science in the classroom. The costs are minimal and the potential impact is high. By capitalizing on existing technology, we can change the face of teacher preparation and ultimately improve student outcomes in STEM disciplines. In addition, we propose to extend this pilot study by supporting six teacher candidates as they develop their own teaching strategies and assessment methods during their clinical experience. Given the critical need for qualified teachers in the areas of mathematics and science, teacher preparation programs must work to ensure that new teachers entering the field are well-prepared and supported. The use of concept mapping and ConcepTesting offers a cost-effective means by which to provide pre-service teachers with the experiences and immediate supportive feedback that is crucial in improving content knowledge.

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INDIVIDUAL CONSTRUCTION OF KNOWLEDGE IN AN ONLINE COMMUNITY THROUGH CONCEPT MAPS

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Abstract. This study investigated the use of an asynchronous online community of learning and inquiry and concept maps as strategies to facilitate individual construction of knowledge. The community of learning and inquiry proved to be an effective strategy for designing the interactive aspects of the online course and creating an environment to explore different ideas and concepts, share knowledge, and learn from each other. The concept maps facilitated students' individual construction of knowledge after participating in collaborative learning. Using the concept maps, students were able to prioritize information, integrate concepts, confirm knowledge, and construct new knowledge. The skills learned by using concept maps can be transferred to other learning situations.

1 Introduction

Learning in online communities has become more widespread in higher education with the advent of online education. Garrison (2003) indicates that the goal of the community of learning and inquiry in an asynchronous online environment is to promote "independent thinking in an inter-dependent collaborative community of inquiry" (p. 49). In this environment, learners have the potential to be part of meaningful social and cognitive experiences and gain higher-order learning. However, one may argue that the social nature of an online learning community focuses primarily in the experience of the community as a whole, rather than the individual learning outcome. Our study investigated an online course that used the community of learning and inquiry as the basis for designing an asynchronous online learning environment. In addition, concept maps were utilized as a tool to help students construct individual knowledge after participating in collaborative learning.

2 Concept Maps and Collaborative Learning

There have been a fair amount of publications on the topic of concept maps and collaborative learning in journals and conference proceedings. Many of these publications are descriptions of the authors' experiences using concept maps in various contexts within online environments. Themes from the literature include challenges in creating concept maps, the use of different concept map tools for facilitating students' thinking process, exploration of different instructional methods based on concept maps, use of concept maps to increase communication, the effect of collaborative concept maps on learning, and the integration of ideas and knowledge between learners during collaborative concept mapping.

Rábago (2004) describes the difficulties that students have creating concept maps, which in part is due to the lack of tools necessary to build them or a lack of knowledge about the concept map subject. Laampere, Matsak, and Kippar (2006) found technological and pedagogical challenges in creating concept maps in online environments because of the poor integration of concept map tools and learning management systems. Luckie, Harrison, and Ebert-May's (2004) experimental study revealed that the use of the CTOOLS Concept Connector facilitated students' visualization of their thinking process online.

Cabral, Zeve, Nicolao, and Amoretti (2004) explored methods to design instructional materials using concept maps. Calderón, Agüera, and Alfageme (2004) also looked at instructional approaches to use concept maps; the results of their investigation reported that concept mapping assisted students in acquiring or improving their skills in studying, thinking, and teaching.

Tarouco, Geller, and Medina's (2006) study addressed the benefits of using concept maps to increase organized communication among participants. An extensive literature review done by Basque and Lavoie (2006) described 39 studies on collaborative concept mapping at a distance and face-to-face, including topics such as the quality of concept maps, the effect of collaborative concept maps on learning, and the integration of ideas and knowledge between learners during collaborative concept mapping. One of the studies reviewed included Cañas et al., (2001), which focused on Latin American school children using asynchronous concept mapping and sharing them through a network called Knowledge Soup. Rice, Ryan, and Samson (1998) studied the use of concept maps in seventh grade life science classes to assess student learning.

A significant amount of these studies focused on K-12 students, but a few such as the one examined by Calderón, Agüera, and Alfageme (2004) explored the effectiveness of concept mapping as a tool for higher education. De Simone (2007) investigated and reviewed three commonly used applications of concept mapping in higher education. She compared physical concept mapping (hand drawing), mental concept mapping (creating the maps only in one's mind but not on paper), and electronic concept mapping with Inspiration software to share in an online environment. Fonteyn (2007) discussed the use of concept mapping in nursing education as an easy way to deepen understanding of concepts and stimulate critical analysis. MacNeil (2007) describes concept mapping as a means of course evaluation in an undergraduate wellness program. Students completed concepts pre-lecture and post-lecture which were later compared by complexity.

There is no doubt that the use of collaborative learning strategies plays an important role in the individual construction of knowledge. There seems to be a dearth of information considering individual construction of knowledge through concept maps in an online community of learning and inquiry. Therefore, the purpose of this study was to investigate an online course that used the community of learning and inquiry as the basis for designing an asynchronous online learning environment and concept maps as a tool to help students construct individual knowledge after participating in collaborative learning.

3 Conceptual Framework

Marzano and Pickering (1997) developed the Dimensions of Learning model to define the learning process. The model helps maintain the focus on learning, examines the learning process, and assists in mapping the curriculum, instruction, and assessment considering the five aspects of learning: (1) attitudes and perceptions, (2) acquire and integrate knowledge, (3) extend and refine knowledge, (4) use knowledge meaningfully, and (5) habits of minds. The five dimensions of learning served as the basis for analyzing the individual learning process and how the creation of concept maps assisted individual construction of knowledge in the online course.

The first dimension stresses the need to assist learners to develop positive attitudes and perceptions about the educational climate and tasks. These attitudes are developed when learners feel accepted by the teacher and peers and have a clear understanding of the task to be completed. Initial course exercises, such as self-introductions, helped in the development of group trust, and the availability of the instructor as well as the clarity of the syllabus facilitated in learners positive feelings toward tasks.

The second dimension tells us about the acquisition and integration of declarative knowledge (what we understand) and procedural knowledge (what we are able to do). In this course, learners acquired knowledge through group discussion of theories and principles, and integrated knowledge by internalizing and constructing individual concept maps.

The third dimension occurs when learners extend and refine the knowledge they initially acquired by debating multiple perspectives of an issue (different learners' points of view), analyzing the reasons and logic behind each view, and by changing or maintaining and defending their own perspectives when constructing the individual concept maps.

The fourth dimension focus on using knowledge meaningfully. Learners were encouraged to explore theories and principles and use personal experiences as examples during the online discussion. By applying the learned knowledge in contexts that were close to them, learners gained confidence in practicing using the new concepts. The required individual concept map engaged learners in a complex thinking process which involved decision making, problem solving, and invention.

The fifth and final dimension of learning, habits of mind, relates to the development of critical thinking. The acquisition of this skill was demonstrated by the progressive evolution, throughout the course, of the individual constructed concept maps. Learners demonstrated to be open minded and effective in responding to other's feelings and knowledge but at the same time clear and accurate at taking and defending a personal position that was reflected on their respective concept maps.

The five dimensions of learning served as a basis for analyzing the individual learning process and how the creation of concept maps assisted individual construction of knowledge in the online course.

4 Methodology

4.1 Online Course Context

The online course, *Distance Education for Adults*, used in this study was offered within a period of three years at a higher education institution in the Midwest of the United States. The purpose of this online course was to allow students to gain a set of skills to process and generate information and beliefs and to self-assess their own thinking processes through the analysis of concepts, theories, and research on distance education and development and assessment of distance education programs. Course content was distributed into five modules during which specific readings were assigned. Each module lasted two to three weeks. Learners were required to participate in online group discussions for each module, create concept maps of their understanding of the concepts addressed in the readings and online group discussions upon completion of each module and a synthesis concept map summarizing the whole course at the end of the semester, self-reflect on the concept maps immediately after they created them, and participate in a team project to develop a distance education program.

A face-to-face course orientation in the beginning of the semester and a meeting at the last day of the class were also part of the course. For the online portion of the course, students met virtually via the learning management system Desire2Learn (D2L). The face-to-face orientation included a scavenger hunt of D2L (i.e., learning about the different features of the course such as content information, discussion forums, announcements, gradebook, drop box, chat, links, and survey), completion of a learning style inventory and a "Getting to Know You Survey," and online message postings introducing themselves to the rest of the class. During the orientation, students gained access to the syllabus and course timeline with required due dates and course assignments.

The first week of the course was reserved for the course orientation. The instructor assigned individuals to groups and group members were involved in logistical tasks to prepare for the module discussions and team project. After completing each module, students received prompted feedback from the instructor on the individual participation in the group discussions, team project tasks, and concept map assignment. These strategies helped students develop positive attitudes and perceptions about the online environment (learning climate), feel accepted by the instructor and peers, and experience a sense of comfort and order.

4.2 Research Question

This study was based in the following research question: How can concept maps be an effective tool to construct individual knowledge after participating in an asynchronous collaborative online learning environment?

4.3 Data Collection and Analysis

Data for this qualitative study were collected using concept maps, reflective journals, and transcripts from online discussions (N=30) offered during a period of three years (2003 [n= 8], 2004 [n= 13], and 2005 [n= 9]). Concept maps, reflective journals, and transcripts were analyzed to identify patterns of achievement in the three courses. These three sets of data were used to compare the initial postings of the students and concept map creation with the contributions and concept maps at the end of the semester in order to analyze developmental changes in students' thinking processes. Data analysis of concept map reflective journals was guided based on students' perceptions and attitudes toward their individual construction of knowledge as a way to triangulate data.

Participants were asked to respond to the following reflective questions about their process of creating the concept maps:

- After creating the concept map, did you see relationships among concepts that you did not see before?
- What was the easiest relationship among concepts to depict? What were the most difficult relationships to depict? Why were they easy or hard to depict?
- Look at the concept map and think back to the online discussion you participated during this module. Is there a relationship between the concepts you read and the online discussion? Were there moments in the online discussion you felt disoriented or confused? Does the concept map provide any clues about why you felt this way?

5 Findings

In this online course, students participated in collaborative problem-solving and threaded discussions through asynchronous communication. These online discussions were established to promote learner-driven environments. Group members shared responsibility for their own learning as well as the learning of the group (Prestera & Moller, 2001). It was through the concept map assignments that individual construction of knowledge was most evident. It became clear that learning was a developmental process throughout the semester as one student stated: "…I am gaining experience with each map…" Creation of concept maps and students' reflections of their own learning were important aspects of the course process. According to students' reflections, they felt that when creating the concept maps they were able to prioritize information, integrate concepts, confirm knowledge, and construct new knowledge.

5.1 Prioritizing Information

Students felt that creating concept maps assisted them in organizing their thoughts; articulating, clarifying, and understanding the discussion topics better; relating concepts in readings more clearly; and defining conclusions. Some of the students' reflections explaining how they prioritized information include:

- "Do I think the concept map is an accurate representation of what I learned from the two mediums? Yes, I believe so. I think anything I have the chance to articulate and to discuss ad nauseum helps me understand the topic better."
- "…it wasn't until I created my concept map that the connections became clear to me."
- "I used the maps I created before to refresh my memory…"
- "It was nice to be able to see the main concepts that I learned throughout the semester on one page."
- "The concept map gave me the ability to organize my thoughts."
- "When you see everything you are thinking about put into a diagram, it becomes clear how everything inter-relates to one another."

Students commented that there were so many different topics covered in a module that it would have been impossible to depict everything in a map, so they chose (prioritized) what they felt was most important.

5.2 Integrating Concepts

In addition to prioritizing information when creating the concept maps, students were able to integrate information better once they created their individual concept map. One student expressed this new ability this way:

> When talking about a topic, it is difficult for me to express that concept without bringing in the examples, questions, and scenarios used in the online discussion. The two [content and online discussion] really become one. The literature is theoretical and distant to me until we discuss it, then it seems to have more merit or weight to it so that I can fully conceptualize and remember it.

Integrating concepts was accomplished when students synthesized information through the concepts as these two students stated, "Mapping has made it much easier to see and define conclusions from all of the readings and research in this area as well," and "Summarizing all of the readings through this concept map helped tie all of the information together and helped me reflect on which topics I enjoyed the most." As students gained more integrative abilities through the construction of the concept map, they were able to let go of the segments tied to particular chapters and began mapping the overarching concepts. One student expressed, "My concept map is a collaborative effort between online discussions and my own interpretations." It was a general comment from students that after composing the concept maps they were able to see relationships that had not been apparent when reading or discussing the content with others. Developing the concept map helped the students look at the readings from a different perspective. Figure 1 shows the course synthesis in the final concept map created by a student.

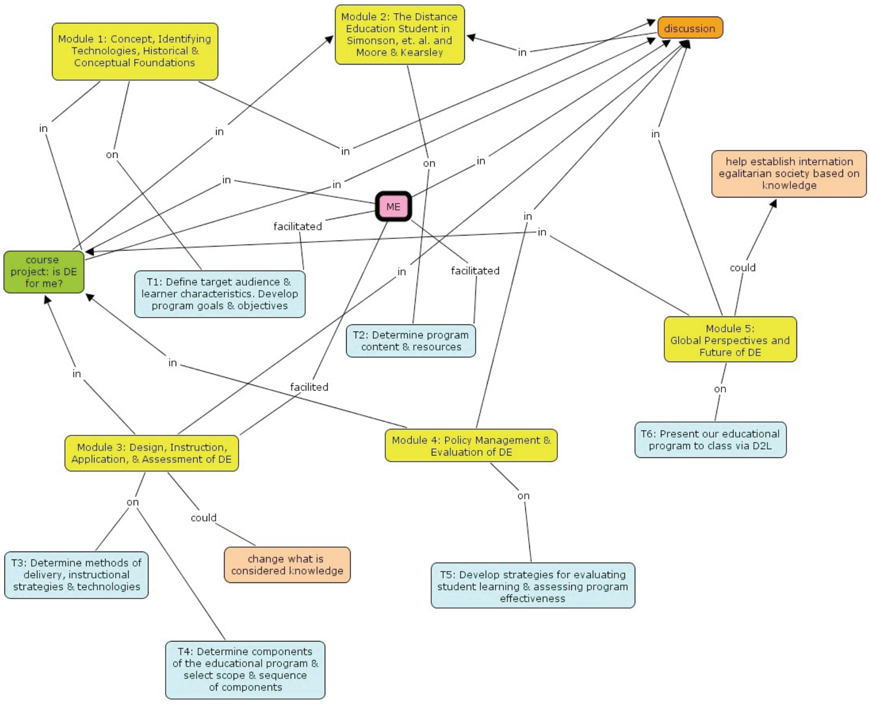

Figure 1. Final Concept Map

5.3 *Confirming Knowledge*

Students indicated that creating the concept map after the module discussion was a good way to reinforce their thinking and understanding relationships among concepts better. One student stated, "I didn't see any new relationships after completing the concept map, just reconfirmed what I've known or learned over the semester." Another student stated that "…the process of creating a concept map refreshed my memory about the discussion and reconfirmed my understanding." After the creation of concept map for a few modules students realized that the concept maps not only helped them clarify some issues in the readings, but also forced them make their own connections and confirm what they had learned. Figure 2 shows how the final concept map confirmed knowledge for this student.

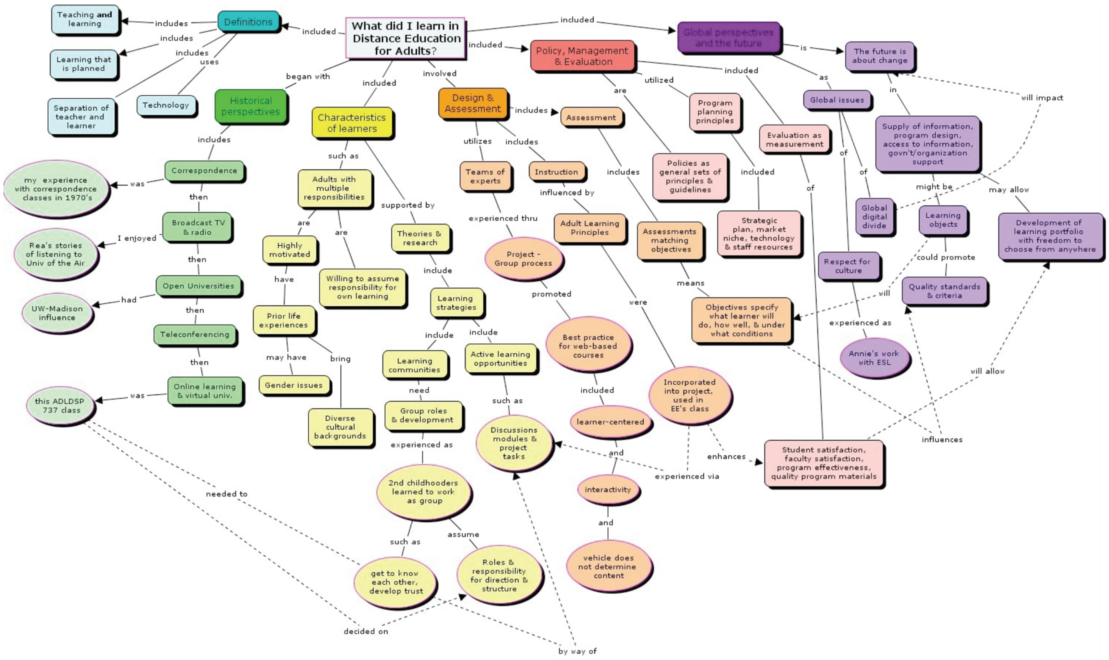

Figure 2. Final Concept Map

5.4 Constructing New Knowledge

Some students realized that after creating the concept map, they discovered several relationships among concepts that they didn't see before, as this student explained: "It is easier to see how the requirements in one area play out in another when they are mapped on a single sheet of paper." Over the period of the semester, students thought that the concept maps became personally meaningful to their learning. One student stated, "Both our online discussion and the concept map process helped me see relationships that I didn't consider before." Another student reflected on the different possibilities of creating the concept map based on the readings and discussions: "The association provided by the map has opened me up to interest in further exploration."

For the final concept map students had to create the synthesis of their own learning gained in the course. It was at this point in the course that most students recognized they were constructing new knowledge and taking responsibility for their own learning process. One student stated after completing the final concept map: "After taking responsibility for my learning, I realized the map was my knowledge or understanding of the readings."

6 Dimensions of Learning Model and Concept Mapping

The creation of concept maps in this study proved to be a developmental learning process that served to acquire and integrate knowledge, extend and refine knowledge, and use knowledge meaningfully as the focus of learning. The critical aspects of learning characterized by the Dimensions of Learning Model (Marzano & Pickering, 1997) are supported by the use of concept maps to facilitate individual construction of knowledge in the online community of learning and inquiry:

- The introductory phase of the course (face-to-face orientation) helped students develop positive attitudes and perceptions about the class tasks such as perceiving tasks as valuable and interesting, believing they had ability and resources to complete tasks, and having a clear understanding about the tasks.

- Students acquired and integrated knowledge through declarative knowledge (i.e., descriptions, process/cause-effect, scenarios, principles, and concepts) by constructing meaning, organizing concepts, and storing information through concept maps.

- Students extended and refined knowledge they initially acquired from readings and discussions through comparing, classifying, abstracting, and analyzing perspectives when synthesizing concepts through concept maps.

- Students used knowledge meaningfully when they were challenged to use knowledge in context meaningful to them, making learning authentic, practicing using the knowledge, and thinking and reasoning different than recalling and recognizing through the construction of concept maps. Students were engaged in complex thinking and reasoning through the creation of concepts maps because they had to make decisions in order to generate and apply criteria to select information to include in the concept map, problem solve in order to overcome constraints in way of accomplishing the concept map, and develop unique processes when creating the concept map to fulfill the assignment.

- The outcome of the concept map is the blueprint of the student's critical, creative, and self-regulating thinking, which Marzano and Pickering (1997) call "habits of mind." If students are able to use the habits of mind as a strategy for learning, the process of learning can be a rewarding one for the individual in any learning situation.

7 Implications for Practice

The findings of this study can have practical implications for designing online courses. One of the most valuable aspects of the construction of concept maps in an online course was the reflective component of the assignment. After completing the concept map, often students refined and expanded their knowledge by rethinking and recreating their original concept map. The process of creating the concept map made it clear to students the knowledge they had acquired through readings and the connections they made through interactions with others in the online discussion.

By experiencing the sense of comfort and order students develop positive attitudes and perceptions of the learning experience in general. It is important to give students time to establish and build the online learning community, so they feel a sense of comfort in the class environment.

The use of concept maps can be especially effective when students are learning new theories because students can critically analyze complex concepts and connect them with previous knowledge. The skill of critical thinking gained through creating concept maps can help students make use of knowledge meaningfully in other situations.

8 Conclusions

This study shows that concept maps are effective strategies for the individual construction of knowledge when students work in a community of learning and inquiry in an asynchronous online environment. The community of learning and inquiry was a good strategy for designing the interactive aspects of the online course and creating an environment to explore different ideas and concepts, share knowledge, and learn from each other. The concept maps facilitated students' individual construction of knowledge after participating in collaborative learning. Using the concept maps, students were able to prioritize information, integrate concepts, confirm knowledge, and construct new knowledge. With the widespread use of online learning communities in higher education, concept maps can be a valuable tool for enhancing individual learning and constructing personal meaning.

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INTEGRATING KNOWLEDGE, FEELINGS AND ACTION: USING VEE HEURISTICS AND CONCEPT MAPPING IN EDUCATION FOR SUSTAINABLE DEVELOPMENT

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Abstract. Children are nowadays showered with information and knowledge about environmental issues; however, this is very rarely transformed into concerned action probably because the content matter was not meaningful and/or was highlighted at the expense of the more important personalized process of learning. Researchers in Education for Sustainable Development (ESD) reveal that rather than just the acquisition of knowledge, important determinants of commitment include feelings, psychological factors and active participation while learning. Therefore, the misconception that the transmission of knowledge would be sufficient to trigger off an attitude of responsible environmental action has evolved into something more complex where what matters is not *what* knowledge is delivered but *how* it is delivered and experienced. This paper describes the use of Vee Heuristics and Concept Mapping as pedagogical tools, placed within a context of learners' different learning patterns, in a primary classroom. It provides illustrations of Concept Maps constructed before and after the learning programme and discusses some implications of the findings. This paper suggests that the use of Vee Heuristics and Concept Mapping along with an awareness of how the child prefers to learn may be a step towards tapping-in the child's internal talking so that, as educators, we can understand how each learner responds to incoming information so that learning about environmental issues becomes relevant, meaningful and, in the long run, conducive to an improved environmental responsible behavior.

1 Education for Sustainable Development: going beyond transmission of knowledge

In today's world, children are showered with information and knowledge about various issues particularly about the environment; however this is very rarely transformed into concerned action probably because the content matter is not meaningful and/or is highlighted at the expense of the more important personalised process of learning. In this premise, one assumes that what matters is, not ***what*** knowledge is delivered but ***how*** it is delivered and experienced.

As the world's environment seems to be in jeopardy all the time, different forms of Environmental Education (EE) have been readily taken up by educational institutions – the most recent version being Education for Sustainable Development (ESD) – as they were regarded as important strategies in achieving a good quality of life. Although educational programmes have succeeded in providing a vast amount of knowledge about environmental awareness they have very often failed to produce the change in attitudes and values and committed action that was originally targeted by the EE principles proposed by the Tbilisi 1977 Conference (UNESCO, 1980), subsequently confirmed at the Moscow 1987 Congress (UNEP, 1987) and the Thessaloniki 1997 Conference (Scoullos, 1998) and reconfirmed in Ahmedabad (CEE, 2007). Due to the traditional concern of formal education institutions with narrow monodisciplinary structures that promote the transmission of subject content, cognition, i.e. the processing of information or knowledge, was highlighted at the expense of feelings and behaviour (Pace, 2000). Therefore, the misconception that the transmission of knowledge about environmental issues would be sufficient to trigger off an attitude of responsible action evolved into something more complex where, as Orr suggests, "*the way in which learning occurs is as important as the content*" (Orr, 2004:14).

Borden & Schettino (1979, as cited in Newhouse, 1990) also reveal that the more important determinant of commitment (action) was the level of feeling rather than the level of knowledge. Simmons (1991) defined responsible environmental behaviour not only through cognitive factors, but also through conative and affective factors such as problem-solving skills and psychological factors (especially attitudes and the development of self-esteem). Making environmentally responsible decisions requires social and psychomotor skills as well as affective attributes (responsibility and commitment towards sustainable development), i.e. the development of a sustainable development ethic. In turn this is dependant on whether "*knowledge is interrelated to personal behaviour and social values, and if the learner experiences ethical demands in decision making*" (Schleicher, 1996:2).

Chawla (1998) reveals that one of the most important factors of commitment is environmental sensitivity. She describes sensitivity as "*a predisposition to take an interest in learning about the environment, feeling concern for it, and acting to conserve it, on the basis of formative experiences*" (Chawla, 1998:9). Furthermore, Chawla explains that formative experiences may be characterized as exchanges between an external environment (physical surroundings, social mediators) and an internal environment (how the child responds to the external environment). Any effective ESD programme therefore needs to place the learner and his/her personal development at the centre of the learning programme.

2 The Interactive Learning Model: Integrating Cognition, Conation and Affectation

The present study delved deep into the learning process and revealed that if we only look upon cognition, we would be only looking at one-third of who the child really is as a learner. This research highlighted the Interactive Learning Model (ILM) (Johnston, 1996, 1998) which proposes that learning is a process occurring because of the continuous interaction of no less than three mental processes: Cognition (I think), Affectation (I feel) and Conation (I act). Currently, a group of national and international academics along with several hundred school practitioners (teachers, staff developers, and administrators) have worked to develop and test this model of learning. What they have discovered is that the ILM gives teachers, students, parents, and administrators another means of identifying **how** each student processes information, uses her/his personal tools for learning, and develops as a confident and successful lifelong-learner. These researchers and practitioners have observed how the three mental processes of cognition, conation, and affectation, form patterns of behaviour within each learner. These patterns consist of sequence, precision, technical reasoning, and confluence (see Table 1). Furthermore, every learner uses each of these interactive patterns in concert and to varying degrees.

Learning Pattern	Learner prefers
Sequence	order, plans, directions, linear logic, continuity
Precision	facts, information, documentation, measurement, correctness
Technical Reasoning	problem solving through design, structure, physical and pictorial representation without the burden of words , use of combat engineering to fix physical/abstract problems
Confluence	risk taking, learning through failure, rapid ideation, extreme imagination, readiness to suspend rules and the limitations of reality in order to move beyond the known

Table 1: Summarised description of the four learning patterns.

To measure the degree to which each learner uses each of the patterns, Johnston & Dainton (2005) developed the Learning Connections Inventory (LCI) which has withstood empirical and theoretical testing for more than ten years in different countries around the world. The LCI consists of two parts: Part One consists of 28 descriptive statements which the learner reads and then indicates his/her responses on a 5-point numerical continuum and in Part Two the respondents are asked to answer 3 open-ended questions. The LCI scores reveal whether one uses a learning pattern at a "Use First" level, "Use as Needed" level or seek to "avoid" it altogether.

Figure 1 shows that information enters the brain through our sensory systems and some of it is processed in our working memory. Some of this information is stored for future retrieval in our long-term memory. Bruer compares our working memory to "*a computer's central processing unit*" while he compares our long-term memory to "*a computer's hard disk*" (Bruer, 1993). He further suggests that cognitive psychologists reveal that long-term memory comes in an array of structures and they distinguish between declarative memory which stores facts and events and non-declarative memory which stores skills and procedures. Nonetheless, unlike a computer we do not retrieve information by giving it "*an address*" in our brain but by creating associative links between chunks of information. This suggests that new learning is integrated into pre-existing structures which psychologists call *schemas*. These pre-existing structures effect how we process and interpret incoming information. Bruer argues that "*prior knowledge affects how we interpret school instruction and thus affects what we can learn. School instruction that ignores the influence of pre-existing knowledge on learning can be highly ineffective*" (Bruer, 1993:28) and, we add, potentially damaging to a student's plans for further education as success within the system is dependent not on the competency of the learner, but on his/her ability or inability to adapt to the 'set menu' offered by the school.

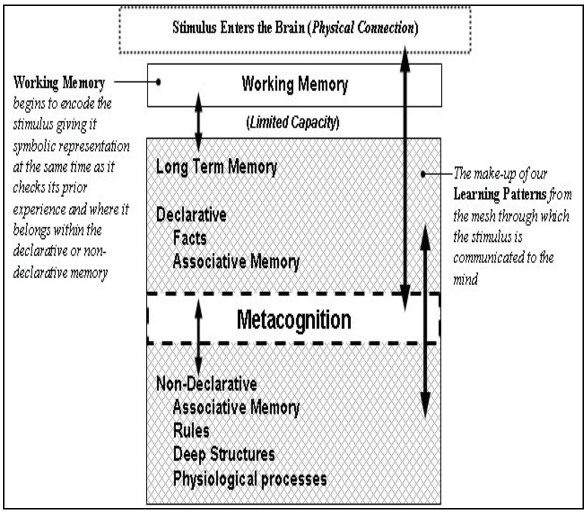

Figure 1: The LML Representation of the Architecture of the Brain and Mind. (after Johnston, 2005)

Similarly, the ILM suggests that when a stimulus enters the brain, the brain sends neuro impulses to the mind which translates the impulses into symbols that it can store, process and retrieve while at the same time it checks its prior experience and where it belongs within the declarative or non-declarative memory. This is where Metacognition comes into play. In fact, it is suggested that it is through metacognition that these symbolic representations are transferred into the non-declarative memory. More importantly ILM suggests that our learning patterns form the filter through which the stimulus is communicated to the mind when we are learning i.e. one responds and interprets incoming information through these learning patterns which occur differently in each learner.

Metacognition is an intrapersonal communication where time is given to quietly think and reflect on what one is learning (Vanhear & Borg, 2000). Behaviourist models emphasise the multistage model of memory where practicing past tasks leads to over learning which results in resistance to extinction (Vanhear & Borg, 2000:10). This model clearly promotes rote learning. However, ample research in this field (for example; Freire, 1970; McLaren, 1989; Novak, 1984,1998); reveals that the cognitive key to retention is meaningfulness. In other words, research is distinguishing between neural patterns stimulated by simple reaction to stimuli and those constructed from reflection. One of the ways in which rote learning is challenged is through metacognitive instruction (Novak, 1998; Bruer, 1993). Metacognition challenges the transmissive views of learning and teaching held by certain teachers and perceptions about the passive role of learners. This is because metacognition lends itself to a process of praxis (Vanhear, 2006). The equation is as follows: "*by being reflective, revisiting the learning process making comparisons between prior and current conceptions, and being aware of and analysing difficulties, learners gradually maintain deeper understanding of the learned material ... maintaining better understanding sets the bases for successful transfer*" (Georghiades, 2000:128).

3 Methodology

On the basis of the theoretical background presented above, the following research question was constructed; how can teachers help learners to reflect upon their knowledge and experience of the environment and to act upon these by helping them construct new meaningful knowledge? This research question revolves around the notion of the learners' structures of knowledge and how they respond to it or as Gardner (1991:253) argues "*we must place ourselves inside the heads of our students and try to understand as far as possible the sources and strengths of their conceptions*". This is also what Bruner (1996:49) sought for throughout his studies "*I have long argued that explaining what children do is not enough; the new agenda is to determine what they think they are doing and what their reasons are for doing it*".

In this premise, this research aims to make use of two validated tools namely: Vee Heuristics and Concept Mapping in a primary classroom to improve on meaningful learning of specific environmental knowledge related to biodiversity. For this study, nine students (all girls) with different learning patterns were chosen randomly using the LCI. Although nine girls were selected for an indepth study, the whole class participated in the whole procedure and learning programme of this research. A semi-structured interview was carried out with these nine learners to find out details about their knowledge and misconceptions about the chosen topic and how these developed to construct new meaningful knowledge. Vee Heuristics were used by each child to chart her individual learning experience. Since Gowin's original Vee was too complex for 6 year olds, the study opted for Ahoranta's adapted version of Åhlberg's improved Vee Heuristics (Åhlberg & Ahoranta, 2002) to trace the learning process. Concept Maps were constructed by the children **before** and **after** the learning process and the differences that emerged and their implications were discussed with the children. The different learners' learning patterns shall be taken into consideration, discussed and evaluated whether they contribute to diverse structures of knowledge.

4 Data Analysis

The paper will now present, analyse and discuss in detail the learning patterns of two learners with two different learning profiles.

4.1 Maria (her LCI scores are summarised in the grid below)

Learning Pattern	LCI Score	Preference
Sequence	16	Avoid
Precision	22	Use as Needed
Technical Reasoning	27	Use First
Confluence	20	Use as Needed

The LCI score presented above exhibits a 'dynamic learner' (Johnston, 2005) who makes use of Technical Reasoning at a Use First level. She uses her Confluent and Precise processing as needed while she avoids Sequence processing. From this learning pattern, one can deduce that Maria doesn't like to write in detail, she makes use of very few words to express herself, she prefers to work by herself and needs to see the purpose for what she's doing. Furthermore, she tends not to read directions since she finds following directions quite confusing if not frustrating (Johnston, 1996, 1998).

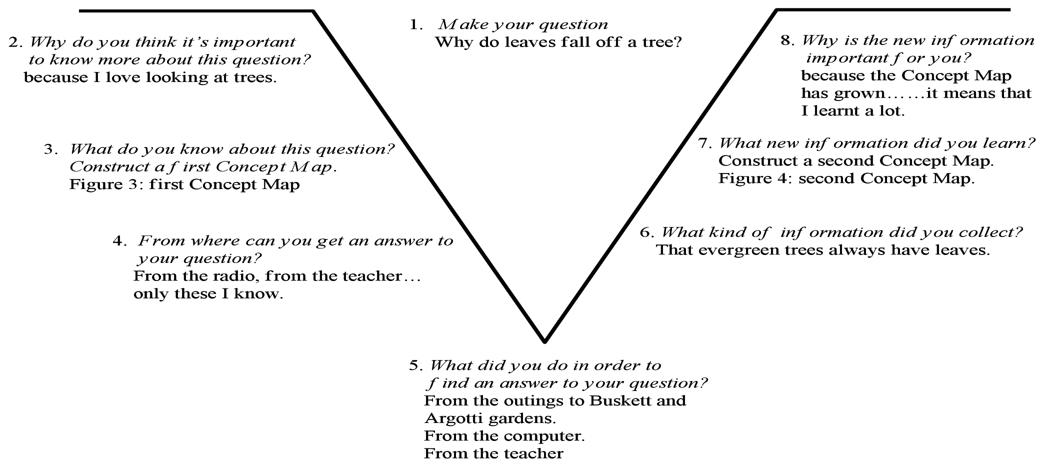

Figure 2: Maria's Vee Heuristic

The responses exhibited in the Vee Heuristic presented in Figure 2 correspond to this learner's learning patterns. Reply to question 2 is clearly conveying that scoring high in Technical Reasoning, this learner looks for relevance and practicality for her learning to occur. Children who score high in Technical Reasoning don't feel comfortable in traditional classroom settings since their learning doesn't occur through the use of pen and paper, therefore, they very often regard themselves as 'non-learners' since they feel that they do not fit in the class, in fact Maria's response to question 4 shows that she was hesitant and unsure. Her instant reply "the radio" stands for an outside the classroom setting while "the teacher" represents this learner's Sequence in the "use as needed" level. The response to question 5 was immediate and sure thus showing an increase in this learner's self-confidence and motivation along the learning programme. It also reveals that her primary sources for learning were the computer, where she had time to figure things out on her own, the outings which presented hands-on experiences (Technical Reasoning) and from what the teacher told her (Sequence). The difficulty this learner encounters when trying to communicate what she learnt is shown in her answer to question 6, in fact, she only mentioned one aspect of her learning whereas, if we observe her second concept map in Figure 4, we can easily note that this concept map reveals more about her learning than what she was able to express in words. It is worth giving some thought to the reply to question 8 where Maria stated *"because the Concept Map has grown"*. Actually, this learner was enjoying altering and adding to her first Concept Map although she needed guidance in parts of the map especially when it came to cross links.

During the interview referring to her response to question 8, Maria was asked *"What does that mean?"* she eagerly replied that *"It means that I learnt a lot"*. As previously stated, highly technical people who also score low in Precision are very often labeled as "non-learners" since they find it very difficult to express and communicate what they learnt through paper and pencil requirements. Therefore, this reply evidences that she was satisfied with herself for being able to visually express what she had learned.

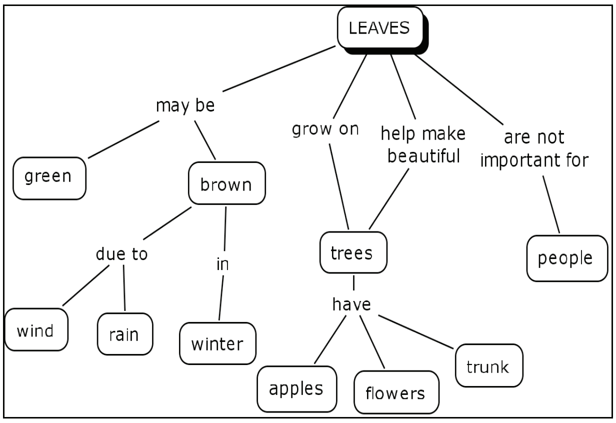

Figure 3: Maria's first Concept Map before the learning programme

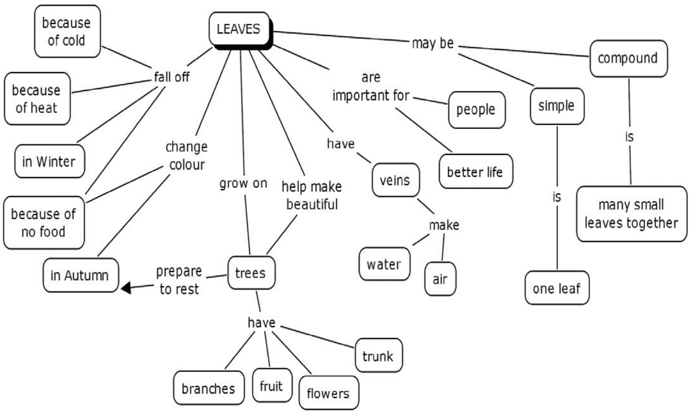

Figure 4: Maria's Second Concept Map after the learning programme

When comparing the two Concept Maps presented in Figures 3 and 4, an increase in concepts and propositions is easily noted, showing that learning has taken place. Being an abstract concept and highly technical learners don't normally do well with abstractions especially in the classroom setting, it can be concluded that the second Concept Map demonstrates a high ability in learning new concepts and a readiness to change previously held knowledge while also exhibiting an increase in the learner's motivation to learn and to express it in this way. Furthermore, much of the new knowledge learnt represented in her map such as *"leaves may be compound like many small leaves together"*, *"leaves may be simple that is one whole leaf"*, *"leaves are important for a better life"*, *"leaves have veins"* and *"trees prepare to rest in Autumn"* were all concepts which were delivered through the guided walks in Buskett and Argotti gardens. Maria also changed her misconception that *"trees have apples"* to *"trees have fruit"* while also changing that *"leaves are important for people"*. As exemplified by this latter case, she also showed instances where she extended instances in which she made value judgments. Finally we can also note the addition of propositions related to the focus question *"Why do leaves fall off a tree?"* Therefore, prior knowledge was developed; misconceptions were altered and new knowledge constructed.

4.2 Rita (her LCI scores are summarised in the grid below)

Learning Pattern	**LCI Score**	**Preference**
Sequence	28	Use First
Precision	26	Use First
Technical Reasoning	21	Use as Needed
Confluence	16	Avoid

Rita's LCI score reveals that she "uses at first" level her Sequence and Precise patterns, the Technical Reasoning pattern is "used as needed" while she "avoids" the Confluent pattern. This means that this learner needs clear step-by-step directions; she wants to do her work neatly and wants to know whether she's meeting her teachers' expectations. She also tends to want thorough explanations and asks a lot of questions. She likes details and she prefers written work to show what she has learnt. When needed she can also learn through hands-on experience, while, on the other hand, this learner avoids taking risks and prefers her work to be as accurate and as correct as possible.

Rita's Vee Heuristic (Figure 5) discloses a lot of useful information about how she prefers to learn. The left hand side reveals why is it important for the learner to want to know more.

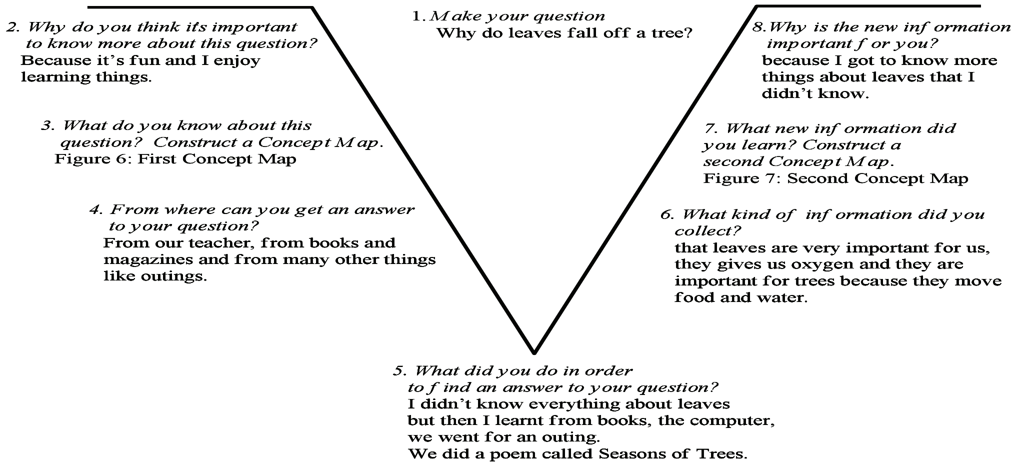

Figure 5: Rita's Vee Heuristic

Furthermore, her reply to question 4 conveys how she plans to learn and with the knowledge of how her learning patterns work most efficiently for her, both the teacher and the student can together build a learning programme which would make sense to the learner. Rita plans to learn through books and the teacher (Sequence and Precision) but also through outings (Technical Reasoning). Her learning patterns are evidenced also in her reply to question 5 which shows what the learner actually did in order to learn, and this substantiates her learning patterns since she mentioned books, the computer, the outing and also a poem.

Therefore, her primary sources for learning occurred in the classroom setting but having a score of 21 in Technical Reasoning where she makes "use as needed" of this learning pattern, she also mentioned the outing as another source for her learning. The right hand side of the Vee Heuristic exhibits how the learner constructed and developed her knowledge. Her reply to question 6 shows that she developed her knowledge about the importance of leaves as exhibited in her second Concept Map presented in Figure 7. In question 8 she was able to compare her prior knowledge with the present knowledge and in fact, learners with this kind of learning pattern are very good in comparing.

By comparing the Concept Maps in Figures 6 and 7 which were respectively constructed before and after the learning programme one can easily note an increase in concepts and propositions where prior knowledge was developed, misconceptions were corrected while new knowledge was constructed. This learner went into greater detail in her second Concept Map like for example to the concept *"different shapes"* she added *"compound", "simple", "narrow"* and *"wide",* or to the linking phrase *"fall off"* she added four other different appropriate concepts. She was also able to correct her misconception that *"leaves fall off in Spring"*. One of the most remarkable details was that she was able to exhibit the proposition *"in Autumn comes out* [they show] *their real colour such as red, orange, yellow"*.

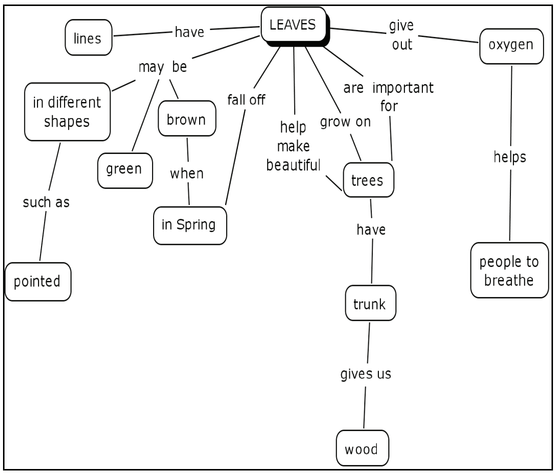

Figure 6: Rita's First Concept Map **before** the learning project

5 Discussion

This research challenges conventional and restrictive classroom practices that emphasize rote learning at the price of meaningful learning because learners are considered passive recipients rather than dynamic actors who commit themselves to thinking, acting and learning critically. The data collected in this research reveals that each learner processes incoming information differently and it is very unrealistic to expect that all children respond to whatever happens in class in approximately the same way. Furthermore, it reveals that different learners learn in different settings and therefore not all learners learn best in a non traditional setting and vice-versa (Zelezny, 1999). The results confirm that for a learner "*to take interest in learning*", the teacher must be aware of the learner's own preferred way of learning in order to address his/her needs and enhance his/her learning experience. This is where the ILM can be valuable since it reveals how each learner prefers to learn and how he/she responds to incoming information.

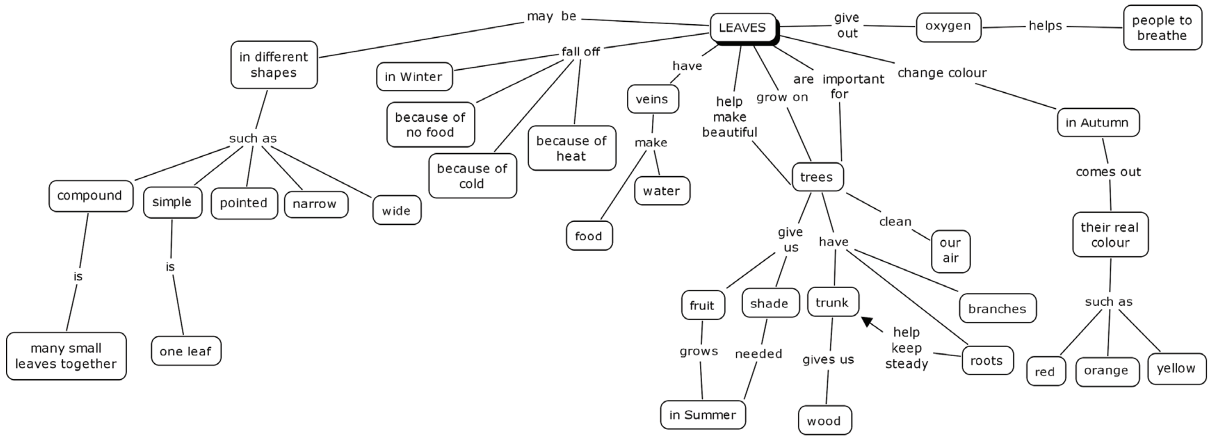

Figure 7: Rita's Second Concept Map **after** the learning programme.

The Vee Heuristic lent itself beautifully for a process of reflection and action where the child's internal talking became visually overt and explicit. In this way learners are taught to think aloud and reflect on what's going on in their heads and how they can proceed to act and develop it. Research has shown that new meaningful knowledge does not occur in a vacuum (Bruer 1993, Johnston 1996, 1998; Novak 1998) and thus prior knowledge has to be taken into consideration if we expect meaningful learning to take place. By constructing Concept Maps for the focus question under study, the children clearly conveyed at a glance, "*what they already know*" thus providing educators with the opportunity to build upon it. The two Concept Maps constructed before (on the left hand side of the Vee) and after (on the right hand side of the Vee) the learning programme were very effective in allowing both the teacher and the learner to easily see what prior knowledge was present, what new knowledge was learnt and how this was integrated within the pre-existing cognitive structure and elaborated. One has also to bear in mind that for learners who are used to learning through rote or memorisation of facts, Concept Maps may offer quite a challenging task at first and it may take some time before they feel comfortable working with them.

The integration of these metacognitive tools: the Vee Heuristic, Concept Mapping along with an understanding of how the learner prefers to learn, provided the teacher (and the learner him/herself) with a clear picture of how the learner responds to and acts upon incoming information. These metacognitive teaching strategies shift the control from the teacher to the learner (Bruer, 1993). Consequently, learners become the agents of their own learning since they are actively participating in their own learning process. Moreover, the learner exhibits how he/she plans to learn more and this is very important for the teacher to be able to collaboratively build a learning programme which would be relevant to the learner's way of responding to new information and thus prove to be truly motivating and meaningful.

6 Conclusion

ESD promotes a particular lifestyle which highlights not only knowledge but also feelings and attitudes that call for commitment and responsibility towards sustainable development. It is dependent on informed action and the development of autonomous critical learners. The methodology proposed by the study proved to be an effective way of giving the learner ownership of learning in a way that s/he is conscious of how s/he is learning and thus can direct (i.e. is empowered) its course. A paradigm shift has to occur in the way we see things, prevailing discourses have to be questioned and this is why various authors (O'Sullivan, 1999; Orr, 2004; King, 2005) are now calling for a transformative vision of learning – not just the transformation of students into functional citizens, but also the transformation of the learning institutions themselves to provide these enabling pedagogies. Effective ESD at formal education institutions is dependent on a change in praxis; and change is not always a welcomed alternative. Consequently, alternative methodologies are viewed with suspicion and need to be acknowledged and legitimized within the institutions' administrative structures for them to proceed.

Consequently, alternative methodologies are viewed with suspicion and need to be acknowledged and legitimized within the institutions' administrative structures for them to proceed.

Concept Maps and Vee Heuristics lend themselves for this process of transformation for both the teacher and the student. It is a process through which the prevailing model of education is challenged. This research has shown that the use of these two tools facilitates the achievement of ESD targets and may, in the long run, bring about the desired environmental responsible behaviour. This is because these two tools present a process of praxis and through their use learners are trained in decision-making, reflective and problem solving skills by effectively identifying the child's "internal environment" and leading them to understand what is going on in their heads and why and how they respond differently to different situations. However, the characteristics of and how this translates from meaningful knowledge to responsible environmental action needs to be studied further. It is not what we teach them that matters but how they will respond to it. This paper is just a very small part of a larger research project presented as a Masters in Education Theses for the University of Malta (Vanhear, 2006).

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INTERACTION BETWEEN TOPOLOGY AND SEMANTICS IN CONCEPT MAPS: A NEUROLINGUISTIC INTERPRETATION

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Abstract. This article analyses, from a neurolinguistic perspective, results obtained from the application of a taxonomy of concept maps developed at the *Conéctate al Conocimiento* Project in Panama to a sample of over 500 maps. The 2-part taxonomy consists of a topological taxonomy and a semantic scoring rubric. Of particular interest to us is the association found between structural and semantic complexity of completed concept maps. Results of this first application of the complete taxonomy indicate that positive changes in semantic levels tend to be accompanied by positive changes in topological levels; also, negative changes in topological levels tend to result in negative changes in semantic levels. The converse does not appear to be true, that is increasing the complexity of the special configuration of concept maps does not translate into more intricate and sophisticated semantic texts. These results evidence a need to focus on improving semantic quality in order to achieve overall improvement in map quality, including its viso-spacial configuration or topology. Neurolinguistic Theory seems to contribute to understanding the nature of this relationship, and provides theoretical guidance for the design of new didactic strategies to improve significant learning based on concept maps.

1 Introduction

A study carried out by Miller (2008) at the *Conéctate al Conocimiento* Project in Panama (Tarté, 2006) has made evident the degree of association that exists between topological and semantic aspects of concept maps. The results of the cited study indicate that positive changes in semantic levels tend to be accompanied by positive changes in topological levels; also, negative changes in topological levels tend to result in negative changes in semantic levels. The converse does not appear to be true, that is increasing the complexity of the spatial configuration of concept maps does not translate into increased semantic complexity.

The present article attempts to offer elements for analysis from a neurolinguistic perspective that might contribute to explain these results. The paper is organized in the following manner: 1) summary of relevant neurolinguistic theoretical arguments; 2) brief description of the study that gave rise to the results being considered; 3) neurolinguistic analysis of these results; and 4) conclusions and recommendations for classroom applications.

2 Summary of neurolinguistic arguments

"Language is so much a part of our daily lives that we tend to take it for granted and not to stop and think about how useful language is for translating commonly recognized regularities into code words we can use to describe our thoughts, feelings and actions. An awareness of the explicit role language plays in the exchange of information is central to understanding the value and purpose of concept mapping and, indeed, central to educating" (Novak & Gowin, 1984, p. 17).

Language is used to articulate each person's model of the world, but at the same time, neurological processes are organized and sequenced through language; hence, language reflects the way each person perceives the world. Being such a psycho-biological process, one could say that mental maps are a sort of biological path along which words travel. The mental representations of individuals depend on their experiences, culture, and physiology, among other things. Language refers to the way individuals makes use of verbal expression to communicate experience, and this is done with the structure implicit in their own language. At the same time, all human experiences, as well as their expression through language, are subject to processes that may constitute evidence of failures in the representation of the world, failures in the form of omissions, distortions, generalizations.

According to Cobb (1997), every individual has a particular way of relating and ordering perceived sequences of events that is captured through his/her conversations. This is because human beings communicate through a narrative language that has a time, a space, and a logic for building relationships, all of which is reflected as coherence. In conversing, human beings express the manner in which they relate things, but also the manner in which they relate to one another. This is done through words that express meanings.

In every conversation human beings construct a sort of text that can be understood as an analyzable object in which different structures can be identified, ranging from concrete organizations to abstract entities (Serrano, 2001b). Meaning is built up through language; hence, the semantic value of the resulting text.

In an effort to give meaning and significance to the texts, human beings apply a variety of organization strategies, assigning to structures defined as semantic units, a relational order. This order (M.V.G. De Erice, 2002), may be a positional order, where language alignment is mediated by space-time variables (also known as syntagmatic order); a functional order, of codified association, since semantic units can only take on value on related to others that may substitute it and constitute contextual relationships (called paradigmatic order). There exists an ordering of text production and interpretation conditions, communication phenomena that go beyond pragmatic factors to include situations of codified communication inherited from culture and history. There is also included a referential order, that determines the influence of the linguistic over the non-linguistic strata in practice. In this manner, the interpretive path of a text entails a series of operations that allow us to assign one or more meanings or senses to a linguistic series.

The interaction among different semantic units gives cohesion to a linguistic series, which is defined by its internal semantic relationships. However, the dynamic interaction also defines a coherence mediated by the relationships it establishes with its environment. The hermeneutic order is the one guiding the production and interpretation of texts, that is to say, the one generating the content which is what has been defined as the text's plan, made from the set of meanings.

The specificity of a text "results from the intersection of a great number of structures which, when taken separately, are quite general" (Serrano, 2001a). Nevertheless, experience shows that it is the point of view of the text, from a hermeneutic perspective, the one compelling the addition of contextual elements: without this, interpretation is incomplete, and comprehension unsatisfactory. In this manner the semantic process, the discourse, which is the set of codified linguistic uses together with a certain social practice – understood as the sphere of shared mental representations – defines a sort of associative network between units of meaning, which in their interactional dynamics define the context for reinterpreting the text.

The object of concept maps is to represent meaningful relationships between concepts in the form of propositions. A proposition consists of two or more concepts joined by linking words to form a semantic unit, that is, a unit with meaning (Novak & Cañas, 2008). For Novak & Gowin (1984, p. 15), a concept map "can provide a kind of visual road map showing some of the pathways we may take to connect meanings of concepts in propositions." Several authors have stated that concept maps are networks of semantic relationships, where semantic refers to the meaning or interpretation of the meaning which individuals attribute to a given symbol, word, language or other formal representation. According to Novak & Gowin (1984, p. 20), it can be "useful to think about concept maps as tools for negotiating meaning ... Learning the meaning of a piece of knowledge requires dialog, exchange, sharing, and sometimes compromise."

It is during this negotiation (which may take place with others, but also with oneself), if done conscientiously, that individuals may come to recognize the generalizations, omissions, and distortions contained in their texts, and restructure their narratives. This action is what ultimately results in learning, a modification of cognitive structure or, in the terminology of neurolinguistic theory, a new mental model of the world; hence, the importance of concept maps.

These theoretical arguments seem useful for analyzing and understanding results obtained by Miller (2008), which indicate a relationship between the topological and semantic aspects of concept maps. We now give a brief description of the tools used to evaluate the structure and content of the maps, followed by the results obtained, in order to contextualize the subsequent discussion.

3 Evaluation tools and data

Concept maps were analyzed using the taxonomy for concept maps developed at Panama's Conéctate al Conocimiento Project. This taxonomy consists of two complementary parts: a topological component, for classifying concept maps according to the complexity of their structure; and a semantic component, which evaluates the quality of their content. The former is discussed in detail in Cañas et al. (2006); the latter is described in Miller & Cañas(2008). In the next two sections we offer a brief outline of the criteria taken into account in the design of each of these measurement tools.

3.1 Topological taxonomy

The topological taxonomy classifies concept maps according to five criteria: *concept recognition*, *presence of linking phrases*, *degree of ramification*, *depth*, and *presence of cross-links*. These criteria consider progressively more complex topological entities, beginning with concepts, passing through propositions, and ending with the complete concept map.

We note that in order to apply the first criterion, one must consider content. Therefore, this would appear to be a semantic criterion – and it is. However, the ability to recognize individual concepts is so basic to being able to build up rich, interconnected, flexible concept map topologies that this criterion is included among the structural criteria. In other words, the focus is not on what is actually said, but on whether the mapper is able to recognize concepts in their original context and depict the way in which they are related to one another.

Once nodes (concepts) have been placed in a map, they are related to one another to form larger graphic structures, usually triads, by means of any form of symbolic representation – this is the linking phrase. Ramification occurs when several relationships emanate from the same node or make use of the same linking element; this event is usually thought to be related to Ausubel's (1968) notion of "progressive differentiation"; hierarchical depth refers to the number of levels of concepts nested under the root (main) concept of the map. Though this nesting may indeed be evidence of conceptual subsumption, the two are not to be confused; this topological criterion considers only the number of level, not what concepts are placed in each of them.

The last criterion deals with cross-links. From the perspective of spatial organization, cross-links, when accompanied by all the other elements mentioned above, lead to topological entities of greater overall complexity. They are thought to be associated to "integrative reconciliation," another fundamental principal of Ausubelian theory.

3.2 Semantic scoring rubric

The scoring rubric used to evaluate the maps consists of six semantic criteria: *concept relevance and completeness*, *correct propositional structure, presence of erroneous propositions*, *presence of dynamic propositions*, *number and quality of cross-links*, and *presence of cycles.*

As before with the topological taxonomy, in this semantic rubric content is considered at different, increasingly complex, levels. The first criterion involves the level of individual concepts, what one might call the "atomic" level of meaning present in a concept map; criterion 2 moves up a notch, to the "molecular" level, which involves being able to construct and express coherent units of meaning in the form of propositions; continuing to higher levels, criterion 4 looks at the sophistication of the relationship established between concepts in a proposition along a static-dynamic scale; further up, criterion 3 ascertains the veracity of those units, relative to external objective standards, that is, in relation to contextual elements; finally, criteria 5 and 6, involve the entire concept map, in our metaphor, this might be the level of "matter," where individual strings of meaning present in a concept map are tied together, as the mapper draws from his or her life's experiences to generated an integrated, coherent whole.

4 Results

The results presented below are based on a total of 258 in-service Panamanian public elementary schoolteachers being trained in concept mapping at Panama's Conéctate Project. Initial and final concept maps created using CmapTools (Cañas et al., 2004) were obtained. Completed Cmaps were analyzed in terms of their structure and content, using our topological taxonomy and scoring rubric, respectively. Our interest in this article, however, is centered on the relationship between content and structure; that is, on the association between structural and semantic complexity of the completed maps.

In this regard, calculations yielded a moderate degree of correlation between semantic and topological level: in the initial map the correlation coefficient was 0.50; in the final map the value decreased slightly to 0.37. However, examining the relationship between change in semantic and change in topological level, we found (see table 1) a significant association. On the one hand, those who had a positive change in semantic level were 3.3 times more likely to have a positive change in topology; while those who had a negative change in topology where about half as likely (0.6) to improve semantics. On the other hand, those who had a positive change in topology had only a slightly greater chance to improve semantic level (1.1). Overall, we see that changes in content have a greater effect on structure than vice versa. That is, improving content quality tends to improve topology, not the other way around.

		SEMANTIC LEVEL CHANGE		
		Null or negative change	Positive change	Total
TOPOLOGICAL LEVEL CHANGE	Null or negative change	48	29	77
	Positive change	85	96	181
	Total	133	125	258

Table 1. Contingency table showing a significant association ($P = 0.002$) between changes in topological level and changes in semantic level.

5 Neurolinguistic interpretation of results

As pointed out earlier, a concept map is a graphic representation of a network of semantic units whose interactions define a context of meanings. The "graphed text" has a topological structure which represents the way in which the individual organizes semantic content, concepts and propositions, in his/her cognitive structure through subsumption, differentiation and integration. As Novak & Gowin (1984, p. 40) have noted, "Concept mapping has been developed specifically to tap into a learner's cognitive structure and to externalize...what the learner already knows." Although concept maps certainly do not provide a "complete representation of the relevant concepts and propositions a learner knows... [they do constitute] a workable approximation" (ibid.)

This is the forcing argument that evidences the relationship between topology and semantics, between graphical configuration and meaning, made plain by the results reported in the previous section. These results imply a dynamic relationship between the topological and semantic aspects of concept maps, where the former may be conceived as the dependent variable, and the latter as the independent one. Being a dynamic interaction, in giving expression to a text in a concept map the dependent variable helps to reorganize the independent variable (this is Piaget's concept of intelligence, where the interaction established between the environment and the subject helps to modify the environment, and in doing so the subject itself is modified).

This would explain why it is stated that there are no good or bad concept maps; it is the reason why it is said that the concept map represents the state of a subject's knowledge on the topic at a given moment (assuming the subject has sufficient skill in concept mapping to adequately represent his/her knowledge); it also explains why so much importance is given to dialogue and interaction during map construction. Thus, it is acknowledged that concept maps must be understood as cognitive construction processes, rather than as finished products.

The topological-semantic relationship would seem to be led by semantics. In other words, changes on the semantic front give rise to changes on the topological front. Changes in topology however have little influence upon semantics, but do offer important information that can provide feedback to the subject to help produce changes in his/her cognitive structure, that is, to learn in a meaningful way.

The results presented here about the relationship between semantic and topological complexity in a concept map, offer – from the perspective of neurolinguistic theory – interesting opportunities for didactic strategies addressing on the construction of concept maps.

From the view point of the neurolinguistic model, each person said to have a mental representation of the world in which his or her life unfolds. This representation is called the individual's "mental model of the world," which in turn becomes expressed through narrative texts. Thus it can be said that the concept map as a text representing meanings, is a reflection of the person's narrative, of the way the person converses with him/herself and with others. When that conversation is to be represented graphically through a concept map, its physical layout or configuration reflects the way he or she arranges sequences of relationships, makes differentiations and identifies or discovers integrations, all of which serve to construct meanings. But this viso-spacial aspect of a concept map depends on the content with which the subject interprets the world and its relationships.

This is why, from the didactic point of view, concept maps are powerful tools allowing individuals to reread the text of the relationships they establish, and in doing so to discover omissions, distortions, and generalizations, and through this process, to construct new ways of relating to generate a new narrative, a new text. This contributes to the dynamic exchange between assimilation and accommodation stipulated by Piaget, as strategies for the construction of knowledge easier.

When meanings are negotiated in the construction of a concept map, as Novak & Gowin (1984) pointed out, the structure of the individual's mental model is modified. If this process is done together with others, collaborative learning takes place.

Neurolinguistics, from its practical approach (the so-called Neurolinguistic Programming) states that by generating changes in an individual's language, changes in his/her mental model can be achieved and this new model will generate new behaviors. In other words, a change in the cognitive structure occurs, which is what is commonly defined as learning.

When the frame of reference for the mental model is located (be it in memory, imagination, or in the point of view of others), with new words (new symbols and new representations), with the intention of obtaining new meanings within that frameset, the consequence will be a shift in individuals' emotional state, responses and behaviors.

Human beings utilize certain cognitive strategies to integrate coherence and cohesion into meanings. These information organization strategies are generalizations, distortion and elimination of data. For this reason, neurolinguistic theory considers it indispensable that individuals acquire the ability to recognize their generalizations, to recover the parts omitted from their model of the world, and to correct its distortions, in order to guide in a precise way the process of shifting their mental models. In that new context, mediated by "new conversations," underlying mental models are modified, and consequently changes are produced in semantic processes. This requires a new organization, which shows up in a concept map as changes in topological structure. Changes in the semantic structure of a concept map generate changes in the topological structure.

6 Conclusions and recommendations

The insertion of concept mapping in the everyday classroom is an issue that seems to require evermore the designing of innovative methodological proposals to ensure the sustainability of the use of concept maps in school life.

Those who have assumed the task of training teachers in the use of this tool, enriched in recent years by technological tools such as CmapTools, are facing a number of situations such as: a) not all teachers trained in concept mapping use the tool in their classrooms; b) those who do use them, do not do so in a regular fashion and/or use them only as an effective summarization tool; c) few teachers use concept maps to facilitate the construction of new knowledge construction; d) even fewer use them to promote collaborative learning.

Informal inquiries carried out with teachers concerning the reasons for this low usage of concept mapping in school life, relative to the number of teachers who should be using them, we find the following explanations:

- They require too much classroom time
- Only some children enjoy using them
- They require changes in class schedule (time) and classroom arrangement (space)
- They are not applicable to all courses of the curriculum

It would seem that the training strategies used so far, have not attained the expected results. Efforts to provide better theoretical arguments are thus sought.

The previous neurolinguistic discussion of the results of the application of the topological and semantic components of the taxonomy of concept maps (Miller, 2008), offers interesting contributions for the design of didactic strategies aimed at integrating concept maps in the school context. It would seem appropriate to develop a methodological proposal which includes the neurolinguistic approach, that is, an emphasis on semantic elements both in teacher training, as in the strategies those same teachers can apply in their classes.

Some strategies that may contribute to the design of a new methodological proposal include:

1. Teachers, as facilitators of the construction of new knowledge, must consider students' first concept maps as "draft versions" which can be improved through dialogue; likewise, teachers must understand that a concept map is the viso-spacial representation reflecting a person's cognitive structure and state of knowledge at a given moment. This first map constitutes the working material to begin a process of change, an excuse to construct new knowledge.

2. The importance of the use of questions as a way to stimulate the construction of deeper concept maps has been recommended. Such questions are aimed at inducing students into exploring new ways of linking concepts. Hence, it crucial to encourage students to re-read their maps, identifying generalizations, searching for possible omissions or distortions of information, in order to provoke modifications of the previously constructed text. These changes, when mediated by dialogue, conversation and interchange, will generate a new text with a new semantic structure, which will necessarily reflect a change in the topological structure of the map. Examples of such questions are: Is there another way of stating this relationship? Are there related topics that can help to deepening this relationship? How could we complete this idea? Does the map contain information related to or helpful in explaining this relationship? To insist in producing changes in a map's topology in order to improve its conceptual quality, appears to be, in light of present results, a practice that needs to be discarded.

3. Most teachers can not break loose from the practice of using concept maps as a strategy to evaluate academic contents. However, the mere fact of repeating the concepts, the relationships given in textbooks and lectures, does not signify the presence of real assimilation and accommodation processes taking place in the learner's cognitive structure.

Teachers must consider concept maps as a "text under construction," a necessary stage for the creation of new knowledge. Thus arises a new theoretical argument which strengthens the pedagogical proposal, advocated by many in the past, concerning the construction of concept maps: the stimulation of dialogue and exchange mediated by conversation, with the object of impelling changes in cognitive structure.

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INVESTIGATING APPLICATION VALIDITY OF CONCEPT MAPS

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Abstract. To ensure the effective use of a concept map it needs to be validated. Two different types of concept map validity can be distinguished, referring to either the validity of the concept map's content or to the applicability for its designated purpose. This paper concentrates on application validity and outlines an empirical investigation demonstrating a validation approach utilising Knowledge Space Theory. Problem solving behaviour was used as a criterion for application validition of a concept map on a subdomain of geometry. By deriving theoretically expectable answer patterns on geometry problems from a concept map and comparing it with empirically collected answer patterns, the concept map's application validity could be investigated and proved.

1 Introduction

Concept maps are tools for representing semantic knowledge and its conceptual organisation (for an overview see e.g. Novak, 1998; Steiner, Albert, & Heller, 2007). They specify the concepts of a knowledge domain and the relations among them, and thus provide a natural way of expressing and presenting domain ontologies. Mathematically defined, a concept map is a directed graph consisting of a finite, non-empty set of nodes which represent the concepts of a knowledge domain, i.e. $C = \{c_1, \ldots, c_n\}$, and a finite, non-empty set A of arcs which represent the relationships between those concepts (Albert & Steiner, 2005). Every arc is an ordered pair from the set of concepts and is characterised by a relation label describing the relationships between those two concepts. Such a combination of two concepts and the labelled relation between them constitutes a proposition (Ruiz-Primo, 2000), i.e. a statement forming an elementary unit of declarative knowledge (Anderson, 1995). This means, a concept map is basically a representation of declarative knowledge. Most commonly, a concept map is depicted by a graph representation (see Figure 1 for an example), although also other forms of representation (e.g. proposition list, matrix) are possible (Steiner et al., 2007).

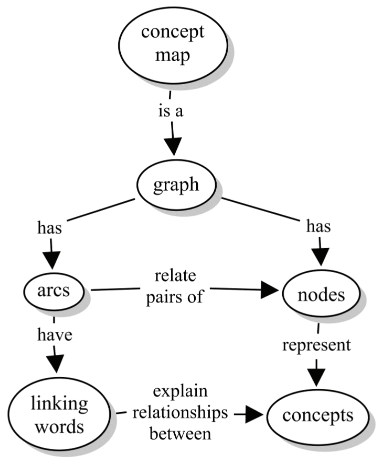

Figure 1. Concept map on what a concept map is (adapted from Steiner et al., 2007).

A concept map constitutes a model of the current knowledge about the world for a given knowledge domain in a given context. For one and the same knowledge domain it is not realistic to assume that only one correct concept map of complete consensus exists; rather there are several alternative concept maps conceivable. This is, because describing and structuring a domain necessarily entails some sort of world view or opinion (Kennedy, McNaught, & Fritze, 2004). Moreover, concept maps will also differ due to their intended purpose and ultimate use. Given a particular purpose, a concept map is needed that represents the knowledge domain with respect to its designated usage and summarising possibly differing perspectives. Having available a well-founded concept map is crucial to ensure its effective and valid use. For instance, for practical use as teaching material in classroom it is critical that a concept map accurately reflects the respective subject domain.

This calls for a theoretical framework for evaluating the empirical validity of a concept map on a specific domain. In the sequel, a concept map to be validated is alternatively also denoted as 'target map'. Different aspects of validity can be distinguished – content validity and application validity – and methodological considerations and approaches suitable for evaluating these validity types have been proposed (Albert & Steiner, 2005; Albert, Steiner, & Heller, 2006). The purpose of this paper is to demonstrate the investigation of a concept map's application validity by an empirical example. In the following section, first the concepts of content and application validity are outlined and an approach for application validation is described. Subsequently, an empirical investigation on the application validity of a concept map for elementary geometry is presented. Finally, the applied validation methodology and implications for further research are discussed.

2 Application Validity of Concept Maps

When considering the validity of a target map, two types of validity can be distinguished – content and application validity (Albert & Steiner, 2005). Content validity refers to the question whether the concept map constitutes a valid model of a part of the current knowledge about the world. For giving evidence of content validity, an approach comparing the target map to empirically gathered individual concept maps has been suggested. Here, we focus on application validity, which refers to the question whether a concept map serves the purpose for which it has been designed. In other words, the practical usability and usefulness of a target map is addressed. For analysing this type of validity relevant situational performance can be utilised (Albert & Steiner, 2005). Situational performance in this context means behaviour in real-world situations that does not consist in performing a concept mapping task, as for example problem solving, answering questions, or even social behaviour in given situations. As naturally a person's understanding of a domain is reflected in his/her behaviour in given situations, situational performance constitutes a suitable criterion for validation. A type of situational performance has to be chosen, that is related to the purpose and intended application of the respective concept map. Depending on the purpose (e.g. presenting learning material, describing social skills) that is foreseen for a target map, different kinds of situational performance (e.g. problem solving, behaviour in social situations) will be appropriate. As a concrete approach for examining application validity of a concept map we suggest to utilise Knowledge Space Theory. This approach assesses the target map's ability to predict relevant situational performance. After introducing the basic notions of the theoretical framework in the sequel, the proposed validation methodology is sketched.

2.1 Knowledge Space Theory

Knowledge Space Theory (Albert & Lukas, 1999; Doignon & Falmagne, 1999; Falmagne, Koppen, Villano, Doignon, & Johannesen, 1990) provides a formal model for structuring and representing knowledge based on prerequisite relationships. A knowledge domain is characterised by a finite, non-empty set Q of problems. The knowledge state of a learner is represented by the subset of problems that he or she is capable of solving. Due to mutual dependencies among the problems of a domain, not all subsets of problems are expected to be observable knowledge states. These dependencies are captured by the so-called prerequisite relation. If two problems a and b are in a prerequisite relation, from a correct solution to problem b the mastery of problem a can be surmised. In other words, problem a is a prerequisite problem for problem b. Assume for example two problems of basic algebra, an addition of variables and a linear equation. The first problem can be regarded as a prerequisite for the second one, as being able to solve the equation will certainly entail being also able to solve the addition. A prerequisite relation can be depicted by a Hasse diagram (see Figure 2 for an example), where descending sequences of line segments indicate a prerequisite relationship.

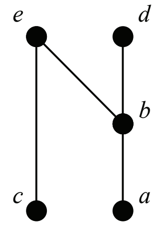

Figure 2. Example of a Hasse diagram illustrating a prerequisite relation on a knowledge domain $Q = \{a, b, c, d, e\}$ (adapted from Falmagne et al., 1990).

According to the prerequisite relation illustrated in Figure 2, from a correct solution to problem b the correct solution to problem a can be surmised, while the mastery of problem e implies correct answers to problems a, b, and c. The collection of knowledge states corresponding to a prerequisite relation, including the empty state Ø and the whole set *Q*, constitutes the so-called knowledge structure $\mathcal{K}$. The knowledge structure corresponding to the prerequisite relation shown in Figure 2 is given by

$$\mathcal{K} = \{Ø, \{a\}, \{c\}, \{a, c\}, \{a, b\}, \{a, b, c\}, \{a, b, d\}, \{a, b, c, e\}, \{a, b, c, d\}, Q\}.$$

The possible knowledge states are naturally ordered by set-inclusion, as can be seen in Figure 3. Given a knowledge structure, there are various possible learning paths from the naive knowledge state (empty set ∅) to the knowledge state of full mastery (set *Q*). The knowledge structure depicted in Figure 3 suggests to present learning objects related to problem *a* (or, equivalently, *c*) first. Subsequently, material related to problems *b* or *c* (*a*, respectively) should be presented, and so on. One possible learning path is indicated by dashed arrows in Figure 3, describing the successive steps of the learning process. Thus, given a learner's knowledge state, a knowledge structure provides useful information which learning content should be presented next, but also which previously learned material should be reviewed. Furthermore, a knowledge structure builds the basis for an efficient adaptive knowledge assessment that allows for determining the current knowledge state of a learner. Through exploiting the structure inherent to the knowledge domain and taking into account previous answers of an individual, only a subset of problems has to be presented.

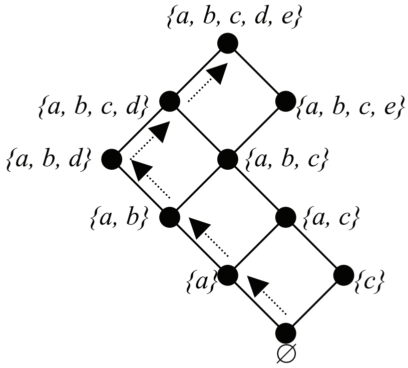

Figure 3. Knowledge structure $\mathcal{K}$ corresponding to the surmise relation illustrated in Figure 2. The dashed arrows indicate a possible learning path.

2.2 Validation Methodology

Assume a concept map representing the declarative knowledge of a particular knowledge domain, for which application validity is to be examined. For testing the target map's ability to predict relevant situational behaviour, problem solving has been identified as an appropriate measure of performance to be used as validation criterion. To this end, a set of typical problems is chosen, representing the domain in the sense of Knowledge Space Theory. For each problem the declarative knowledge that is required for solving the respective problem is determined by identifying the problem with a substructure of the target concept map. This means, each problem is mapped on the concept map, by assigning the subset of propositions required for mastering the respective problem (Albert & Steiner, 2005; Steiner & Albert, 2008). Each proposition could be considered as an atomic skill or competency in the sense of competence-based extensions of Knowledge Space Theory (e.g. Düntsch & Gediga, 1995; Falmagne et al., 1990; Heller, Steiner, Hockemeyer, & Albert, 2006; Korossy, 1999). Based on the problems' representation by substructures of the target map, dependencies between problems in terms of a prerequisite relation can be derived by set inclusion. Assume, for example, a problem *X* that is represented by the propositions *{P3, P7, P8, P9, P13, P15}* of a concept map, and another problem *Y* that has been associated with propositions *{P3, P7, P9, P13}*. As the representation of problem *Y* constitutes a subset of that of problem *X*, it is assumed that *Y* is a prerequisite for *X*. The dependencies derived in this way serve for establishing a knowledge structure that collects the set of possible knowledge states. The knowledge states constitute answer patterns that are expected to be observable, provided that the target map validly represents the domain. The next step in the validation approach is therefore to collect empirical answer patterns on the set of problems. It can then be investigated whether the observed answer patterns correspond to the predicted knowledge states, for example by using a discrepancy index describing the similarity between the knowledge structure and the set of answer patterns (e.g. Doignon & Falmagne, 1999). As the target map has been used for establishing the knowledge structure, the empirically obtained answer patterns serve as validation criterion. If the empirical answer patterns correspond well to the predicted knowledge states, the concept map can be considered to be valid – provided that both, the chosen set of problems as well as the sample of persons are adequate and representative.

3 An Empirical Example of Application Validation

The methodological considerations presented above have been applied in an empirical context in order to illustrate the procedure of validation and to demonstrate its significance and usefulness.

3.1 Method

For examining application validity of a concept map 44 subjects (20 male and 24 female) ranging in age from 18 to 59 (M = 26.23, SD = 8.77) were tested in single investigations.

Having in mind an educational and learning context, the knowledge domain of elementary geometry, more precisely a small subdomain on right triangles and the theorems in right triangles was chosen for the empirical investigation. Based on textbooks and school curricula a concept map was generated that was intended to be usable as learning material in classroom (see Figure 4 for an extract).

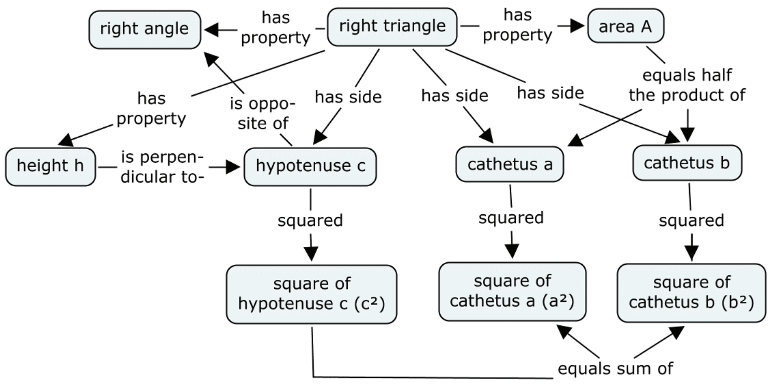

Figure 4. Extract of the target concept map on right triangles.

For examining application validity of the target map it had to be related to situational behaviour referring to the intended use of the concept map. Assuming that the target concept map was foreseen to be applied to teach a subdomain of geometry, problem solving behaviour in the same knowledge domain seemed to be an appropriate kind of situational performance to be used for validation purposes. To this end, a collection of ten geometry problems was adapted from Korossy (1993). These problems constituted typical and representative problems of the knowledge domain in question (see Figure 5 for an example).

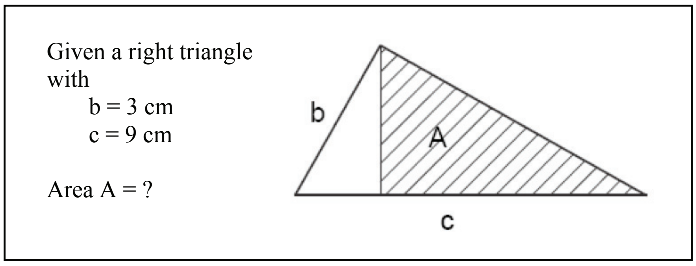

Figure 5. Example of a geometry problem used for the investigation of the target map's application validity.

For investigating application validity, the target map was used for establishing a knowledge structure on the geometry problems. This means, each of the ten geometry problems was mapped onto the concept map by identifying the propositions representing the knowledge necessary for solving it. Here, it had to be taken into account that most of the problems could be solved in several different ways using the theorems in right triangles. For the geometry problem presented in Figure 5, for example, two solution ways are applicable. Thus, first the different solution strategies for each problem were identified and collected based on cognitive task analysis (Korossy, 1993). For every problem, each solution way was then associated with the relevant propositions of the concept map.

For deriving dependencies in terms of a prerequisite relation, the problems' representations (more precisely, their solution ways) were compared to each other by means of the subset relation. In a first step, subset relations between solution ways were identified and documented. These were interpreted as preliminary prerequisite relationships among the respective problems. As most problems were represented in two or more ways on the target map, corresponding to their different solution strategies, the derived prerequisite relationships could potentially be ambiguous, namely if for a certain pair of problems two solution ways indicated a prerequisite relationship in one direction (e.g. problem *X* is a prerequisite of problem *Y*), whereas the comparison of two other solution ways indicated a prerequisite relationship in the inverse direction (i.e. problem *Y* is a prerequisite for problem *X*). Therefore, in a second step, the preliminary assumed dependencies between problems were cleaned up, by eliminating the few arising contradictory prerequisite relationships while retaining only definite ones.

The resulting prerequisite relation established for the ten geometry problems on the basis of their representation on the target map is illustrated in Figure 6. The knowledge structure corresponding to this prerequisite relation consists of 41 knowledge states, and thus considerably reduces the set of on principle possible answer patterns (i.e. 1024). For instance, each knowledge state containing problem *d* also contains problem *a*, and a knowledge state covering problem *g* necessarily also contains problems *c*, *a*, and *f*. The knowledge structure derived in this way served as a basis for investigating the target map's application validity. The knowledge states collected in the knowledge structure constitute answer patterns on the 10 geometry problems that were expected to be observable.

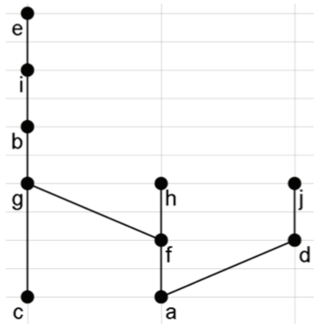

Figure 6. Hasse diagram depicting the prerequisite relation established on the ten geometry problems.

In order to examine whether these theoretically derived and expectable answer patterns predict empirical answer patterns well, the geometry problems were presented to the participants of the empirical investigation. The problems were presented in randomised order and each problem was depicted on a separate sheet. First, three warm-up exercises were presented, which were not taken into account for data analysis, but rather served for making the subjects familiar with the problem solving task and for reducing test anxiety. Subsequently, the ten geometry problems were presented in randomised order. Participants should work at least three minutes on a problem, at maximum ten minutes. This was to ensure that a person being able to solve a problem also brought this ability out, on the one hand, and to limit the duration for one single investigation on the other hand. The average duration for working on the problems was 66 minutes (*SD* = 12.38).

3.2 Results

Out of the ten geometry problems on average five were solved correctly (*M* = 4.82, *SD* = 2.47). For comparing the empirical answer patterns to the theoretical knowledge structure the minimal symmetric distances between empirical and theoretically expected answer patterns were calculated (Garnier & Taylor, 1992; Kambouri, Koppen, Villano, & Falmagne, 1994). The minimal symmetric distance between an answer pattern and a knowledge structure is defined as the distance to the nearest knowledge state. Assume for example the answer pattern *{a,d}* for the five problems presented in the exemplary knowledge structure presented in Figure 3. This answer pattern is actually not part of the knowledge structure, the nearest knowledge state is given by *{a,b,d}* (and *{a}*, respectively) and differs in one problem (i.e. *b*) from the answer pattern. Thus, the distance between the answer pattern *{a,d}* and the knowledge state *{a,b,d}* is one. Assuming that the knowledge structure is correct, in this case it is deemed that in solving problem *b* a careless error has occurred. The minimal distance averaged across all response patterns constitutes a measure for the correspondence between empirical and theoretically predicted knowledge states and gives evidence of the validity of the established knowledge structure and thus, of the target map. The theoretical minimum distance is given by 0, meaning that no deviation from the knowledge structure occurs, i.e. the answer patterns fully correspond to the predicted knowledge states.

The maximum possible distance is given by half the number of items (i.e. n/2 for even, or respectively, (n-1)/2 for odd numbers of items). Hence, for the present investigation with 10 geometry problems the greatest possible distance was 5.

The average symmetric distance between the 44 empirically collected answer patterns and the hypothesised knowledge structure was 0.77 (*SD* = 0.73) (see Table 1). When calculating minimal distances between an empirical data set and a theoretical knowledge structure, it has to be taken into account that trivial answer patterns (i.e. none or all problems mastered) on principle do not provide any information of the validity of the specific theoretical structure, as these knowledge states are contained in any knowledge structure. In the present investigation, only two trivial answer patterns (no problem solved correctly) occurred. Hence, when considering only non-trivial answer patterns for the calculation of mean distances an only slightly higher average distance (*M* = 0.81, *SD* = 0.73) resulted.

Distance	*Frequency* *(44 subjects)*
0	17
1	21
2	5
3	1
mean distance	0.773 (*SD* = 0.73)

Table 1: Frequency distribution of minimal distances and mean distance for the present investigation.

These results for the comparison between theoretical and empirical knowledge states are definitely encouraging and argue for the properness (more precisely, the validity) of the established knowledge structure. For a statistical test of the knowledge structure's validity Heller (2001) suggested to use a frequency distribution of the symmetric distances. Assuming the null hypothesis that the empirical data comprises no structure, the validity of the knowledge structure is estimated by using a one-dimensional χ^2 statistic. The distribution of distances for the items' power set (i.e. all answer patterns) is utilised as a basis for the test. It is examined whether the distribution of distances for the empirical answer patterns differs significantly from the distribution for the expected patterns. For the present investigation the null hypothesis could be rejected (at a 1 % level of significance; $\chi^2_{0.99} = 15.08$ and $\chi^2_{obs} = 172.21$), which argues for the validity of the knowledge structure and hence of the concept map.

In sum, the data analysis leads to the conclusion that the empirically collected answer patterns on the geometry problems correspond well to the theoretically predicted answer patterns (i.e. knowledge structure) as derived from the representation of the geometry problems on the concept map. As the correspondence between knowledge structure and empirical performance can be interpreted as a measure of application validity, the target map can be regarded to be validated and is ready for use.

3.3 Discussion

For the geometry problems used in the empirical investigation actually also a somewhat different knowledge structure had been established and investigated in the past, based on an underlying competence modeling (Korossy, 1993). The respective structure was even more restrictive, featuring only 25 knowledge states (compared to 41 knowledge states in the present investigation). It appeared of course interesting to compare the goodness of fit of the structures in the two investigations. To this end, the distance agreement coefficient DA (Schrepp, 1999) was calculated, which constitutes a measure for the fit between a knowledge structure and an empirical data set, while taking into account the size of the knowledge structure. The resulting DA for the present investigation was 0.349 compared to a DA of 0.356 for the investigation and knowledge structure of Korossy (1993). Thus, this measure indicates marginally better results for our investigation.

The representation of the geometry problems on the concept map, which was used for establishing the knowledge structure, only considered solution ways of the problems using the theorems in the right triangle (i.e. Pythagorean, Altitude, and Euclidean Theorem). Actually, there were also alternative ways for solving the geometry problems (applying trigonometric functions or quadratic equations). As the target map represented only the knowledge domain on theorems in right triangles, those alternative solution ways were not presentable and not intended to be captured. Consequently, for the purpose of application validation only answer patterns using the solution approaches addressed and used for establishing the knowledge structure should be considered. In the present investigation, eight out of the 44 participants partly used such alternative solution ways. When excluding the answer patterns of the respective eight persons from data analysis and calculating the average minimal symmetric distance between the empirical data and the theoretical knowledge structure for the remaining sample, though, the result changes only marginally (M = 0.778, SD = 0.75 for the reduced sample compared to M = 0.773, SD = 0.73 as resulting for the whole sample).

The performance measure chosen for application validation actually involved not only declarative but also procedural knowledge. This is, as the solution of the geometry problems does not only require to know the theorems in the right triangle on a solely factual, declarative level, but rather also requires ability in terms of procedural knowledge, i.e. on how to apply the declarative knowledge elements. The target map in this investigation naturally only covered declarative knowledge, such that the establishment of the knowledge structure relied only on the problem's declarative representation on the target map. Therefore, the concept map's predictive power was investigated using a more comprehensive situational behaviour and thus, an even stricter and more delicate validation criterion. Consequently, the results of the investigation are even more interesting and confirmatory for application validity. However, somebody might claim for an alignment of target map and represented problems. Here, we see two possibilities: either to use problems or questions that require only declarative knowledge or, alternatively, to include procedural knowledge elements in the target map.

4 Summary and Conclusion

A concept map reflects the perspective of its authors and the purpose for which it has been constructed. Hence, given a particular purpose a concept map is needed that validly represents the knowledge of the domain in question, integrating possibly different perspectives, and referring to the designated use of the concept map. A critical precondition for an efficient use of a concept map is that it validly represents the knowledge domain in question. This calls for scientifically sound and systematic methods for concept map validation. Here, two aspects of validity are relevant, referring to the question whether a concept map adequately reflects the knowledge of the respective domain (content validity), on the one hand, and referring to the issue whether a concept map serves the purpose for that it has been designed (application validity), on the other hand. For content validation an approach utilising empirically collected concept map as a criterion has been suggested, whereas for application validity an approach utilising relevant situational performance based on Knowledge Space Theory can be pursued (Albert & Steiner, 2005). This paper focuses on application validity and outlines an empirical demonstration of the proposed validation procedure for a target map on geometry. Application validity was examined through representing typical geometry problems of the knowledge domain as substructures of the concept map and in this way deriving prerequisite relationships among problems by set-inclusion. The identified prerequisite relationships gave rise to a knowledge structure predicting expectable answer patterns on the set of problems. This theoretically derived knowledge structure was compared to empirically collected answer patterns, yielding that they correspond well to each other and thus arguing for the validity of the established structure. As the structure was derived from the target map, in this way the map can be regarded as validated w.r.t. application validity. This constitutes a well founded starting point for the practical application of the concept map.

All in all, the results of the investigation presented in this paper are encouraging and militate in favour of the applied approach for application validation. In general, the knowledge structures established and validated in the course of such an application validation can be re-used, e.g. in the context of technology-enhanced learning, for personalising learning experiences (Steiner & Albert, 2008). This perspective of reuse would mean shared and reduced costs and argues for the real-world utility of the approach presented. Further research should try to underpin the significance of the proposed methodology and broaden these initial encouraging results. Moreover, also the empirical demonstration of a content validation approach would be desirable. By further empirical use of the methodologically proposed procedures, their contextual conditions of use and applicability can be further investigated and opportunities for improvement and refinement can be identified.

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LEARNING WITH CONCEPT MAP: AN ANALYSIS OF A TEACHING EXPERIENCE ON THE TOPIC OF REPTILES WITH 15-YEAR-OLD STUDENTS AT A SECONDARY SCHOOL

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Abstract: Based on the premise that concept map represent an important and relevant tool for the educational process for meaningful learning of scientific concepts, the purpose of this paper is to describe and analyze a specific educational experience involving classes on 'reptiles' for 7th graders (15 years old in average) at a secondary school. Due to the specificity of the educational area and to the various uses concept maps may have, we decided to use the term "map of concepts" to represent a particular type of concept map which is the one that deals only with scientific concepts and the relationship between them. The approach resorted to map of concepts as an aid for teaching the topic. The process consisted of three ninety-minute encounters each with the thirty-eight students of a previously chosen class, in November 2006. With the exception of the introduction of maps of concepts as an instrument for learning the material, the classes used their regular dynamics: an initial free debate, followed by reading of the textbook and a discussion, group activities and, finally, a written evaluation on the newly acquired data. The analysis of the information gathered – maps of concepts developed at the start, during the middle and at the end of the process, answers by the students to the questionnaire about their perceptions regarding the maps – was based on the Meaningful Learning Theory (Ausubel et al, 1978). The results revealed that the students enjoyed elaborating the maps of concepts and saw them as facilitators for learning. Nevertheless, the results also revealed that the short duration of the experience, albeit having contributed to a clear increase of the general vocabulary, was insufficient to stimulate the students into grasping and/or learning the meanings of the central concepts in the topic of reptiles. At the same time, it also failed to establish an overall comprehension of the hierarchical and relational logic of the maps of concepts. As mere suggestions underscoring that the basis for meaningful learning is its process, we recommend greater attention to the process of learning to build map of concepts. Their introduction into the dynamics of formal teaching should occur with themes already familiar to the students, after the teacher negotiates with the class the list of concepts that will make up the map.

1 Introduction

Concepts maps are diagrams that indicate the relationship between concepts (Moreira, 2006) or, according to Novak and Gowin (1984:14), they are explicit open representations of the concepts and propositions someone has on a particular subject. These characteristics, which are coherent with the explanation given by the Meaningful Learning Theory (Ausubel et al, 1978) about the relation between the structure of knowledge and the manner by which someone organizes it in his/her cognitive structure, reveal why these tools had the negotiation of meanings as the dominant perspective in their original conceptualization. It is clear then why these characteristics promoted their immediate acceptance as an important tool for teaching in schools, where evidence shows that their use has always been very successful since the 1970s even though the original use was in research areas (Novak & Gowin, 1984).

More recently, there has also been a productive appropriation of these tools in various contexts for all sorts of purposes (Novak, 1998; Cañas et al, 2004). However, it is predominantly in the educational field that their application in the original conception – focusing on scientific concepts (Novak, 1998; Novak & Gowin, 1984) – occurs. Therefore, it is this original conception that contributes to the successful use of these tools as instructional, learning, curricular planning and evaluation resources. Due to the specificity of the educational area and to the various uses concept maps may have, we have made the option to use the term "map of concepts". We have done so having them represent "bi-dimensional diagrams that try to show hierarchical relations between concepts of a certain body of knowledge and exactly the conceptual structure of this body of knowledge from which they derive" (Moreira, 2006:10). In sum, **we propose the use of "map of concepts"** as a more adequate variation of concept maps **for the educational context, structured primarily by scientific concepts, when the goal is conceptualization**.

Investigations in the educational field have demonstrated that the potential of map of concepts in the optimization of the quality of teaching and learning processes is similar in its various functions, a fact that reveals an existing interdependence. Since they represent relations between scientific concepts, in their diversified use they end up favoring meaning negotiation. That, in itself, is a condition for the learner to grasp the meanings, to establish a consensus about them and finally to learn them (Gowin, 1980). A good part of these investigations have highlighted the didactic and meta-cognitive potential of these tools, and use them as a basis for characterizing the impact of teaching on the acquisition of conceptual knowledge by those that elaborate these maps. For that reason, the analyses tend to give priority to the difference between the initial maps (as evidence of previous knowledge) and the final ones (as evidence of meaningful learning), and not to the process of learning itself. Therefore, it is not common to find accounts of investigations and/or experiences that have analyzed the learning process in constructing maps of concepts. More specifically, they have not also analyzed the relation between the knowledge represented in these maps of concepts, the evolution of the learning process and the teaching process developed during the experience. It is precisely in this partially unexplored direction that the material we are presenting here goes. The data we are about to describe, considered as a pilot study for an ampler project, focuses on understanding the teaching and the learning processes that come about with the elaboration of map of concepts.

Bearing this in mind, we now view the learning process of the meaning of what a map of concepts is, and, consequently, the attention its elaborator dedicates to the selection of the scientific concepts that will integrate the map, besides the (inter)relations he/she has chosen to explicit. We believe these aspects are fundamental for an autonomous management of meaningful learning, even when the learner chooses any other strategy and/or learning resource and/or any other theoretical reference.

The meaningful learning process demands both personal negotiation of the new meanings – when the student compares and negotiates the new piece of information with the ones he has already got –, and interpersonal negotiation, when the student compares and negotiates what he thinks about the topic with the interpretation of his interlocutor. These steps demand attention (not only from the one who teaches, but also from the one who learns) to central concepts of the topic at hand and to the relations established between them. This aspect justifies the potential of the map of concepts as a facilitative resource for meaningful learning. On the other hand, it validates the coinciding steps in the orientations of specialists in the field to construct such maps: the selection and list of eight to ten key concepts, the ordination of the concepts from the more general to the more specific and the establishment of the vertical and horizontal relations between the concepts using lines and words (connectors) that explain these relations (Novak & Gowin, 1984; Moreira, 2006).

From what we have discussed, we will describe the teaching process accomplished. With priority to the concepts present in the constructed maps of concepts, we intend to analyze the nature of the knowledge of the students shown by these tools they elaborated during the three different moments of the intervention. From these data we will discuss the influence of the teaching in the maps of concepts elaborated at the time. Finally, we will present some considerations and suggestions for the use of these maps of concepts as an instructional resource, as well as a tool for the investigation about the teaching process.

2 Teaching about Reptiles with Map of Concepts

2.1 The proposal of the Intervention

One of the authors of this paper, in partnership with a science teacher, developed the activity during regular classes with 7th grade secondary school students in a public school in Garanhuns, in the Brazilian northeastern state of Pernambuco. The class was composed of 38 students, averaging 15 years of age but we have considered as the population for this study only 22 students, for they were the ones that performed all the activities. Besides being in accordance with the school syllabus for the subject, the main objective of the experiment was to favor conceptual meaningful learning (Ausubel et al, 1978) on the topic of 'reptiles'. Starting from this point, there was an introduction of the maps of concepts, until then unknown to this group of students, inserting them in the dynamics of the classes as a learning tool.

The experience was comprised of three one and a half-hour encounters each, during three consecutive weeks. In the first encounter, right after the explanation of what a map of concepts was, the teacher prodded an oral and collective discussion. At that point, the students characterized what reptiles were like without recurring to any text, making up a map of concepts of this group of animals individually and again without any help once the discussion was over. On the second occasion, they worked on the topic during the first half of the class in the usual procedure applied by the teacher and the school: reading from the textbook by the students and a collective discussion on the elements of the text resulting from questions asked either by the teacher and/or by the students themselves. Next, they discussed the topic using posters the students had prepared and comments heard or read in the media. They summed up the topic by developing another map of concepts. During the third and last encounter, they elaborated a final map and had two evaluating activities: one about the content of what had been studied (reptiles) and another about the insertion of the map of concepts as a learning strategy for the school subject. The three maps and the questionnaire for the students' evaluation of the experience, based on their impressions after the implementation of this new element in the dynamics of the classroom activities in a science class represent the data we have collected. We will now go on to present the process and its analysis.

2.2 *The elaboration of map of concept as a facilitative strategy for learning during the teaching of the topic 'reptiles': description and analysis of the process*

As we have already mentioned, the intervention had the purpose of describing and analyzing how the maps of concepts work to bring out the full potential of their aim: to favor meaningful learning on the topic of reptiles by the students. The application of this learning tool was the only alteration in the daily dynamics of the class, aiming at bringing about individual and/or collective reflection on the concepts and the relation they established among themselves to characterize the topic of study in question. The expectation based on the idea that learning is a process that demands time and negotiation of meanings was that the maps elaborated during three distinct moments – despite being very close in time – could show an evolution in the knowledge of the students during the teaching process.

Thus, taking into consideration the fact that the group of students had no previous knowledge on map of concepts – ignoring both their meaning and the organization of their logic –, the first encounter started by the introduction of these maps. Showing several examples of maps, the teacher explained the guiding principles and the criteria for the building up of such tools. She tried to emphasize the fact that although the maps did not have a rigid format, it is important to respect both the hierarchy and the horizontal relations that the concepts established among themselves in representing a particular body of knowledge. She also pointed out that the maps of concepts are personal, and, due to this aspect, corresponded only to one of the possible interpretations for a certain conceptual structure, which demanded a clear explanation of this particular characteristic.

Next, she outlined on the blackboard an example of a map using the concept 'table'. Having done this and wanting to draw up the students' previous knowledge about the topic she was going to introduce, she proposed a collective discussion on the topic she was about to teach. While they answered orally what they knew about reptiles, the students – most of them participating actively – talked about the ideas that came up, questioning and discussing them. They finally drew up Map of Concept I individually and without consulting any source of information. The information used was taken from their previous knowledge on the subject. The process of elaboration was calm, with few questions and with apparent enthusiasm on the part of the students.

As it can be inferred from Figure 1, this first set of maps of concepts has diversified forms, and, although it is possible to perceive a concern for hierarchy, it is the vertical direction that prevails, despite the fact that the frequently the relation between the general, intermediary and specific concepts is inadequate. Likewise, the concepts placed in the same horizontal position rarely respect that type of relation. Apart from these aspects, what most calls attention in these maps is the diversity in concepts. In average, they have twelve concepts (ideas) which, as a whole, totalize 124 different types. When analyzed these were put together into seven categories: classification, origin (date) and family (ancestors and descendants), vital functions, bodily structure, temperature, habitat and examples.

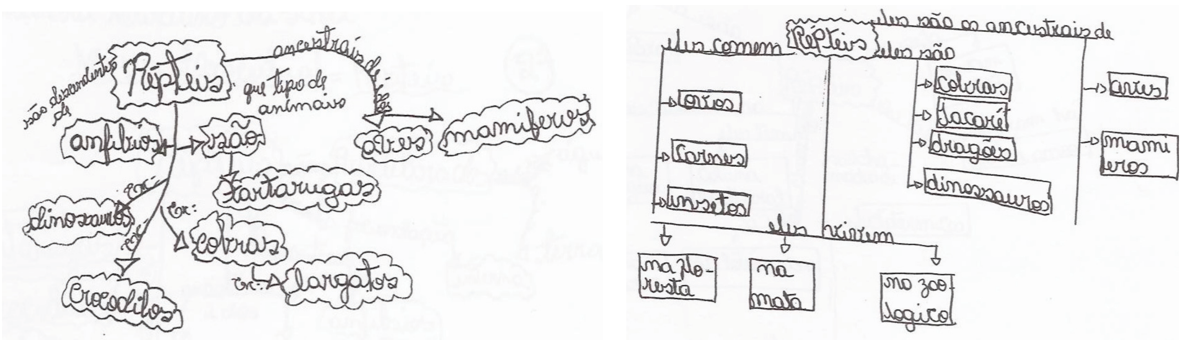


Figure 1. Maps of Concepts I – Students 17 and 5.
[The translation of the concepts and or connectors is: anfíbios= **anphibians**; ancestrais de= **ancestral of**; aves= **birds**; carnes=**meats**; cobras= **snakes**; crocodilos= **crocodiles**; dinossauros= **dinosaurs**; dragões= **dragons**; eles comem= **they eat**; eles são= **they are**; eles vivem= **they live**; ex.= **example**; insetos= **insects**; jacaré= **alligator**; lagartos= **lizards**; mamíferos= **mamals**; na floresta= **in the forest**; na mata= **in the bush**; no zoológico= **in the zoo**; ovos= **eggs**; répteis= **reptiles**; são= **are**; são descendentes de= **they are descending of**; tartarugas= **turtle**]

The most frequently cited aspects were the types of food (nutrition source/nutrition), type of skin and their (external) organs and appendices, and examples. Besides some inadequate relations, "wrong" concepts were limited, having come from three students. Student 1 named "ophidians" as a "class" of reptiles, not an "order"; student 9 stated that reptiles lives "up to 350 thousand years", that they were "the offspring of mammals", and that they fed on their mothers; finally, student 6 used the term "mammal" to exemplify an animal of that group. We can infer from these observations that the class knew about reptiles, knew how to give examples of them, but resorted to external and behavioral characteristics, especially feeding habits and the type of locomotion, in order to characterize the animals in question.

As we have already mentioned, during the second class there was a discussion on the topic resorting to several strategies: shared reading of the textbook used by the school (Cruz, 2005), posters, discussion about pieces of news in the press, radio and TV and the individual construction of a second map of concepts. The class showed enthusiasm about and commitment to all the activities. The posters, elaborated from magazine clippings brought in by the students themselves and put up on the walls of the classroom, were then the focus of the discussion. For the construction of Map of Concepts II, as it had happened in the prior encounter, the students were free to decide about what concepts to use. During the elaboration of the map of concepts, the students recurred to teachers for guidance not only about the hierarchical organization of what they were putting together, but also about the words that they were trying to use as connectors. When the discussion centered on the bits of news the head teacher had brought to class, the students made comments about some programs they had seen on TV on the subject or about experiences of their daily lives in comparison to the textbook. They said they considered “the material in the textbook was too brief”, adding that they had learned more by the elaboration of the map of concepts than by the reading from the textbook.

The analysis of these maps of concepts followed the same pattern applied previously, checking the nature of the hierarchical relations, the list of the concepts and their organization into categories. The result shows little difference between the maps that inaugurated the process and this second ones. Hierarchies were still poorly contemplated and the diversity of concepts/ideas, despite smaller, maintained the emphasis on examples and external characteristics and behavior.

Among the 102 concepts cited, 31 were new and not much representative of the central and specific characteristics of reptiles, and the distribution into categories was similar as the ones cited before. Of this total only “eggs with shell” and “poikilotherm” characterized correctly reptiles despite not being exclusive characteristics of that animal group. The new concepts/ideas were: “is born”, “grows”, “reproduces” and “dies” (S9, S22); “280 millions years ago” (S5); “350 million years ago” (S14); “the turtle was born first” (S14); “similar to birds” (S4); “testicles” and “deferential duct” (S2); “eggs with shells” for “protection” and for “nutritional reserve” (S4); “don’t drink milk” (S7); “jaw”, “rectum” (S2, S16); “lung” (S2); “urethra” (S2); “vertebral spinal column” (S5, S6); “caudal vertebrae” (S16); “poikilotherm” and “cold blooded animals”, “impermeable skin” (S26); “shell”(S10); “bone carapace cast into the spinal column” (S14); “rib” (S6, S16); “locomotive limbs” (S4); “swamp” (S8); “water as habitat” (S5, S7, S11, S17); and “cat, dog and rabbit” as examples (S9). Except for some inadequate relations, the examples just mentioned were the only mistakes present in the Map of Concepts II chart.

In the third and last class, the students developed individually the final map and took part in two evaluation activities. The first, concerning the contents of the topic (reptiles) under study, is not analyzed in this paper. The other was about the insertion of map of concepts as a learning strategy in that particular school subject (science). Despite their certain degree of agitation, the students were able to carry out the activities in a calm and cooperative atmosphere. Among the concepts used in these maps, only seven-out-of 87 were new in relation to the ones found in the two preceding moments. They are: “toothless” (S4, S14, S20); “ear” (S10); “neck” (S14, S15); “habitat on land” (S4); “endotherm”, “amphibian” and “mammal”, the three being wrong. The Maps of Concepts III, elaborated at the final phase of the intervention, show us that still at that final moment there wasn’t an improvement in the level of attention on concepts/ideas that effectively differentiates reptiles from the other vertebrates. On the other hand, there wasn’t neither an increase in the use of hierarchical relations what evidence that, although the concepts present in the maps were part of the conceptual structure, the topic ‘reptile’ was incorrectly perceived or perceived loosely and in fragments.

These impressions are confirmed when we compare, the frequency of the concepts in the three maps. There is no expressive difference in the number of concepts/ideas in each category, nor in the frequency of their use by the 22 students. The gradual decrease in the number of concepts in the second instance, which we could initially interpret as a positive impact, did not reveal any closer attention to the more general and central concepts on the theme. On the other hand, the number of concepts grouped in the categories indicates that those students were frequently recurring to different concepts (words/labels) to express one same idea or meaning. Thinking about these results, w**hat can we say about the learning process of the students and about the influence of the map of concepts on that process?**

Meaningful learning is a process in which new information relates substantively and in a non-arbitrary fashion to a relevant aspect of our cognitive structure (Ausubel et al, 1978). The more stable and consolidated these structures are, the greater the possibility of using this knowledge the person will have, especially in novel and therefore unfamiliar situations. In this perspective, to evaluate meaningful learning requires close attention to the type of use the person makes of his/her own knowledge in distinct situations under conditions that are unfamiliar to him/her. In the current study, the elaboration of map of concepts was in itself an unknown situation for the students. The topic – reptiles – was not completely new to the students, although barely known from that educational perspective. Thus, one of the possible evidences that there has effectively been some learning from maps of concepts – still considering the students as a whole – should be the perception of a tendency to focus on the central concepts of the topic and of some improvement of the hierarchical relations between them. We have already mentioned that we did not observe this tendency in the construction of the maps with the students we were working with.

Summing up what we have so far presented, we have a teaching process that intended to favour meaningful learning on the topic of reptiles with the aid of maps of concepts, together with an assessment of these maps built by the students – which was loose and fragmented at first, but which did not evolve much as the teaching process progressed. Finally, there is our interest to get to know and understand the type of influence the insertion of map of concepts exerted in this process. In other words, the partial results impose upon us questions that precede our main goal. These questions, on the one hand, explicit that both the insertion and the analysis of an instructional strategy need a theoretical base to back them up. It is not our aim here to qualify the teaching process as having been good or bad. Nor do we intend to affirm whether the influence of the use of map of concepts was either positive or negative. Our purpose is to understand what happened. The Theory of Meaningful Learning, which guided us to propose the use of map of concepts in the first place, offers us important elements for our reflection. These will be the core aspects of what we will now discuss.

3 How did the Insertion of Map of Concepts in the Teaching Process influence the students' learning on Reptiles?

The choice of applying the principles of the Meaningful Learning Theory (Ausubel et al, 1978) implies that the teacher should necessarily build up potentially meaningful material and that the students should have the intention of using the tools available in this type of learning process. Hence, it is fundamental for us to assess if these two conditions have been simultaneously present in order to understand the nature of the acquired knowledge expressed in the maps by those students, analyzing above all their choice of concepts for the construction of the referred maps.

In relation to the students, from the description of the teaching activities we learn that they showed "favorable disposition to learn meaningfully", and, furthermore, that they interacted friendly with other students and with the teachers, reacting positively towards the topic they were supposed to study. Aside from their active participation in the activities that were familiar to them, they were equally receptive to deal with two new objects: the map of concepts as a new learning tool, and 'reptiles' as a new topic. Even faced with these two unfamiliar elements, they were committed to the process.

The evaluation by the 22 students themselves about the insertion of the concept maps confirms these impressions. The first of the four questions asked for the students' opinion about the potentiality of the concept maps as facilitative tools for learning. Eighteen students were explicit in answering positively to the issue saying they liked the experience. Eleven emphasized that they had learned more due to the specific influence of this tool. The second question asked about the difficulties that they may have had when building the maps. Only three students affirmed they had none. For the rest, the difficulties referred to the choice of words (4 students), to the structure of the map in its organization, format and relations (8), to the need of further explanation (4) and to the general difficulties with the first map (3) or because "did not know what to do" (1).

The third question was about the advantages and disadvantages about the use of those tools in the year they were studying. The answers remained personal, and ten students pointed out that there were advantages. Five students stated they had liked it and two approved the aspect of conferring grades (scores). One mentioned about the possibility of making the maps, but also of talking about their contents. As to the disadvantages, two students stated that they "had not liked it". Three affirmed that they had difficulty in making the maps, while another one mentioned his/her difficulty in finding the correct words. Finally, when they were asked to say "what they thought about an eventual utilization of map of concepts in other school subjects", fifteen defended the appropriation of these tools in other classes, seven related the advantage to its facilitating learning. In smaller proportions, there were comments about "teaching in a different way", which made classes "more interesting ('cool')". Besides, grading was included as disadvantage by three students.

Summing up, there was no evidence that the students had no interest to think with and about what they were learning. Therefore, lack of interest cannot explain the fact that their level of knowledge at the end of the experiment was very close to the one they had in the very beginning (after a diagnosis of this aspect), when the intervention had started. There was neither lack of interest in negotiating and grasping new meanings, nor in relating them substantively – and not at all arbitrarily – to the previous knowledge they had on the subject. Being fully aware of that, we now turn to reflect if the second condition was met: **was the teaching materials in fact potentially meaningful to this group of students?**

According to Ausubel and to others who shared his views (Ausubel et al, 1978), the teaching material is potentially meaningful when it is possible to relate it to some relevant aspect already present in the cognitive structure of the learner. Thus, reproducing his premise, we affirm that, in order to promote meaningful learning, it is necessary to have a diagnosis of what the students already know, and from there teach them accordingly. In turn, teaching accordingly requires, as we have mentioned, the analysis not only of the structure of the knowledge that there is to teach, but also of what the students already know about the topic. Based on the difference between both, we find what there is to teach, and plan the teaching process.

The study of reptiles (in Latin = crawl, creep) at this level of teaching involves, in broad terms, situating it as a group (Class) of **Living Beings** in the **Animal Kingdom** (multi-cellular heterophics), **Filo Chordate** and **Sub-filo Vertebrata** that, in the evolutional scale, primarily present evident adaptations to life on land: **impermeability of the skin** (carapaces, scales and corneal plaques); **hard shell eggs**, offering protection against dehydration and allowing nutritional storage, not only for the **oviparous** but also for the **ovoviparous.** Apart from these specific aspects, the conquest of land environment was also promoted by lungs with more internal folds (**lung respiration**); hearts with three (partially divided ventricles) or four cavities divided ventricles, but still **incomplete circulation;** complete digestive system; **sexual reproduction** with **internal fecundation; developed sense organs;** with (two pairs of) extremities or with these extremities either reduced or absent, among others. Despite these adaptations, reptiles remained ectoterms, which makes them dependent on external sources of heat, limiting their occupation of spaces. They are sub-divided into **Orders**, the most representative of which are the crocodilians, the scaled and the chelonians. The main criteria for the differentiation of these groups are the types of skin coverage and the locomotive appendices.

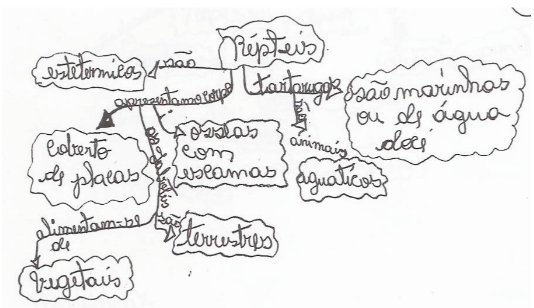
After we have defined what the students should learn, it is necessary to make a diagnosis of what they already know about the topic. In order to do so, our attention should focus on the concepts they already know, on the relations they establish between them and to the meaning that this set represents to the learners. In other words, it is important to verify how close or how distant the student's knowledge is from what one desires to teach. The evaluation of their previous knowledge by means of maps made it evident that, by means of the concepts that were mentioned, the students knew the characteristics of the reptiles, although the relations were inadequate. Furthermore, they could not group them – mentally – in an organized totality that would allow them to become aware of the interdependence between anatomy, physiology, external characteristics and behavior. **Therefore, what was important to teach the students?**

In this case, according to the diagnosis on their knowledge, in order for the teaching material to be potentially meaningful it should give priority to the integrative reconciliation (Ausubel et al, 1978) of the concepts and ideas already known by the students. This requirement indicates that the strategies chosen for the development of the teaching process were correct, since all of them made personal and interpersonal negotiation of meanings possible. The map of concepts structural organization corresponds to the manner we organize knowledge in our mind (cognitive structure). They can promote the establishment of substantive and non-arbitrary relations (meaningful learning), as well as the diagnosis – despite only being an approximation – of the elaborator's steps "in his structuring, establishing hierarchies, differentiations, relations, discriminations and integration of concepts of a determined unit, topic or subject area" (Moreira, 2006:19).

Such characteristics of the maps of concepts allow for not only the initial evaluations, the final one, but also the evolution of the students' knowledge along the teaching experience. This last focus is the one which agrees with the goal of this study, for it is the quality of the difference of the concepts and their respective relations that will allow us to consider the insertion of this tool as having optimized the teaching of the topic 'reptiles'. Hence, if the comparative analysis of the maps of concepts developed reveals that the concepts found in Map III were qualitatively better than those in Map I, we can accept this result as evidence that the teaching process was potentially meaningful, which reveals that it promoted the grasping of meanings.

In order to find this answer, we have to evaluate whether the concepts used only in Maps III and both in Maps II and III – and which are absent from Map I – correspond to the central and general aspects of the theme. Equally, if the concepts found only in Maps I correspond to the non-specific characteristics of reptiles, we will have one more indicator of the success of the event. On the other hand, if the "major" concepts are found in the three maps, we would have to assume that the influence of the teaching on the knowledge of the students was incipient, and that it did not alter much their knowledge. Let us then see what the maps tell us.

Map of Concepts III totalized 87 different concepts/ideas, seven of which were new to the precedent concepts. Thirteen coincided with the ones that were found in Map II and 67 were the same as the ones found in Map I. With exception of the idea "terrestrial" (pertaining to the land), none of the 7 new concepts listed in the preceding was relevant for the topic. Apart from that, three of them (endoterm, amphibious and mammal) were wrong. The thirteen concepts/ideas exclusive to Maps II and III, whose origin could be related to the teaching developed during the experience are: "280 million years ago"(1); **egg with shell** - protection (1); jaw (2); rectum (1); tail vertebrae (1); **impermeable skin** (1); rib (2); locomotive limbs (1); water (3); is born (5); grows (5); reproduces (5); dies (5). In this set, egg with shell, impermeable skin and locomotive limbs are fundamental in the characterization of reptiles, integrating the categories well cited by the students. Among the 67 concepts found in Maps I and III, the most frequent are: reptiles (20), turtles (15), snakes (12), lizard (10), crocodilians, scaled, alligator (8) ophidians, chelonians and tail (7), **internal fecundation, carnivorous, carapaces**, eyes, crocodile, turtles (of another specific kind) (6), **ectotherm** and **scales** (5) and others mentioned from one (the most frequently among them) to four times. The concepts common to Maps of Concepts I, II and III are the ones that are closest to the characterization of reptiles, despite their having maintained the profile of the one described earlier. They are: vertebrate (1), reptiles (20), crocodilians (2), with scales (2), chelonians (2), oviparous (1), eggs directly on the ground (1), mouth (2), feed themselves (1), breathe (1), nostrils (2), skin (1), eyes (3), tail (1), snake (5), crocodile (2), dinosaurs (1), turtles (of the Brazilian variety "jabuti") (2), alligator (5), turtles (5).



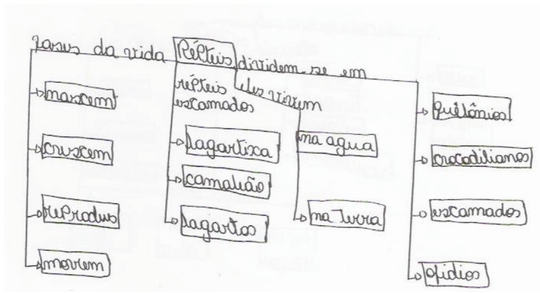


Figure 2. Maps of Concepts III – Students 17 and 5

[The translation of the concepts and or connectors is: alimentam-se de= **they feed themselves of**; apresentam o corpo= **their body have**; camaleão= **chameleon**; com escamas= **with scales**; crescem= **they grow**; coberto de placas= **covered of plates**; crocodilianos= **crocodilians**; eles vivem= **they live**; escamados= **with scale**; exotérmico= **cold blooded animals**; fases da vida= **fases of life**; lagartos= **lizards**; lagartixa= **small harmless lizard**; morrem= **they die**; nascem= **they are born**; na água= **in the water**; na terra= **on land**; ofídios= **ophidians**; os jabutis são= **a Brazilian variety of turtle**; ósseas= **boned skin**; quelônios= **chelonians**; répteis= **reptiles**; são= **are**; são marinhas ou de água doce= **they are marine or of candy water**; reproduzem= **they reproduce**; são animais aquáticos= **they are aquatic animal**; terrestre= **habitat on land**; vegetais= **vegetables**; tartarugas= **turtle**].

In short, as anticipated, although the more important concepts for the characterization of reptiles appear in the set of all the elaborated maps, only a small number of students mention them. The nature of these concepts centered on the examples and external characteristics and behavior is very similar to the one we diagnosed in the first encounter. Just to illustrate the hierarchies we present in Figure 2 the maps of concepts draw by the same students whose maps of concepts we presented as example in Figure 1.

Therefore, even without having analyzed in full detail the hierarchies established by the students among these concepts on the maps, the analysis authorizes us to say that the students kept on using various concepts to express similar meanings because they did not grasp and did not share the meanings that were "taught" to them. For this reason, in case they choose to learn, they make the option for doing it in a mechanical form. Before qualifying the insertion of the maps of concepts in this process we should take into consideration the fact that we based our reflections on the premise that Maps of Concepts I represent what **the students previously knew** before the beginning of the process. It so happens that, as we have described, the students drew up these maps after a collective oral discussion. As there were no notes on the principal ideas of this debate, we cannot ignore that the diversity of concepts diagnosed afterwards – coincidentally very similar to the contents of the textbook – can be a consequence of this interactive activity and/or even of any previous consultation of the material in the textbook. It is very likely that this decision has covered up the positive impact of the teaching and the maps of concepts during the experience.

According to the students, the influence was positive because the tool helped them to learn in a pleasant form, despite the difficulties they came up against in choosing the "words" and in establishing "relations". The process of evaluation of the maps tells us that the number of concepts utilized had an expressive decrease (from 124 to 87). Aside from these aspects and considering that the integrative reconciliation – here understood as this group of students' main demand – has not been perceived in this analysis, it is important to make a point at this stage of our study. It amounts to the fact that the maps of concepts elaborated by the students were the elements that enabled us to analyze in fuller detail the nature of the knowledge this group had represented mentally. In the daily routine where the teacher had been teaching, and the students had been learning, it would have been more difficult to identify the specific demands of this group.

4 Final Coments

In this investigation, as the report on the experience attests, the plan for the intervention gave priority to the presentation of the map of concepts, dedicating little attention to the conceptual structure of the topic. The latter aspect was what should have been at stake. This does not mean that there was a lack of commitment by the teacher to the organization of the teaching process. On the contrary, the revision of the process allows us to perceive that the concern with the insertion of the map of concepts in the process, in addition to the teachers' experience in this level and with this class in particular, diverted their attention from the relation content-learning-teaching-context-evaluation, as deemed appropriate, to the teaching strategies. According to them, it was a difficult group of students to work with. Getting them involved in the process demanded dynamic studying strategies (explaining the diversification in the activities that went on despite the little time allotted to their development) and some form of gratification. In this kind of context – which reproduces the predominant practice in most Brazilian schools – the textbook was the guide for what they should present to the students. Nevertheless, it is true that the contents of newspapers or magazine clippings brought in by the teacher and the students' previous knowledge on the topic had some influence in the process.

Finally, among the various considerations that the study allows us to make, we would like to emphasize that the use of map of concepts is not a trivial task. For this reason, we suggest that their introduction into the dynamics of a class take place with themes from the school curriculum the students already know or are familiar with, stressing that it is also fundamental that, with negotiating with the students the central concepts of the topic, the teacher indicate the concepts that must integrate the first maps. In other words, gradual familiarization of the tool 'map of concepts' is at the basis of an autonomous success of its use. This is what we will continue trying to do …

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LEARNING, PEDAGOGICAL THINKING AND COLLABORATIVE KNOWLEDGE BUILDING BY CMAPTOOLS

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Abstract. We are reporting research on collaborative knowledge building compared to individual conceptual change during a professional study unit in Laurea University of Applied Sciences. As educational research that is a design experiment, a multi-case, multi-method study. We used both individual and collaborative concept mapping in the same design experiment. The theme of the design experiment was 'Coping at Home'. In the competence based curriculum it was a research project as a learning environment. The core concept of the research project and study unit Physiotherapy of the elderly was 'successful ageing'. The subjects were Bachelor of Health Care students in Laurea University of Applied Sciences in Finland. We monitored both individual and collaborative learning and knowledge building related to this concept. The focus of the study was professional and generic competence, especially the reflective competence of physiotherapy students. Students' conceptions developed greatly. Collaborative knowledge building was meaningful for the individual conceptual change. There were seen both cognitive and socio-cultural perspectives. The discussion during the concept mapping process was like a shared thinking process. Students continued each others talking and thinking very fluently like they had had "common brains". It took lot of conversations and many speech acts before the common understanding was created. After collaborative interactions, multidisciplinary concrete links were made between all concepts almost in all individual concept maps and interconnectedness of concepts in different subject areas was understood. Concepts in these individual concept maps were also more at the same time more theoretical and practical than in previous concept maps of these subjects. Also the wider context of the concepts was recognized in many individual concept maps. Students' conceptual frameworks developed from novice level to more advanced expert level. According to students the research project as a learning environment was interesting and useful. They attained new knowledge, skills and attitude and new perspective to their professional knowledge.

1 Introduction

The purpose of the study is to monitor and promote quality of learning and development of the professional and generic competences of physiotherapy students. The generic competence focused in this study is reflective metacognitive competence which means students ability to evaluate their own learning and competence, to identify development challenges and problems, to develop her/his competence independently and with others, to share what she/he has learnt and to assume a role in a group/team and acquire and analyze information systematically. The learning environment - the research project - is based on real needs of elderly people (over 75 years) who still live at home and wish to stay home. The physiotherapy students are going to design programs for an interactive TV – Caring TV-project in aim to support the functional ability, activity, social and mental welfare of the elderly and also to give possibilities to the elderly to discuss with other elderly people in similar positions with the help of different counseling, teaching and instruction methods. The aim of the project is to support successful ageing and sustainable welfare. The needs and expectations of the elderly exist in four themes: welfare, safety, functional activity and possibility to take part in activities. Students try to find out these themes in their professional basis and to plan evidence based interactions as programs of that interactive television. To plan the programs they need to understand and learn more about the main concept of project: successful ageing. The teaching and learning method is Learning by Developing (LbD), which is a concept developed in Laurea University of Applied Sciences, Finland (Raij 2007). In this study learning is understood as a meaningful conceptual change. Physiotherapy students' learning is monitored and evaluated by the quality tools of high quality learning: improved concept maps (1) as an individual conceptual change and (2) as collaborative and social learning and knowledge building of two student groups.

2 Backgroud

Sinatra & Pintrich (2003, 6) characterize intentional conceptual learning with few dimensions: intentional conceptual learning is goal-directed, the goal is to change conceptual understanding; intentional conceptual change is characterized by conscious initiation and regulation of cognitive, metacognitive and motivational processes to bring about a change in knowledge. According to Vosniadou & Kollias (2003, 2) the conceptual change is the outcome of a complex cognitive as well social process. An initial naïve theory is restructured in order to agree with currently accepted scientific and expert views. Studies of conceptual change have shown that this is a slow and gradual process. Dillon (1993, 229) describes the relationship between conceptual development, context and characteristic models of learning for a given issue. He creates a theoretical model for how people develop an understanding of environmental issues. The first exploratory, stage is characterized by developing an awareness of key concepts in a limited contextual framework. In the second stage, often involving some rudimentary work across disciplines, tentative links are made between concepts. In the third stage, usually characterized by extensive subject- based study, concrete links between related subjects are made, the contextual framework is broadened and there is some recognition of the interconnectedness of concepts in different subject areas. In the final, multidisciplinary, stage, concrete links are made between all concepts, interconnectedness is understood and the wider context dependency of the concepts is recognized.

Concept mapping is a way to describe and visualize the conceptual understanding and its change. According to Novak and Cañas (2008) concept maps are graphical tools for organizing and representing knowledge. Åhlberg (2004) discusses varieties of concept mapping. In this paper his improved concept mapping is applied. Concept mapping is one of the quality tools to monitor and promote high quality learning. According to Åhlberg (2005) high quality learning is divided into individual and social learning, learning from personal level to organizational and the humankind levels. Concept mapping enhances integration of learning and thinking.

In the late 1990s, Laurea University of Applied Sciences chose as its strategic approach the integration of education, research and development, and regional development. While implementing the pedagogical strategy, Laurea's practical developers refined this principle into the Learning by Developing (LbD) model. Competence development in the LbD- model and its values like authenticity, partnership and creativity etc. are described in figure 1. Learning by Developing combines two of the major orientations of polytechnic universities: professional education (learning) and research-oriented higher education (developing). (Rauhala 2007)

An initiative is now under way to develop methods to aid the user during concept map construction. These aids are designed in response to observations of snags which may arise during concept mapping. During concept mapping, users often stop and wonder what other concepts they should add to the concept map they are working on, frequently spending time looking for the right word to use in a concept or linking phrase; they search for other concept maps that may be relevant to the one they are constructing, and they search through the Web looking for additional material that could help them enhance their maps. The following sections describe three methods developed to address these issues.

3 Methods

The purpose of the study is to monitor and promote quality of learning and the growth of the professional and generic competence of the physiotherapy students (Laurea 2006). The teaching and learning method was learning by developing. In this study learning is understood as a meaningful conceptual change. Physiotherapy students' learning is monitored and evaluated by the quality tools of high quality learning: improved concept maps: (1) as an individual conceptual change and (2) as collaborative and social learning and knowledge building of two student groups. The core concept of the course and developmental project is 'successful ageing'. The research questions are:

1. What kind of individual conceptions do the students build on the concept of successful ageing? What kind of concepts and propositions they have a) before the project, b) after the project and c) after they have built together a summarising concept map?
2. What happens in collaborative learning as social knowledge building? a) What happens when a concept map of the same theme is built by group of students? What kinds of differences (if any) are in collaborative learning processes and products when the two groups are compared? c) What kind of socially built conceptions (concepts and propositions) do the students have after the project?
3. What kind of individual conceptions do the students build on the concept of successful ageing after they have built together a summarising concept map?

As educational research this is a design experiment, a multi-case, multi-method study. The subjects are Bachelor of Health Care students in Laurea University of Applied Sciences in Finland. They are third year Physiotherapy students and they all are female. They are studying their professional study unit **Physiotherapy of the elderly** in the Coping at Home research project and in its Caring TV- project. In the two study groups there are 22 students. The individual chance of conceptual change is evaluated by 9 research persons who have a different knowledge level in baccalaureate qualification, in the matriculation examination of Finnish language test. Three research persons are chosen by random choice in each group: high achieving, average achieving and low achieving group.

In September 2006, before the study unit of Physiotherapy of elderly starts, the students built their **first individual** concept maps of the concept of successful ageing based on their own common sense knowledge and after study unit their **second** concept maps. Because of practical scheduling reasons the students were divided into two groups: group A had 15 members and group B had 7 members. In January both group A and B created collaboratively a **group level concept map** of the theme' successful ageing' These face- to – face interaction sessions were both videotaped and recorded by Cmap Recorder. In February 2007 the students built **third** individual concept maps, individual professional concept map based on shared knowledge creation.

Both individually and socially built concept maps were evaluated and analysed by content analysis; content maps also by simply statistical analysis. Collaborative group level concept mapping processes, videotaped sessions, were analyzed by dialogue analysis. Before dialogue process analysis, the dialogue was divided into dialogue turns. A turn is an interval of expression by a single participant. The units were either turns or parts of turns, such as sentences or single words. The categories in analysis were developed applying Aarnio & Enqvist (2001).

4 Results

Before the study unit, in first concept maps of a concept of "successful ageing" the research persons (N=9) created 48 concepts and 32 propositions. (Figure 1.)

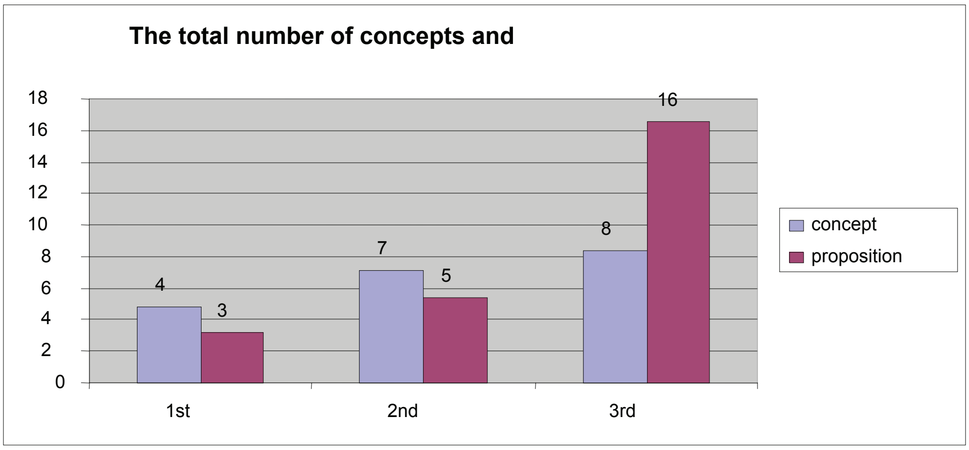

Figure 1. The total number of concepts and propositions in improved concept maps.

Immediately after the study unit, in the second individual concept maps the total number of concepts increased from 48 to 71 and the total number of propositions from 32 to 54. After the social concept mapping, in the third individual concept maps, the total number of concept increased from 71 to 84 and the total number of propositions increased from 54 to 166.

There were no qualitative differences between students who had different knowledge level in baccalaureate qualification, in the matriculation examination of Finnish language test. There were only few differences between numbers of concept but more differences in numbers of propositions in individually build concept maps. In first concept maps the following kinds of abstract concepts were used: 'life' (good life, quality of life, life satisfaction) 'health' (physical and mental health), 'welfare', 'functional ability', 'human relationships', 'economical situation', and concrete concepts like 'home' and 'environment'. In Figures 2, 3 and 4 is an example of conceptual change according high achieving student.

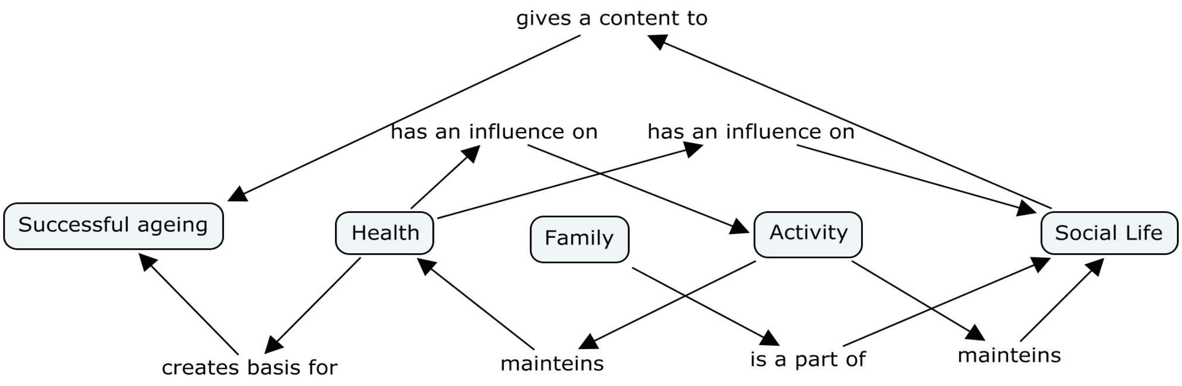

Figure 2. "Successful ageing" according a high achieving student before study unit.

In second concept maps the content categories remained similar as earlier. Professional, active functional aspect was very prominent and concepts of 'independency' and 'activity' were mentioned many times. In propositions there was found five themes: "supporting the health", "physical -", "social -", "environmental -" and "psychological existent".

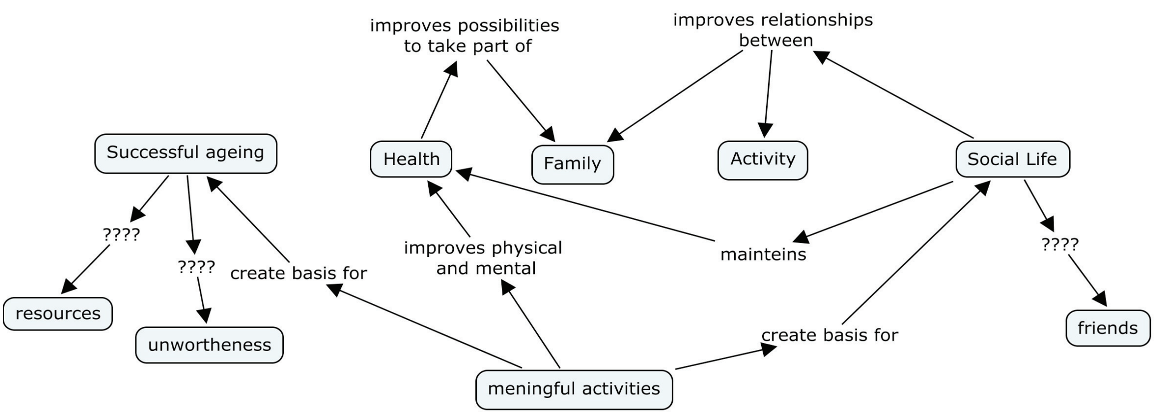

Figure 3. "Successful ageing" according a high achieving student immediately after study unit.

After the social concept mapping in third individual concept maps, there were lot of new propositions and concepts like "optimistic attitude", "sexuality", "good physical condition" "social support" and "pets" which did not exists in first or second individual concept maps. In propositions there were found very similar themes like before and a new theme "safety". Themes in third concept maps had changed to become more concrete compared with second maps like "environmental existent" which had changed to "stimulating environment". Even those students who didn't participate orally in social concept mapping used socially build concepts in their third concept maps.

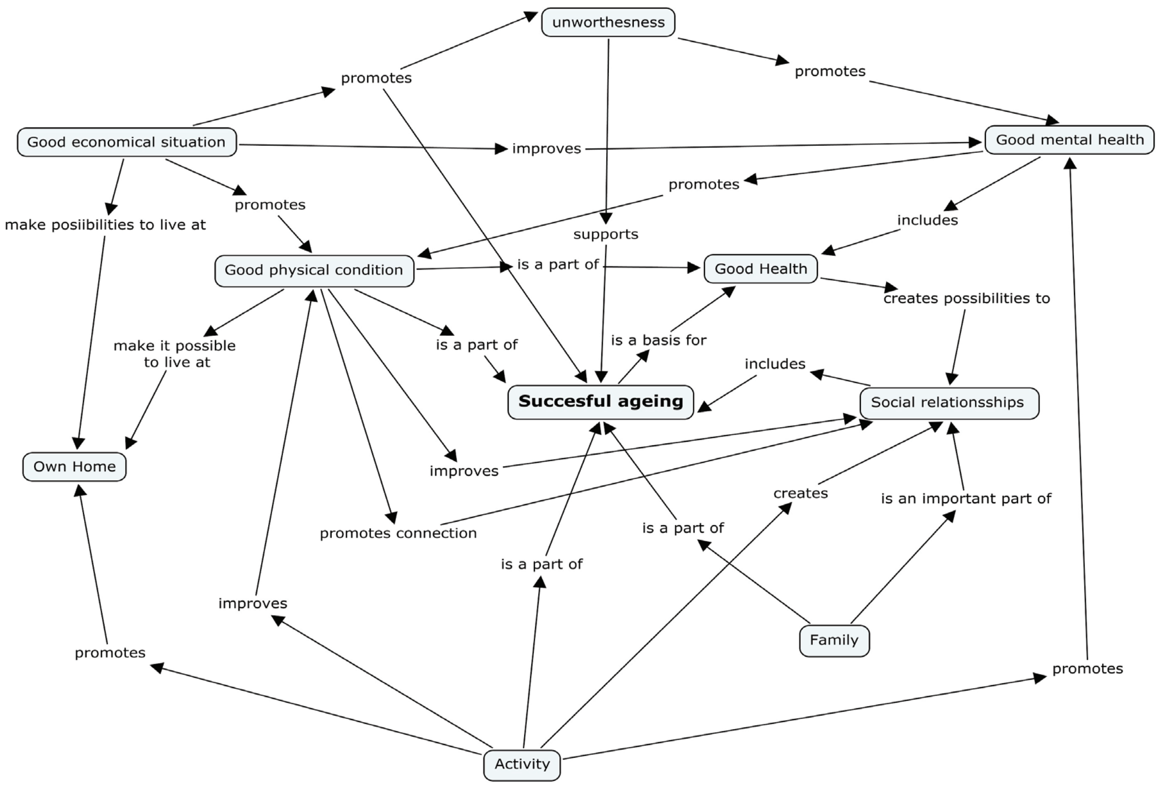

Figure 4. "Successful ageing" according a high achieving student after social concept mapping.

There were differences in processes of student groups. After the second concept mapping the number of concepts increased in the "high achieving" group from 18 to 26; in the "average achieving" group from 12 to 23 and in the "low achieving" group from 18 to 22. The number of propositions increased in the "high achieving" students from 12 to 28, in "average achieving" students from 12 to 22 and decreased in "low achieving" students from 8 to 4. The increase of relevant propositions indicates increase in meaningful learning.

After the social concept mapping, in the third individual concept maps the "high achieving" students increased their total number of propositions only from 28 to 49 and the "average achieving" students from 22 to 61. The "low achieving" students' group increased the number of propositions from 4 to 56. The number of relevant concepts increased only a little. (Figure 5. and 6.) The increase of relevant propositions indicates increase in meaningful learning. Like Dillon (1993) presents, in the final third individual concept maps, multidisciplinary, stage, concrete links are made between all concepts, interconnectedness is understood and the wider context dependency of the concepts is recognized.

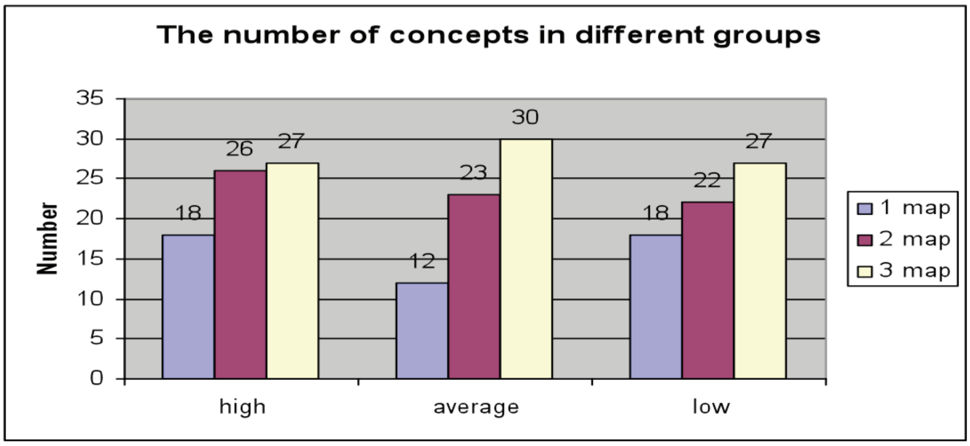

Figure 5. The number of concepts in different groups.

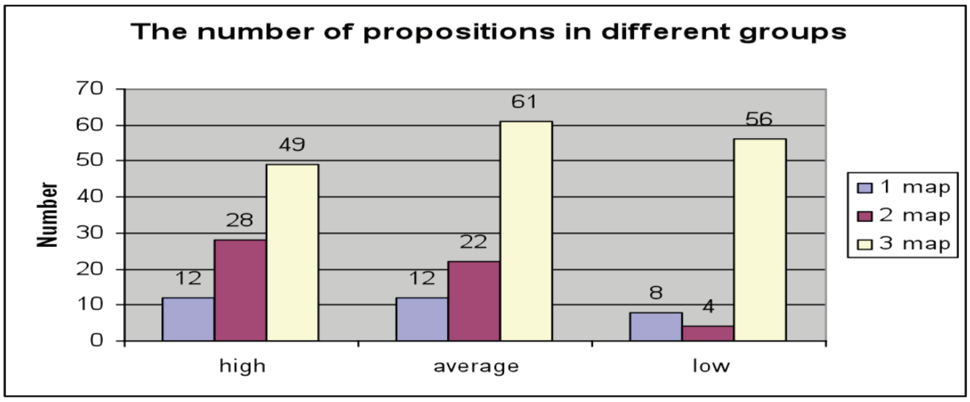

Figure 6. The number of propositions in different groups.

Between the second and third individual concept maps a group level collaborative concept map was created in both groups; 22 students in two groups. The first group (15 members) created its collaborative concept map in January 2007. The whole process took one 45 minutes session. Students of this group created 262 speech acts. The variance of speech act was from 0 to 82. In that bigger group five of the 15 students did not say anything during the process. The most active speaker was the student, who acted as a secretary in social concept mapping. The second group (7 members) created its collaborative concept map also in January 2007. The whole process was over in one 45 minutes session. Students of that smaller group created 384 speech acts and the variance was from 17 to 101, so in that group all seven students participated also orally. The most active student was, like in first group, the secretary of that social concept mapping. The discussion during the concept mapping process was like a shared thinking process. Students continued each others talking and thinking very fluently like they had had "common brains".

The videotaped conversations speech acts were divided into dialogue turns as a part of building group level concept maps. These dialogue turns were **classified by the category system (socio-cultural aspect) developed by applying Aarnio & Enqvist** (2001). In both groups the category used mostly was to support others opinion to connect or to agree. Almost a half of all dialogical turns were classified in that category. There were only a few unnecessary opinions. In the group #1 it took 379 and in the group #2 totally 464 dialogical turns before the synthesis of concepts or propositions had determined.

The dialogue turns were also classified by cognitive point of view. There were found peer-teaching, peer-counselling, evaluating, arguing as a pedagogical thinking and knowledge creating. There were 32 % pedagogical activities and 68 % knowledge creating activities in these knowledge building interventions.

In the collaborative improved concept mapping of the second group, they produced 11 concept synthesis and 22 proposition synthesis. So it means lot of discussion and conversation before the synthesis had existed. (Figure 7.)

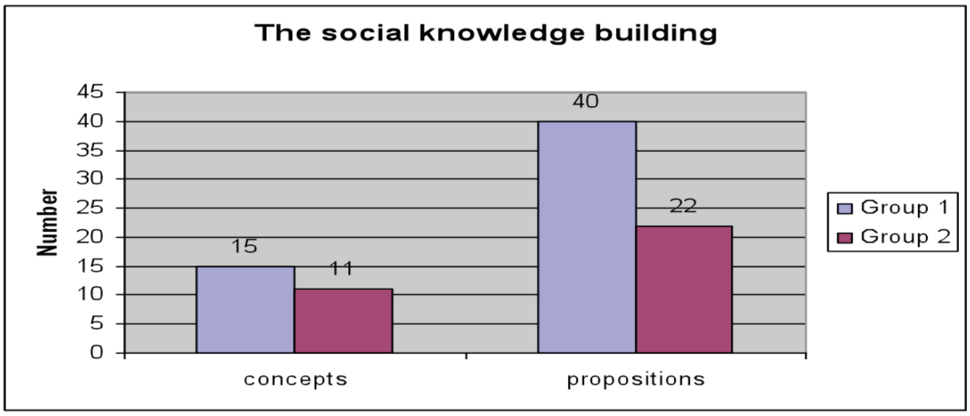

Figure 7. The number of concepts and propositions in socially built concept maps.

In the socially built concept map, there were few concepts, which did not exist in first or second individually built concept maps, like “supporting network”, “accepting the death”, “free environment” and few concepts, which was so meaningful, that students had them in their third individual concept maps created after social concept mapping, like “safety”, “social network” and “good economical resources”. The safety – theme was also mentioned in many propositions.

The process and content of collaborative concept mapping of two groups was quite similar according to data from Cmap recorder. Both groups started by the concept of “successful ageing” and continued by themes like health (good health, comprehensive health), home (home of own), independency (to make own decisions), environment, services (good services) and social network (supportive social network). In the first group the important concepts were connected to mental, social and environmental area like “accepting to become old and to die” or “good economical situation”. There were no mentions of specific physical aspect (Table 2.) In the second group the free living environment was important, but there were no mentions of specific physical or mental aspects. (Table 3)

Successful ageing	INNER RESOURCES			ENVIRONMENTAL RESOURCES
Common level	Physical aspect	Mental aspect	Social aspect	
Good health	**0**	**Good mental health**	**Social network**	**Active environment**
Independency		**To accept becoming old**	**Good economical balance**	**Own environment**
Activity of own		**To accept dying**		**Home of own**
Functional ability		**Safety**		**Good services**

Table 2. **Concepts (N= 15)** in the collaborative concept mapping of the first group.

Successful ageing	INNER RESOURCES			ENVIRONMENTAL RESOURCES
Common level	Physical aspect	Mental aspect	Social aspect	
Comprehensive health	**0**	**0**	**Supportive social network**	**Living environment**
Possibility to make own decisions			**Family,**	**Free environment**
				Home
Active life style			**Society**	**Services**

Table 3. **Concepts (N=11)** in the collaborative concept mapping of the second group.

5 Conclusion

The focus of the study was professional and generic competence, especially the reflective competence of physiotherapy students. Students’ conceptions developed greatly althought the change between first and second individual concept map was small. Collaborative knowledge building was meaningful for the individual conceptual change. Even those students who didn’t participate orally in social concept mapping used socially build concepts in their third concept maps. Difference between high, average and low achieving students in group level had almost disappeared.

The social concept mapping process was very similar in both two groups. There were seen both cognitive and socio-cultural perspectives. Student asked and answered on each others questions, they explained meanings of concepts, they supported each others opinions and created the social conception of the concept “successful ageing” together. There were found peer-teaching, peer-counselling, evaluating, arguing as a pedagogical thinking and knowledge creating. The discussion during the concept mapping process was like a shared thinking process. Students continued each others talking and thinking very fluently like they had had “common brains”. It took lot of conversations and many speech acts before the common understanding had existed. After collaborative interactions, multidisciplinary concrete links were made between all concepts almost in all individual concept maps and interconnectedness of concepts in different subject areas was understood. Concepts in these individual concept maps were also more at the same time more theoretical and practical than in previous concept maps of these subjects. Also the wider context of the concepts was recognized in many individual concept maps. Students’ conceptual frameworks developed from novice level to more advanced expert level. According to students the research project as a learning environment was interesting and useful. They attained new knowledge, skills and attitude and new perspective to their professional knowledge.

The social atmosphere was excellent in both groups and there were plenty of informal qualitative positive evidence for collaborative learning and thinking. The concept mapping centred teaching, studying and learning process was a success in these university level groups. Students discussed much more than in traditional teacher centred teaching of the earlier years. The Cmap Recorder data gave a lot of new information of the process. For scientific purposes it is important to replicate these kinds of design experiments. For us this was an optimal way to monitor and promote quality of learning in this kind of course.

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LINGUISTIC BIAS OF CONCEPT MAPPING: IS WORD ORDER A MATTER?

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Abstract. This paper investigates linguistic limitation of concept mapping (CM) where word order is different with English sentence structure: Subject-Object-Verb. One of the main distinctions between CM and other knowledge representative techniques is adoption of proposition, as the smallest linguistic unit, for developing a concept map (node-link-node). Consequently, a concept map, which is developed in English, can be read as same as a sentence presented in a text. But this distinction causes confusion and creates learning problems when a concept map drawn in languages with different word order, such as Subject-Verb-Object languages. This paper briefly reviews the related literature and suggests some solutions for solving the problem.

1 Introduction

Although there are a variety of knowledge representative techniques (such as semantic network and mind map), concept mapping (CM) is the most popular of them, especially in academic and educational situations. The most important reason for CM popularity is enormous body of research showed its effectiveness for several purposes in different subject matters (see for example, Cañas & Novak, 2006). Although more than three decades have passed since its establishment, there are still many researchers and educators who are interested on the application of CM as an effective learning technique; Concept Mapping Conference (CMC) and many journal papers (378 journal papers was retrieved in ERIC database about “concept mapping” between 2000 and April 2008) are reflected this interest.

CM technique was established on the basis of English sentence structure, Subject-Verb-Object (SVO), and the main distinction, which differentiates CM from other techniques, is the application of proposition, as the smallest linguistic unit. For developing a concept map, two concept or nodes is related by a link, which in most cases is a verb (node-link-node). Thus a concept map, that is generated in English or other SVO languages, can be read as same as its related sentence in a text.

However, this unique characteristic of CM causes a limitation for developing concept map in some languages. Many people around the word are speaking and studying with languages that their word order is not SVO. For example, some languages, such as Korean Turkish, Arabic, Persian and Japanese, have Subject-Object-Verb (SOV) word order. In SOV languages, the link (verb) between two concepts comes at the end of the sentence. When a concept map is developed in a SOV language, it cannot be read as same as its related sentence presented in the text. Users of CM technique, whom their formal language does not have SVO word order, would experience confusion and problems, or at least inconvenience, for developing a concept map (see for example, Kilic, 2003; Lee, 1999). In this situation, CM technique might be accused of linguistic bias. In addition, it might question the application of CM as a worldwide technique and forces educators and learners to use other techniques. It seems research is needed to investigate: “how should CM technique be used in SOV languages or, in general, languages with word order other than SVO?”

2 CM versus other visual knowledge representative tools

First, the main difference between CM and other knowledge representative techniques should be addressed. There are many words that seem to be synonymous with or related to CM, including, mind map, semantic map, semantic net (or networking), cognitive map, roundhouse diagram, concept circle and flowchart. Some of these terms are sometimes used interchangeably. However there are some elegant and theoretical differences between them. Semantic network is the most popular term that is usually used instead of CM and some authors prefer to use it (e.g., Jonassen, Peck & Wilson, 1999). The exact definitions of these terms are presented in table one.

Although researchers have presented many definitions for CM and a clear distinction among these definitions would be difficult, most of them are common in the application of few words: node (concept, point, or vertices), link (line, arc), proposition and graphical or visual representation. Reader and Hammond (1994) suggested a simple definition for concept map as “a graphical representation of domain material generated by the learner in which nodes are used to represent domain key concepts and link between them denote the relationship between these concepts” (p. 52). The proposition refers to the combination of two nodes (concepts) and a link that joins them (Ruiz-Primo & Shavelson, 1996). According to Anderson (2005), a proposition is the smallest linguistic unit that carries meaning.

Name	Definition
Mind map	This technique invented by Tony Buzan. Its primary role is as a note technique that helps learners to take note during a lecture or reading learning materials. It has only one main or central concept (word). Around this central concept there are 5 to 10 main ideas that relate to that word. Each of these child words can be taken and as a main word and 5 to 10 related words is drawn. Mind map can be represented as a tree.
Flow chart	Flowchart is graphical representation of a process which depicts through the steps of the process in sequential order.
Semantic network	Semantic network is the most popular term that usually are used instead of CM and some authors prefer to use it.
Concept map	A technique invented by Novak as an educational tool. It can be use to explore prior knowledge and misconceptions, encourage meaningful learning to improve students' achievement and measure concept understanding. A concept map may have several main concepts and can be represented as a network. CM is based on a logical and graphical organization of concepts.

Table 1. *Definitions* of concept map and some familiar terms

The use of the proposition for developing a concept map is the main point which differentiates CM from other knowledge representative technique. In most of other techniques, the concepts are linked by a line that is usually not labeled. Thus, if this distinction is ignored, there won't be any specific difference between CM and other techniques. Some research, which is conducted in SOV languages, does not pay attention to this distinction and, incorrectly, use other techniques instead of CM (see for example, Takeya, Yasugi, Funabashi & Nogaoka, 2006).

3 Word order in language

A question might arise here that "how many languages are there with word order other than SVO?" and "is it worth to discuss this problem?" Word order typology is a linguistic subject. It investigates the different ways in which languages arrange the constituents of the sentences. Although some languages allow flexibility, most languages however have preferred word order which is used most frequently (Tomlin, 1986).

It is possible, for most languages, to define a basic word order. There are six possible word orders for the subject, verb and object: subject verb object (SVO), subject object verb (SOV), verb subject object (VSO), verb object subject (VOS), object subject verb (OSV) and object verb subject (OVS). However, the majority of the world's languages are either SVO or SOV (Dryer, 1991). These are in the order of most common to rarest as below (Wikipedia Encyclopedia, 2008):

- SOV languages: For example, Japanese, Turkish, Korean, Persian, the Indo-Aryan languages and the Dravidian languages;
- SVO languages: For example, English, Portuguese, French, Chinese, Bulgarian, and Swahili;
- VSO languages: For example, Classical Arabic, the Insular Celtic languages and Hawaiian;
- VOS languages: For example Fijian and Malagasy;
- OSV languages: For example Xavante;
- OVS languages: For example Hixkaryana.

Table two shows some of the most common languages in the world (summarized from information presented at UCLA Language Material Project, 2008). Among most common languages (with more than 200 millions speaker), Arabic and Bengalia have SOV word order. It shows millions of people around the world are speaking with SOV languages (especially in Asia) and this large population cannot be ignored.

4 Different between SVO and SOV languages in developing a concept map

In SVO languages, the relationship between two words (concepts) is expressed by a verb or a preposition. In consequence, a concept map is read as same as a correct sentence in its related text. In contrast, in SOV languages, objects precede the verb and so when a concept map is read, it does not make a complete and meaningful sentence. Figures one to three show three simple concept maps and their related sentences, in one SVO language (English) and two different SOV languages (Turkish and Persian).

Continent	Language	Population (Million)	Dominant word order	Continent	Language	Population (Million)	Dominant word order
Asia	Burmese	30	SOV	Europe	Albanian	5	SVO
	Nepalia	16	SOV		Dutch	20	SVO
	Assamese	15	SOV		Bosnian	2	SVO
	Marathi	70	SOV		Serbian	11	SVO
	Sinhalese	13.2	SOV		Croatian	6	SVO
	Tamil	66	SOV		Bulgarian	9	SVO
	Telugu	69	SOV		Danish	5.5	SVO
	Sindhi	21.5	SOV		Finland	6	SVO
	Maithili	25	SOV		Belarusian	10	SVO
	Kashmiri	6.6	SOV		Chez	12	SVO
	Bhojpuri	25 to 30	SOV		Estonian	1.5	SVO
	Oriya	N/A	SOV		Hungarian	14.5	SVO
	Urdu	60	SOV		Latvian	2	SVO
	Punjabi	104	SOV		Lithuanian	3.5	SVO
	Gujarati	46	SOV		Romanian	25	SVO
	Hindi	180	SOV		Polish	43	SVO
	Kannada	35	SOV		Tatar	6 to 57	SOV
	Malayalam	36	SOV		Buriat	.450	SOV
	Baluchi	7	SOV		Chechen	1.2	SOV
	Brahui	2.2	SOV		Bashkir	2	SVO
	Uzbek	15	SOV		Slovak	5.5	SVO
	Cantonese	64	N/A		Ukrainian	46	SVO
	Hmong	3	SOV		Swedish	8	SVO
	Tibetan	3 to 7	SOV		Basque	.580	SOV
	Uighur	7.5	SOV		Icelandish	.280	SOV
	Korean	72	SOV		Macedonian	2	SVO
	Japanese	121	SOV		Catalan	7	SVO
	Mongolian	6	SOV		Maltese	.500	SVO
	Armenian	6	SVO		Norwegian	4.5	SVO
	Azerbaijani	7	SOV		Welsh	N/A	SVO
	Greek	12	SVO	Africa	Fula	12 to 15	SVO
	Turkish	56	SOV		Bambara	3	SOV
	Arabic	N/A	SOV		Hausa	22	SVO
	Georgian	4	SOV, SVO		Yoruba	22	SVO
	Kurdish	13	SOV		Lingala	10	SVO
	Persian: Farsi	23	SOV		Wolof	7	SVO
	Hebrew	5.3	SOV		Ewe	3 to 5	SVO
Most Common Languages (with more than 200 million speakers)	English		SVO		Igbo	18	SVO
	French		SVO		Mende	1.5	SOV
	Spanish		SVO		Sotho	10	SVO
	Germany		SVO		Malagsay	13	VOS & SVO
	Russia		SVO		Afrikaans	6	SVO & SOV
	Portuguese		SVO	America	Quechua	8	SOV
	Arabic		SOV		Navajo	.148	SOV
	Mandarin		SVO		Haitian	6	SVO
	Bengalia		SOV				

Table 1: Most common languages in the world and their word order

The following figure shows a simple concept map in English. The correct and meaningful sentence in the text is: “Children <u>love</u> their mother” and the concept map is read in a similar way: “Children <u>love</u> their mother”.

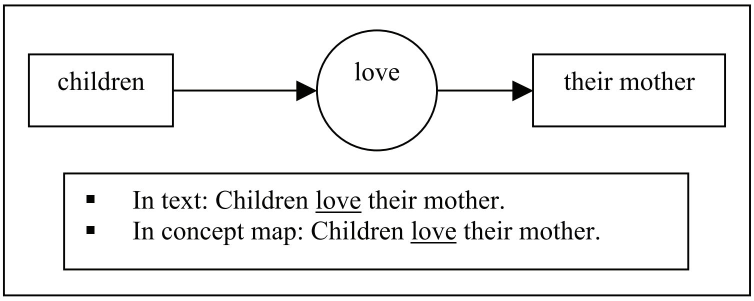

Figure 1. A simple concept map, and its related sentence, in English language

Figure 2 presents a simple concept map in Turkish. Turkish is a SOV language. “Cocuklar” means children, “Anne” means mother and “Sever” means love in Turkish. The correct and meaningful sentence in the text is: “cocuklar anne sever” but the concept map is read: “cocuklar sever anne”.

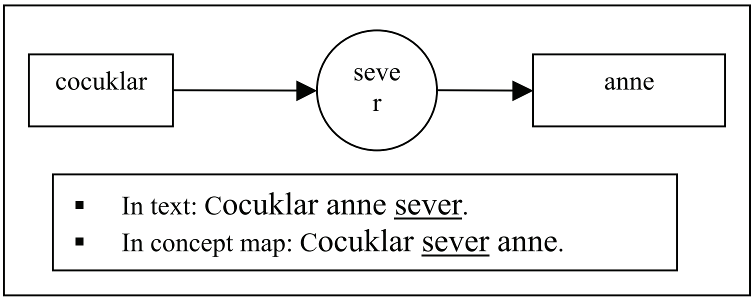

Figure 2. A simple concept map, and its related sentence, in Turkish language

Figure 3 presents a simple concept map in Persian. Persian or Farsi is a SOV language. In Persian (and some Asian languages, such as Arabic) sentence is written from right to left. “ ” means children, “ ” means mother, “ ” means their and “ ” means love in Persian. The correct and meaningful sentence in the text is: “ ____________.⇦” but the concept map is read: “ ____________ ⇦”. It is an incorrect sentence in Persian language because the verb (____________) came before object ( ).

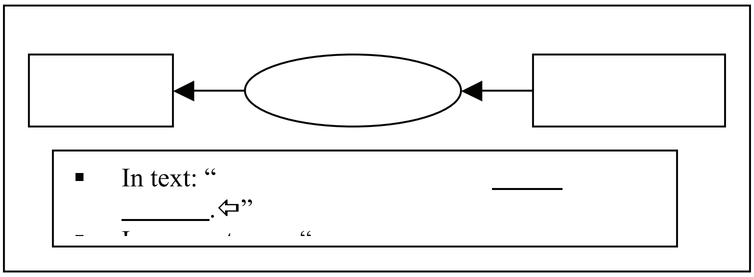

Figure 3. A simple concept map, and its related sentence, in Persian language

5 Research on CM conducted in SOV languages

Although CM was originally developed for use in English, with its unique characteristic in expression of a labeled link among concepts, it was welcomed in other SVO languages as an effective learning tool, such as French and Spanish. Therefore most of research published on CM conducted in the countries where the first languages were SVO. A review of papers presented in the first and second CMC show almost all of the papers reported the research conducted in SVO languages (Cañas & Novak, 2006, & Cañas, Novak & González, 2004). However, there are some papers that presented the results of CM research where the first language was SOV; for example, Turkish (Kilic, 2003), Persian (Mesrabadi, Fathi Azar & Ostovar, 2005), and Korean (Lee, 1999). These researches could be summarized into following categories:

- Using CM in situations where English, or other common SVO languages, is formal educational language (see for example, Kozminsky, Nathan & Vaizberg, 2006; Kharade & Thomas, 2006);
- Using CM for teaching and learning English, or other SVO languages, as the second languages. CM has been used as an effective tool for teaching and learning English as a foreign or second language (see for example, Tumen & Taspinar, 2007; Ojima, 2006; Vakilifard & Armand, 2006; Yamada, 2005);
- Application of CM without considering the distinctive characteristic of CM. In fact, they used other forms of knowledge representative techniques, instead CM. In this case, they did not undertake to connect the concepts by link among them (see for example, Takeya, Yasugi, Funabashi & Nogaoka, 2006; Mesrabadi, Fathi Azar & Ostovar, 2005; Grow-Maienza, Hahn & Joo, 2001).
- Some research investigated how CM could be used in SOV languages (see for example, Kilic, 2003; Lee, 1999).

6 Suggestions for using CM in SOV languages

If the distinguished characteristic of CM is ignored, it will mean CM does not have any priority for representation of knowledge to other techniques. For solving the problem of using CM in SVO, some solutions have been suggested (Kilic, 2003; Lee, 1999). Based on research and practices, a concept map can be developed in SOV languages in one of the following ways (all examples, presented in the figures, are in Persian language):

- Drawing a concept map in the same way as in a SVO language, but its complete and meaningful sentence, in SOV format, is written below the concept map (figure 4).

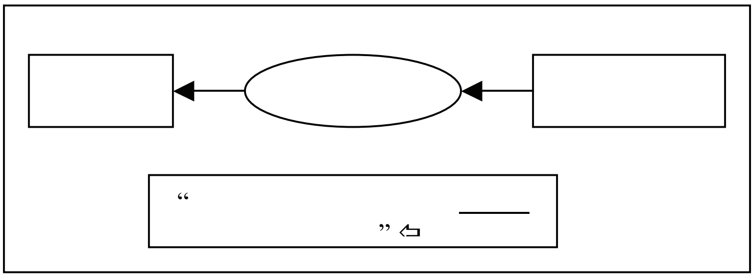

Figure 4. Writing relationships between concepts in a complete and meaningful sentence below the concept map

- Writing the complete and meaningful sentence in the link between two concepts (figure 5).

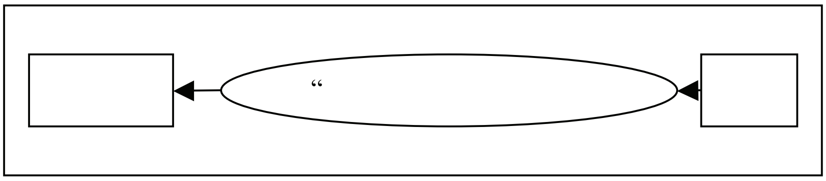

Figure 5. Writing complete and meaningful sentence as a link between nodes

- Writing the link (or verb between two concepts) in the second node, following the object (figure 6). When the concept map is read, it will be the correct and meaningful sentence in SOV language. The apparent form of the concept map is as same as other representative techniques but it will give the convenience of drawing concept map to learners.

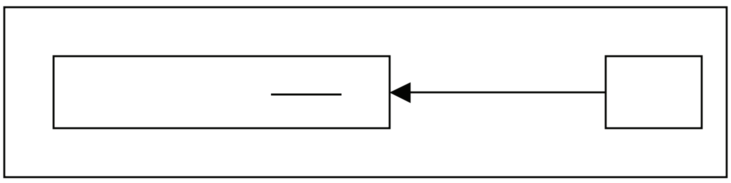

Figure 6. Writing link in the box of the second node

- Another alternative is drawing a concept map in a way which presented in figure 6, but the box of the second node divided by a line, to separate the verb (link) from object.

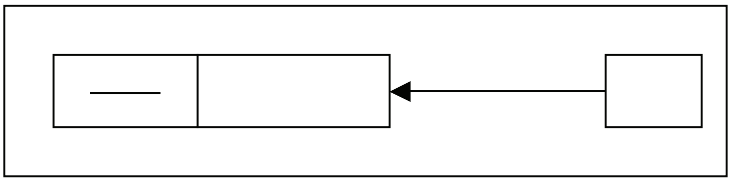

Figure 7. Writing link in the box of the second node separated with a line

- In computer version of CM, using a dialog box in which the proposition presented the SOV language.
- Constructing a concept map in SVO format, but the relationship between the concepts is explained verbally.

7 Summary

Given the way concept maps are currently drawn and constructed, the word order of some languages, that are different with English and other SVO languages, is very difficult to depict in a traditional node-link-node format. When learners in SOV languages construct a concept map, they have to use SVO word order that is different with their first language and makes an incorrect and incomplete sentence. This change can cause confusion and create some problems in learning process. There are some alternative ways to use CM in these languages, but research is needed to investigate which method should be used.

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LONGITUDINAL STUDIES OF COGNITIVE CHANGE AMONG STUDENTS AND THEIR SUPERVISORS IN THE COURSE OF RESEARCH SUPERVISION LEADING TO A PHD

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Abstract. This project uses concept mapping and interview techniques to track changes in knowledge and understanding among students and their supervisors in the course of full-time research towards a PhD. The on-going work measures *both* cognitive change in the specific subjects that are the topic for research *and* in the understanding of the process of PhD level research and supervision. The data makes a unique contribution to our knowledge of research processes and an understanding of the ways in which knowledge is created by research. It also helps to provide documentary evidence of the ways in which supervisors can act to facilitate learning and discovery. In order to ensure that the results are applicable as widely as possible, the study group includes students and supervisors from among the natural and applied sciences, the arts and humanities and clinical practice. The approach is essentially ethnographic and comprises detailed case study analysis rather than any broad inferential comparison.

1 Background and Context

The PhD is a key step in the emergence of academic status. Not only is it a 'gateway qualification' for an academic career, it is also evidence of an ability to make original and innovative contributions to a body of knowledge or technology. It is of considerable economic significance too, both to the individual who invests time and money in the research and to the wider society. Research-led discovery during or after study for a PhD often leads to publication, patent registration and other activities with potential social, economic or technological benefit.

The full economic costs of a PhD are difficult to establish. The costs to institutions are usually estimated at £87,317 for clinical studies, £71,446 in the natural and applied sciences and £52,383 for the arts and humanities (HEFCE, 2005a). These figures are based on the conventional three year completion rates that are expected by the majority of Research Councils. Recent data from HEFCE (2005b), suggests that in reality only 36% of full-time research council students complete on time, and that among those who are part-time and/or self funding, completion rates can be much lower. It is therefore surprising that there is so little published research documenting the pedagogy of the PhD supervision process. Despite considerable policy review in England, Wales and Scotland since 2000 (e.g. HEFCE 2005b, 2001; HEC 2002; HEFCW 2000a,b), Baron and Zeegers (2002) remain largely justified in the observation that most researchers understand research processes through 'osmosis' rather than any comprehensive or research-based understanding of what it means to do research or to supervise research studies. Lovitts (2007) remarks, "through the simple act of having faculty make explicit their implicit standards and expectations…everyone is provided with information they need to move up a notch or two more on the road toward excellence" (p. 50). However, we have very little data on students' understanding of the rules of engagement. In particular, there is a complete absence of data tracking the simultaneous processes of cognitive change among students and supervisors in the course of research leading to a PhD. This is a key omission in the literature on academic supervision and it is indicative of the general neglect for the support and development of research skills (see for example, the Roberts Report, HM Treasury, 2002). Furthermore, even where implementation of the Treasury recommendations has had significant impact on PhD student funding and training entitlement, support for researcher supervisors has improved little (Taylor, 2004).

This project addresses many of these issues and importantly, it attempts to lay the foundations for the subsequent development of a research-led pedagogy for dissertation supervision. To date, only Hetrick and Trafford (1995) and Salmon (1992) provide detailed analysis of the processes involved in PhD supervision. However both neglect to document the process through time and report instead, individual expectations of the supervisory role. The results indicate the importance of supervision as a process, but do more to highlight the need for future research than to explain exactly what this 'process' might entail. One supervisor in the study of Hetrick and Trafford (1995), for example, is quoted as follows:

"…supervision should involve a journey of discovery for both tutor and student."

[supervisor M quoted in Hetrick and Trafford, 1995]

Nevertheless no extant literature provides empirical data for such a journey through time and no studies to date have attempted to do this simultaneously among supervisor and student. As a result any attempt to formulate pedagogy for dissertation supervision lacks an underpinning research base. This is despite Salmon's

(1992) consistent emphasis on the importance of change and the support for change in the course of research. Documenting change in knowledge and understanding among PhD students and their supervisors is key to understanding what the joint processes of research and of supervision entail (Brew, 2003), and it is surprising that this has not yet been done. Perhaps the relative intractability of the learning process is the most compelling explanation for this lack of empirical data. However, recent theoretical and methodological developments in the fields of concept mapping and of higher education pedagogy mean that these issues can be addressed. This is explained below.

2 Theoretical and Methodological Frameworks

For nearly a decade, Kinchin and Hay have been working to develop the concept mapping method for the enhancement of pedagogy in higher education. Their work has utility for both theory generation and subsequent testing; here the methods are explained and then used to create simple models of research and supervision outcomes that are tested in the study.

2.1 Concept Mapping: A Tool for Identifying Knowledge and Understanding

Concept mapping (*sensu* Novak, 1998) is a method of graphic organisation. Its considerable utility stems from its origins within the human constructivist epistemology and it is now widely reported in the literature for use in the sharing of individual knowledge and understanding. The concept mapping work of Novak and others has been used in studies of learning (Kinchin, 2001b); measurement of learning quality (Hay, 2007); assessment (Edmondson, 2000); cognitive typology (Hay & Kinchin, 2006; Kinchin *et al*, 2000); learning style (Hay *et al*, 2005; Kinchin, 2004); and expert identification (Kinchin, 2001a; Novak & Gowin, 1984).

In 2000, Kinchin *et al* published an important modification to the concept mapping method that encouraged a radically different approach to analysis. In particular, this work proposed a qualitative approach to concept map analysis based on gross structural morphology and it proposed a classification of map structures in three categories: spokes, chains and networks (Kinchin *et al*, 2000). These three typologies are shown in Figure 1. Since the publication of this work, this broad classification of map types has proven remarkably robust, and has now been documented among school children and adult learners, health-care professionals, and academic teachers (see Kinchin *et al,* 2000; Hay and Kinchin, 2006; Kinchin & Hay, 2005; Kinchin *et al,* 2005 and Kinchin & Hay, 2007 respectively). Furthermore, it is indicative of varying roles within the learning process at university (Kinchin, Lygo-Baker & Hay, 2008). Concept mapping can therefore be seen as an integrated mixed methodology.

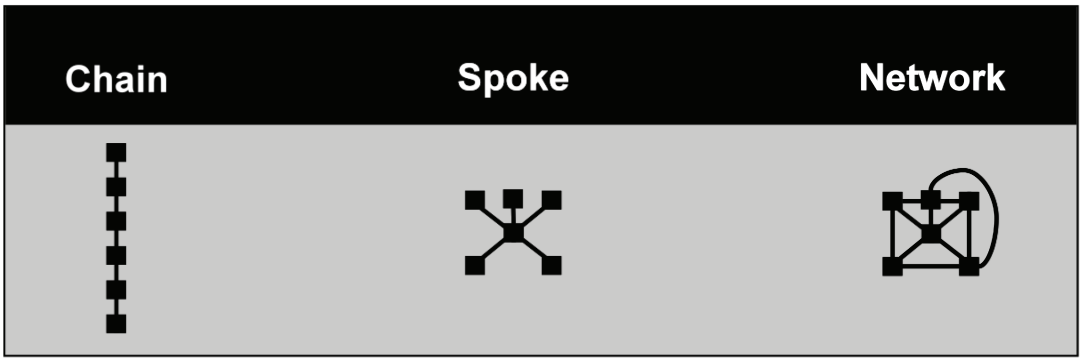

Figure 1. Concept maps comprise three basic structures (after Kinchin *et al*, 2000).

Subsequently, the work of Kinchin *et al* (2000) has had considerable impact on our understanding of 'novice' and 'expert' status (Kinchin, Cabot & Hay, 2008). This is because the three basic knowledge structures (chain, spoke and network) have been shown to be synonymous with rote learning, the emergence of 'learning readiness[1]' and expertise respectively (e.g. Hay & Kinchin, 2006). Furthermore, the spoke, chain and network structures provide a theoretical framework for the measurement of emerging student expertise and the assessment of teaching and learning.

[1] The term 'learning readiness' was used by Hay & Kinchin (2006) to describe individuals who used their tentative and emerging understanding to produce spoke like concept maps that were indicative of their first steps towards individual meaning making (rather than the repetition of the knowledge given from other sources).

2.2. Using Concept Mapping in the Development of Teaching Practice

Recent models of teaching and learning for higher education have emphasised the emergence of 'expert status' as the authentic goal of university teaching (Biggs, 2003; Kinchin, Cabot & Hay, 2008; Kinchin & Hay, 2007; Prosser & Trigwell, 1999). In particular, the work of Kinchin and Hay (2007) suggests how rote and meaningful learning outcomes are alternative and competing endpoints in conventional university level teaching.

In this approach, the two alternative outcomes of learning (meaning-making and rote learning) are characterised by alternative conceptual structures that can be discriminated through concept mapping. Rote learning outcomes will be represented as simple linear chains identical (or very similar) to the linear narratives used by the teacher to describe the topic. Meaningful learning, however, will be characterised by the radical restructure and organisation of concepts, first to form simple spokes structures ('learning readiness'), and later to make 'expert networks'. In the model of Kinchin and Hay (2007), the term 'transformative learning cycle' is used to describe the process of interaction by which students and teachers share and interrogate each others knowledge structures so that new meaning can emerge. Using this approach, Kinchin and Hay (2007) argue that the teacher – student distinction becomes blurred in ways that are legitimate and indeed increasingly appropriate as the student progresses through higher education.

2.3. Measuring the Quality of Cognitive Change through Concept Mapping

One of the most useful applications of the concept mapping method is for the measurement of quality in student learning outcomes. Hay (2007), for example, has developed the technique to be able to differentiate deep, surface and non-learning outcomes in ways that are reducible to empirical measurement. Briefly, Hay (2007) used definitions of learning *versus* non learning (Jarvis, 1992, 1998), deep *versus* surface learning (Entwistle *et al*, 1991, 2001; Entwistle and Tait, 1994; Marton & Säljö, 1976, 1984) and meaningful *versus* rote learning (Novak, 1998), to systematically differentiate conceptual change before and after learning. The work provided the first empirical demonstration that these terms for learning style are more than loosely coined terms and are, in fact, measurable outcomes. This then provides a framework for tracking learning through time (see below) and is an important methodology if subsequent research is to measure the now tangible processes of cognitive change through learning and discovery.

2.4. Using Concept Mapping to Track Cognitive Change in Time

The work of Hay (2007) illustrates the power that concept mapping has to reveal the changes in individual knowledge and understanding that might occur through time. Despite this, however, reports of long term studies to reveal cognitive change are conspicuous, only by their absence. There is now a well developed literature on change in the course of learning. The arguments of Meyer and Land for example, are now widely cited in the literature on higher education teaching and learning (e.g. Meyer and Land, 2003). This work suggests that learning proceeds through a series of 'watersheds' in which failure to grasp 'troublesome concepts' arrests further change, but that once attained, these 'thresholds' represent new vistas for knowledge and understanding. However, such a theory, intuitive though it is, should be subject to empirical measurement before it is widely accepted. Concept mapping, in the way it is described here, affords just such an opportunity. Furthermore, to obtain such data in the course of PhD level research and supervision is the most parsimonious environment in which to carry out such testing. Nowhere in higher education teaching and learning is the importance of 'threshold concepts' likely to rival that encountered in the course of research-based learning. Here, meaningful contributions to the body of knowledge can be made only when new thresholds are broached in order to provide new insights and new ways of understanding existing knowledge. How this can happen at an individual level and in the course of supervision is essential to understanding how research is done and how it can be developed and sustained among emerging researchers by supervision.

It is important for this research that the data illustrate particular cases of cognitive change and show patterns of incremental change as distinct from threshold concept acquisition. Furthermore, the simultaneous assessment of students and supervisors is important for understanding how the cognitive changes of one might affect the other and *visa versa*. What for example are the consequences of new discovery by the student researcher on the extant knowledge structures of the researcher? Do these constitute new thoughts and new ways of seeing things for both parties? Furthermore, will the active demonstration of change (or the lack of it) through concept mapping impede or enhance the rate of cognitive alignment towards new understandings of the field of research and possible of the research/supervision process itself? These are important issues that are able to be addressed through the teaching of conceptual change using concept mapping in the course of research.

2.5. Using Concept Mapping to Describe Processes of Supervision and Learning

There are four valid distinctions between student – supervisor knowledge structures before and after research (see Figure 2). For two, comprising a shared start state, the end point may also be common to both the student and the supervisor (A: concurrent change), or the research may be interpreted differently by either party (B: divergent change). Alternatively, and from different start states, the outcome of research may be consensus (convergent change) or a persistent difference in knowledge and understanding (D: contrastive change).

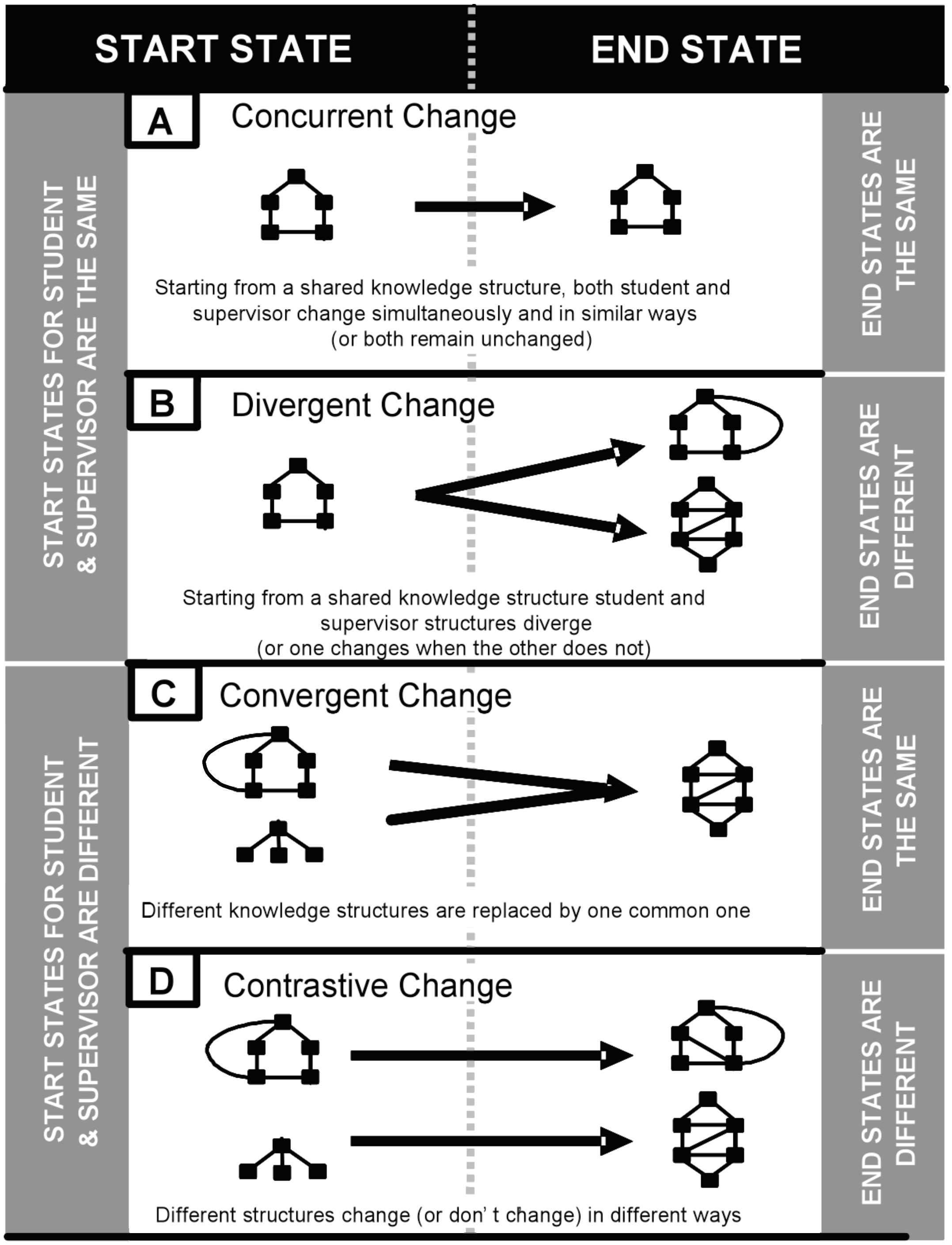

Figure 2. A theoretical framework for assessing conceptual change among student and their supervisors in the course of research

3 Methods

This differs from other investigations of PhD supervision which have focused on 'satisfaction ratings'; 'power issues'; 'completion rates' or 'closeness of supervisor-student relationships', rather we are looking at possible trajectories of mutual conceptual development within the supervisory process, exhibited by students and supervisors up to the production of the thesis. This reflects Wright and Lodwick's (1989) view that for the great majority of students, 'the academic aspects of supervision would take precedence'. In addition, this work follows students through the entire course of study in contrast to most studies that have taken a snap-shot at one point in the supervision process (e.g. Wright and Lodwick, 1989).

An in-depth picture of the patterns that are evident in the ways PhD students and their supervisors work together over time increases our current understanding of PhD supervision and so helps in the design of materials to help novice supervisors to prepare for the process. Cullen *et al.,* (1994) concluded that "programs for staff and students to improve practice can and should be designed to contextualise the generic processes of supervision with attention to disciplinary and usual human variation" (p. 109).

The identification of possible trajectories of mutual conceptual development requires a research design that enables the lived experience of the supervisory process to be explored over time. The method chosen also needs to be congruent with our epistemological position, which relates to the legitimacy of generating data about how PhD students and their supervisors work together by talking interactively with them. The approach most suited to this position is qualitative, utilising what Charmaz (2001) calls "multiple sequential interviews" (p. 682); this type of interviewing "charts a person's path through a process" and creates the opportunity for a "nuanced understanding of that process".

Interviews are conducted with students and supervisors separately so that the research does not interfere with supervision. In-depth, semi-structured interviews are done with the students at four-monthly intervals utilising a grounded theory approach. Interview transcripts are translated into concept map summaries that provide structure for the data: facilitating analysis within cases and across cases. This also helps to identify a route through the developing narrative. Data collection and analysis occur at each stage, and enable each interview to draw upon the experiences of the participants to inform theory generation relating to changes in content and processes over time. Key to the design is the first interview, as the snapshots generated from it are used to inform the subsequent data collection. The interview guide for the first interview explores two complementary lines of enquiry (themes):

1. Topic – looking at the academic area under investigation within the PhD.
2. Process – looking at the conceptions held of the research process and of the PhD as an entity.

Questioning during student and supervisor interviews takes the form of three interconnected phases for each of the two themes. These three phases reflect the three phases of questioning identified by Pedrosa de Jesus *et al.* (2006) as 1) acquisition, 2) specialization and 3) integration. These in turn facilitate the co-construction of concept maps (by interviewee supported by interviewer) by building upon spokes, elaborating chains and finally integrating these as networks. This was guided by careful use of relational language (*sensu* Loewenstein and Gentner, 2005), during the interview to encourage the interviewee to make links explicit.

4 Results

Limited data is available at this point. However, the initial rounds of interviews show promise for this project. Below are concept maps created by a student and supervisor pair in response to the question, "What is a PhD?" The left side of the supervisor map (see Figure 3) indicates a group of skills and the right side details a linear path to becoming an independent scientist. In contrast, the student map (see Figure 4) breaks the PhD into work and study and focuses on learning as a route to publishing. The bottom of the student map indicates a variety of characteristics necessary for publishing. Overall the supervisor map concentrates on acts of doing and being, whereas the student map focuses on learning and acquiring traits and characteristics.

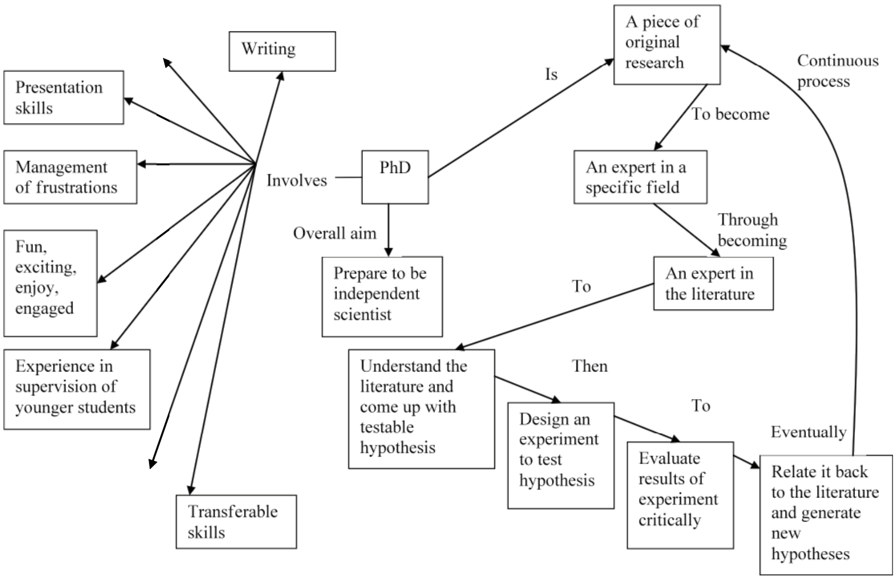

Figure 3. Supervisor map of what a PhD is.

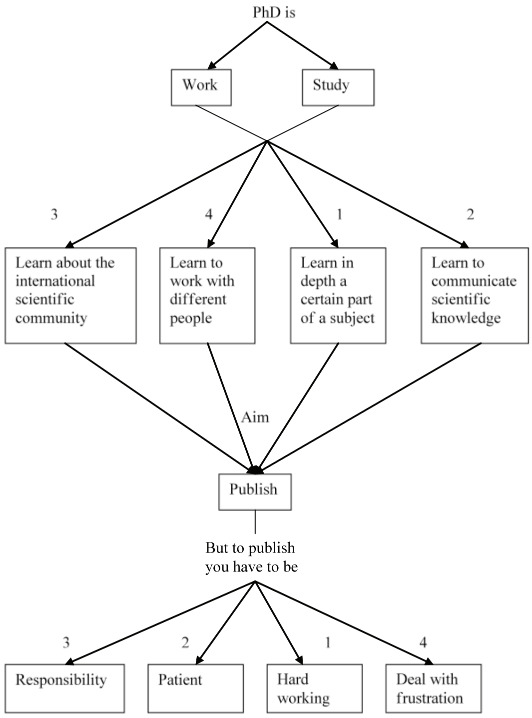

Figure 4. Student map of what a PhD is.

The maps also diverge in the emphasis of the output of the PhD. The supervisor's map details the scientific process of discovery (through hypothesis testing). The student's map centres on publishing, the eventual outcome, but does not indicate the exact path to get there. It will be interesting to see how the two maps shift and change over time. One possibility is the student may move to a more active view of the PhD that matches the supervisor, and the supervisor may move towards a learning-centred model, which would be an example of convergent change noted in Figure 2.

5 Summary

This on-going research project uses concept mapping to explore cognitive change in the PhD supervision process over time. The final results of this study will allow for tracking changes of the understanding of the content and process of the PhD from both the student and supervisor's perspectives. Concept mapping allows for visually tracking these changes over time, and may also be a tool for supervisors and students to use as a way to monitor and track the PhD process. Furthermore, this unique approach to assessing PhD supervision may allow for analysis of the role of 'expert' and 'novice' status in cognitive change. This research has potential benefits for PhD supervision broadly, as well as the continued development and use of concept mapping in education research.

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MAPPING CANTOR'S DUST: MATHEMATICAL UNDERSTANDING OF NURSING STUDENTS

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Abstract. Nursing education literature documents the extent to which student nurses fail to correctly use mathematics to accurately complete such tasks as unit conversions, dosage calculations, and fluid monitoring. Guided by "The Maths for Nurses" taxonomy established by Pirie (1987), a five part protocol was developed and used as the basis for semi-structured clinical interviews with 24 student nurses. Concept maps were used in analyzing the results. These revealed the nature of the conceptual knowledge of the student nurses which, for a significant number, was sufficiently fragmented to merit the designation "Cantor's Dust" (Gleick, 1987). In the absence of meaningful relational connections and integrated cross linkages, the student nurses failed to correctly apply mathematics to nursing in a wide variety of clinical contexts.

1 Introduction

Student nursing programs have been reporting significant mathematical deficiencies among their populations for nearly four decades. Despite various intervention approaches the problem lingers and otherwise excellent candidates for the nursing profession are eliminated for this lack of mathematical competency. The mathematics employed by nurses using the international metric/SI system of weights and measures in medicine is not complicated. Nursing tasks such as unit conversions, dosage calculations, and fluid monitoring each depend on the set up and simplification of expressions that involve notions of ratio and proportion and a good understanding of rational numbers expressed in both fractional and decimal forms. Substantive understanding of these concepts render such calculations routine. Yet, in a 1979 Michigan case study of nursing errors in drug administration, Brown reported that wrong dose and rate of infusion mistakes accounted for 33% of the reported errors and were likely the result of mathematical miscalculation (cited in Pirie, 1987, p.14). The severity of miscalculation is evident in the simulation study published in the *American Journal of the Diseases of Children* the same year. Perlstein et al., whose study involved the staff of a neonatal intensive care unit working with simulated physician's orders, reported that "56% of the errors tabulated would have resulted in administered doses ten times greater or less than the ordered dose" (cited in Pirie, 1987, p.145.) Recent studies indicate that the problem persists. Gillham and Chu (1995) found that only 55% of 158 second year nursing students in their study correctly answered ten questions of common clinical calculations. Lesar (2003) studied and classified 200 tenfold errors in medication dosing that occurred in an 18 month period at a 631-bed teaching hospital, citing such errors as a misplaced decimal point, adding an extra zero, or omitting a necessary zero.

2 Evaluating Student Nurses' Meaningful Understanding of Mathematics

2.1 Conceptual Perspective

Pirie (1987) established a comprehensive taxonomy of mathematical skills required in nursing. Considerable research of student nurses' mathematical deficiencies has been focused on their ability to correctly perform these standard arithmetic operations and apply them to nursing. However, nursing education research has yet to adequately consider the problem from a *conceptual* perspective. The study reported here focused on the nature of the conceptual knowledge student nurses possess regarding the mathematics necessary for nursing. A representative sample of twenty-four student nurses engaged in clinical interviews on a five-part protocol ranging from basic mathematical understandings foundational for clinical practice to actual clinical applications. Those who had learned basic mathematical procedures as rote processes did not have the integrated, relational knowledge necessary for correct and reliable application of mathematics to nursing science.

2.2 Theoretical Framework

If student nurses understand mathematics as a conceptual system, their thinking will indicate a hierarchical structure of ideas with specific ideas subsumed by more inclusive mathematical thought. There will be evidence of ample relational linkages between concepts sufficient to allow for flexible reasoning in problem solving situations. Integrated thinking will be possible across the full scope of mathematical ideas salient to nursing practice.

Ausubel's (1968) discussion of the difference in cognitive effect of meaningful learning in comparison to rote learning is important to consider in attempts to clinically identify the quality of conceptual understanding a study participant may reveal. As a consequence of meaningful learning, a student will have the "availability of relevant and proximately inclusive subsumers that provide clarity, discriminability, cohesiveness, and integration of thought" (p. 136). Ausubel posits that, as meaningful understanding develops, each new concept gets "anchored" into the existing cognitive structure and the processes of *progressive differentiated* and *integrative reconciliation* "make possible the acquisition of abstract ideas in the absence of concrete empirical experience " (p. 507). This is not the case in rote learning where recall is of primary importance and constitutes the only learning goal. In order to further the memorizability of new information, the consequence of rote learning is the establishment of "arbitrary associative bonds between discrete, verbatim elements, isolated in an organizational sense from established ideational systems …." (p 109). In Ausubel's view, rote learning actually "resists progressive assimilation" while meaningful learning seeks "appropriate relational anchorage within a relevant ideational system" that involves those features that concept maps are designed to reveal. Skemp (1976) has described this difference in his work in mathematics education, referring to the result of rote learning as "rules without reasons" and the result of meaningful learning as "relational understanding." Therefore, a comprehensive, well developed conceptual schema is one in which mathematical knowledge is relationally linked in multiple ways

2.3 Betweenness as an Indicator of Meaningful Conceptual Connection

Ausubel (1968) discusses the difficulty of demonstrating that meaningful learning has occurred and makes suggestions on how best to proceed in a clinical setting:

> If one attempts to test for such knowledge by asking students to state the critical attributes of a concept or essential elements of a proposition, one may merely tap rotely memorized verbalizations. At the very least, therefore, tests of comprehension must be phrased in a different language and must be presented in a somewhat different context than the originally encountered learning material. (Ausubel, 1968, p.110).

Ausubel was concerned that direct efforts to evaluate meaningful learning might be compromised by students' extensive test taking experience and their adeptness at memorizing key ideas and formulas. To avoid the substitution of rote memory for meaningful comprehension, Ausubel advises "posing problems that are both novel and unfamiliar in form and require maximal transformation of existing knowledge" (1968, p.111). This advice was applied to the creation of nine problems which required the identification of a decimal whose value lies between two given numbers. The pairs of numbers given were: 1/4 and 3/4, 3/4 and 7/8, 1/2 and .51, 1.715 and 1.716, 3/10 and 1/3, 1/9 and 2/9, 75% and 75/60, one billion and one billion one, and two millionths and five millionths. Safety in estimating, accuracy in calculating, and error free administration of medications depend on the mindful application of the processes of converting fractions to decimals, decimals to fractions, and the meaning of decimal place. Consequently, the analysis of "think-aloud" responses provided the first basis of evaluation of students' conceptual understanding of the mathematics of nursing.

The "betweenness" problems were designed to evoke the mathematical thinking of student nurses at a conceptual level, revealing meaningful connections. The unusual question format differed from typical mathematical problems presented to students. The design intentionally makes problems more difficult for students with isolated procedural knowledge and favors those with connected relational knowledge. In finding decimal values between the pairs of numbers, a student who recognized the relationships between several mathematical ideas was more successful. These students reasoned their way to a correct answer based on the interconnectedness of their understanding. The rational numbers presented in various forms (i.e. fractions, decimals, percents) encouraged students to reveal meaningful associations. The intent was to avoid questioning that directed a respondent to perform a particular arithmetic skill. By incorporating the need for fraction, decimal, and percent conversions within the task of locating a rational number between two others, participants were required both to select their own method (rather than be directed by the question itself), and to reason mathematically across the various rational representations.

Given adequate conceptual understanding of mathematics, correct answers to the nine problems in section 1 can be found quickly and easily. Student thinking that revealed a connected conceptual system of mathematical thought, generated correct answers through quick, mental reasoning. Conceptual discontinuity was associated with complicated methods that involved a struggle to find a valid answer. When a student's conceptual understanding consisted of segmented knowledge, correctness was often compromised and calculator dependency was evident. Results showed that only 38% of the answers provided by nursing students had the combined qualities of being mentally determined, and done quickly and correctly.

3 Conceptual Analysis through Concept Mapping

3.1 Conceptual Essence of Betweenness

Two mathematical ideas figure prominently in the betweenness thinking requested of the student nurses, the density of the real number line and the ordering relation. "Greater than" and "less than" comparisons are required in order to determine if a value in question is between two distinct real numbers (i.e. x is between a and b iff $x>a$ and $x<b$, where $a<b$). Comparision necessarily includes an understanding of the decimal system as positional. Knowledge of the nature of each decimal position provides the relational crosslink that enables fraction to decimal and decimal to fraction conversions. Adeptness with conversion algorithms alone are insufficient for the nine betweenness problems. The task requires conceptual connectedness

3.2 Deficiencies in Conceptual Connectedness

Study participants had difficulty considering what value might exist between 0.50 and 0.51, 1.715 and 1.716. Students remarked that there are no numbers between these pairs or determined only a finite number of decimal values. The fractional pairs 6/8 and 7/8, 1/9 and 2/9 gave evidence of the same confusion. The subsuming concept is fraction. The task is essentially locating the numbers 1/9, 2/9, 1/4, 3/10, 1/3, 1/2, 51/100, 3/4, 7/8, 75/60, 1715/1000, 1716/1000 on the number line (in this order) and then finding other values in various intervals of these locations. Decimals are particular instances of fractions (i.e. those fractions whose denominators are powers of ten). Converting to equivalent decimals 0.111... , 0.222... , 0.25, 0.3, 0.333... , 0.5, 0.51, 0.75, 0.875, 1.25, 1.715, 1.716 can provide a common basis for comparision. However, the relational understanding that makes knowledge of numbers meaningful for some students was insufficient to support acceptance of the density of the real numbers on the number line. The discontinuity in students' conceptual structure, was reflected in their view of the real numbers, which themselves were seen as discontinuous. The following student remarks are characteristic of the difficulties that arose when there were no meaningful connections between mathematical concepts.

Problem 2 : 3/4 and 7/8.
[Having changed 3/4 to 6/8 Lucy can not find a fraction between 6/8 and 7/8.]
Lucy: So I would have to do between six things and seven things. [silence] I'm trying to do it with fractions but I don't know how to. [laughs]

Problem 3 : 1/2 and 0.51.
[Rickie fails to find a decimal value between 1/2 and 0.51 after three tries]
Rickie: In between these is zero point five, zero point three one, zero point [pause] forty two. Forty two.

Problem 4 : 1.715 and 1.716.
[Nel does not understand the completeness of the real number line.]

Interviewer: How many numbers are between 1.715 and 1.716?
Nel: Just one.
Interviewer: How about between 1/4 and 3/4?
Nel : About ten.

Problem 5 : 3/10 and 1/3.
[Katelyn makes incorrect connections between fractions and the decimal system]
Student : 3/10 would be like [pauses], almost 1/3. So I would go between, well 1/3 is 0.3333 . So I would put 0.3334 [laughs] and just bring it out."

Problem 6 : 1/9 and 2/9.
[Mandy does not understand the completeness of the real number line.]
Interviewer: How many numbers are between 0.1111... and 0.2222... ?
Mandy: Do you want me to count them?
Interviewer: Answer any way you want to.
Mandy: There are 10. Is that right? 10 one hundredths [voice fades off to silence] on the other side of the decimal.

3.3 Problem 2: Write a decimal number whose value is between 3/4 and 7/8.

The analysis of problem 2 presented here is representative of the analysis carried out on each of the betweenness problems. Problem 2 generated considerable insight into the mathematical understandings of the student nurses. Answers were the result of 18 different solution paths and 11 of the 24 responses required the use of a calculator. Despite access to a calculator there were 5 incorrect responses recorded for an error rate of 21%. Analysis through concept mapping revealed the requisite understandings involved in problem 2 and the nature of students' meaningful understanding of the required concepts (Figure 1).

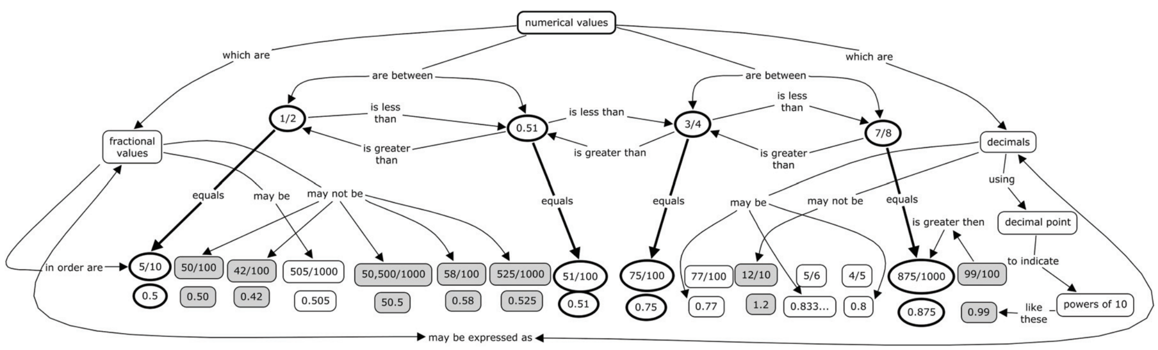


Figure 1. Concept map related to Problems 2 and 3: Write a decimal number whose value is between 3/4 and 7/8, and one between 1/2 and 0.51, respectively. Incorrect student values are shaded.

Deficiencies in conceptual connectedness were marked by an insufficient knowledge of decimal place, awkward numerical work-arounds, and invalid, unsupported mathematical reasoning. The conceptual deficiency was compounded by a limited command of number facts and an associated dependency on calculator support. Expressed insecurity about answers and methods was frequent. Alternative methods of checking for errors or resolving confusion were seldom recognized. Ignoring digits and decimal points further compromised meaningful conceptual connection. The decimal values displayed in order in figure 1 represent specific points on the number line that are relevant to the mathematical reasoning student nurses used in determining a decimal value between 3/4 and 7/8, and between 1/2 and 0.51. Students with meaningful knowledge of the number system required no calculation. A few simple number comparisons were sufficient. Students who did not understand numbers as a part of a relationally connected conceptual system struggled. A typical approach was to convert 3/4 to 6/8 and then try to locate a value "half way" between 6/8 and 7/8. Frequently hesitating at this point, expressions like 6.5/8 (i.e. 13/16) were identified and converted to their decimal equivalence by a division, done on paper or using the calculator. One student, Rickie, thought 5/6 was "half way" because 5 is midway between the original numerators 3 and 7 and 6 is midway between the denominators 4 and 8. 5/6 is between 3/4 and 7/8, but not the midpoint.

The work of Somer, Patricia, Rickie, and Myra further illustrate the mathematical reasoning of student nurses with respect to decimals and fractions. Somer's work on problem 2 was quick, confident, and done mentally. She knew 3/4 to be 0.75, determined 7/8 to one decimal place by a partial division, and chose 0.77 as an answer, confirming on the basis of her knowledge that "7/8 is greater than point eight." Patricia followed the same line of reasoning with somewhat less precision. She too knew the decimal equivalent of 3/4 but her estimate of 7/8 to be 0.99 left open the possibility of error since numbers in the interval [0.875..0.99) would not correctly answer the problem. Patricia correctly chose 0.8 as a value between 3/4 and 7/8, but her method was risky. "It just jumped out at me," was Rickie's explanation. It appeared that she chose a numerator between 3 and 7, and a denominator between 4 and 8, and constructed the fraction 5/6 which is in fact between 3/4 and 7/8. The use of the calculator (Rickie admits to being calculator dependent) provides post facto confirmation that 5/6 as a correct answer but only by chance. It can be shown mathematically that only proportional selections of numerators and denominators will produce numbers between 3/4 and 7/8; other selections do not. Like Patricia's poor estimation of the decimal equivalent of 7/8, Rickie's reasoning is risky, and disconnected from meaningful understanding of the number system.

Myra's response to this problem was incorrect. Myra's work in general was marked by precise knowledge of calculation procedures. Unlike Rickie's dependency, Myra avoided calculator use, preferring to work out problems using paper and pencil. Her careful, clearly legible work on this problem showed that there was no weakness in her ability to calculate, but her answer of 1.2 is unreasonable since neither 3/4 nor 7/8 is greater than 1. Myra converted 3/4 to 6/8 and correctly determined that (6.5)/8 is a value between 6/8 and 7/8. In expressing her answer as a decimal, she reversed the order of the division, dividing 6.5 into 8 rather than 8 into 6.5. Myra's well conditioned arithmetic skill is an example of the effectiveness of rote learning to provide "instrumental understanding" (Skemp, 1976) while missing the relational connection that would have avoided error, the fact that the answer must be less than 1. Analysis of student responses to problem 3 reflected inadequacies similar to those encountered in problem 2 (see figure 1).

3.4 Additional Commentary on Betweenness Problems

Students' lack of knowledge of the decimal equivalence of the ninths (1/9 = 0.1111… , 2/9= 0.2222… , see figure 2) eliminated locating 7/9 as a value between 3/4 and 7/8. Furthermore, some students do not differentiate between the finite decimal 0.77 and the repeating decimal 0.7777… , which would mean that 77/100 = 7/9, which is not true. Recalling Ausubel's notion of progressive differentiation as a quality of conceptual understanding, it is clear that student nurses who do not see the distinction between different rational numbers will have difficulty applying mathematical reasoning that depends on relational understanding. Estimating 7/8 as 0.99 reflects the potential for error in locating a numerical value in a required interval of a number line. This is the essence of what student nurses must do when they are using scaled nursing equipment or rescaling a prescription dosage to a different unit of measure. Numerical knowledge must be integrated in such a way as to make meaningful sense of measurement. For students who understand the real numbers as a conceptual system, knowledge that 5/7 is not between 3/4 and 7/8, and that 7/9 is, should be easy to determine.

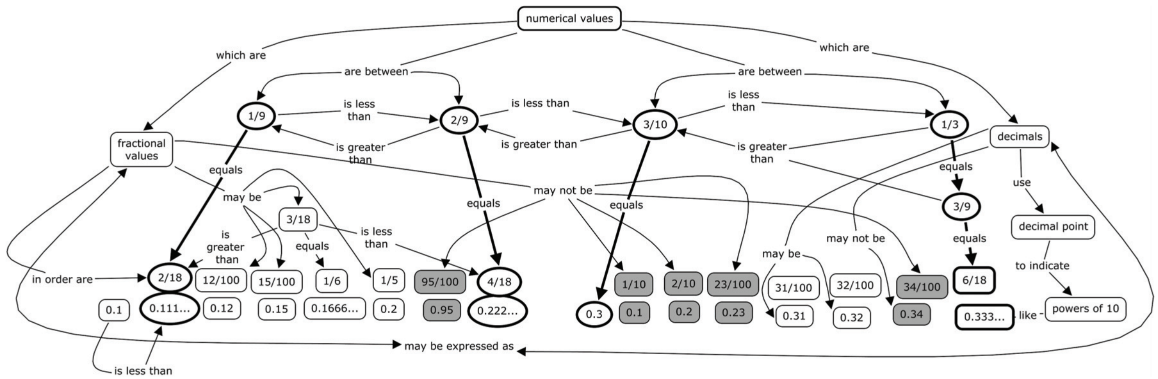


Figure 2. Concept map related to Problems 5 and 6: Write a decimal number whose value is between 3/10 and 1/3, and one between 1/9 and 2/9, respectively. Incorrect student values are shaded.

Only 9 students correctly identified a decimal value between two millionths and five millionths. The other 15 students had no meaningful understanding of decimal positions beyond thousandths. Student values ranged through three orders of magnitude beyond the endpoints of the interval (between 0.3 and 300 millionths for an interval with endpoints 2 millionths and 5 millionths. See figure 3).

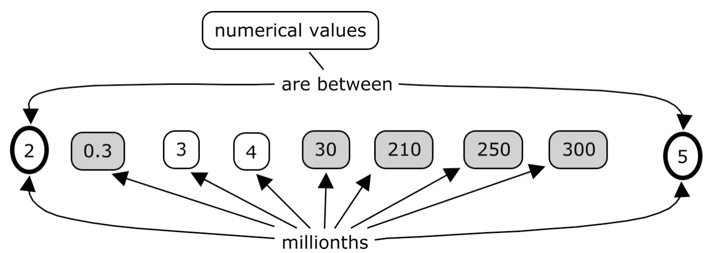


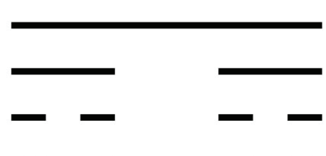
Figure 3. Concept map rescaled in millionths, related to Problem 9: Write a decimal number whose value is between two millionths and five millionths. Incorrect student values are shaded.

4 Findings

4.1 Cantor's Dust

Cantor's Dust refers to the mathematical construction that emerged from the set theory work of nineteenth-century mathematician Georg Cantor. The Cantor Set is constructed by removing the middle third of a line segment, followed by repeated iterations on each resulting segment, ad infinitum. Smaller and smaller line segments remain after each removal with the result that while infinitely many line segments remain, what began as a segment becomes everywhere discontinuous. In short, the clusters of remaining points appear like dust. (See below).

> To make a Cantor Set you start with the interval of numbers from zero to one, represented by a line segment. Then you remove the middle third. That leaves two line segments, and you remove the middle third of each (from one-ninth to two-ninths and from seven-ninths to eight-ninths). That leaves four segments, and you remove the middle third of each, and so on to infinity. What remains? A strange "dust" of points, arranged in clusters, infinitely many yet infinitely sparse.
> (Gleick, 1987, p. 92)



4.2 Findings of Conceptual Disconnection

The nature of a significant number of the student nurses' conceptual understanding of mathematics resembled Cantor's Dust, fractalized and discontinuous. In its most severe form of discontinuity, meaningful conceptual relationships between fractions, decimals, percents, and proportional procedures, either did not exist, were incorrect, or were inadequately developed. In the absence of meaningful conceptual connection, student nurses relied on isolated knowledge of arithmetic methods, formulaic approaches, and the assumed infallibility of calculating devices. Accurate and reliable numerical calculation, precise use of medical equipment, correct interpretation of graphical information, and success at applied problem solving proved difficult. In short, these students were unable to work with the metrics of nursing confidently and without serious error. The lack of density of known values along the number line, the disjoint nature of conceptual connection, and lack of relational integration is indicative of the findings of conceptual disconnection among student nurses.

4.3 Nursing Consequences of Conceptual Disconnection

Students' lack of meaningful understanding of the infinity of numbers between any two values and their failure to associate fractional meaning to decimal positions translates to an understanding of the real number line as segmented, discontinuous, and locally finite. Nursing consequences of this conceptual disconnection were associated with students' limited knowledge relating fractions, decimals, and percents to problems in dosage calculations, use of nursing equipment, interpretation of graphs, and initial IV set up and subsequent fluid monitoring. Students' missing sense of scale, inability to make reasonable estimations, and over-reliance on cumbersome procedures enabled by the calculator, were manifestations of the conceptual disconnection that existed for them. These deficiencies resulted in students incorrectly converting 83.4 grams to 0.834 milligrams, the consequence of "moving" the decimal point in the wrong direction and the wrong number of places. Lack of meaningfully connected knowledge negatively affected efficiency and accuracy in students' work with measurements. Converting 1 pint, 0.9 fluid ounces to liters can be done by inspection by recognizing the irrelevance of the 0.9 ounces (7/1000 of a liter). Knowing one pint is approximately 0.5 liters quickly completes the problem. Yet 26% of student answers were incorrect. In one dosage calculation, a student used the calculator to support a trial and error search for a calculation that resulted in a whole number in order to avoid decimals. Students exhibited the tendency to convert metric units down the scale for the same reason.

The need for meaningful understanding of the number system is especially important in the administration of pediatric medication. Children require considerably lower dosages of important drugs and injections are sometimes measured in a small tuberculin syringe which is calibrated in hundredths of a milliliter. An accurate, reasonable dosage calculation is crucial. Pickar (1996, p. 129) in illustrating the calculation involved in a pediatric order of 0.15 mg atropine sulfate supplied in a solution of 0.4 mg per mL advises student nurses to "Be careful with the decimals. Don't be fooled into thinking 0.15 is more than 0.4." Using the nursing formula D/H x Q (the desired dose over what you have available times the volume it's in) generates the expression 0.15/0.4 x 1mL. A misstep here, of dividing the decimals on the calculator in the wrong order would indicate a truncated volume of 2.7mL be injected instead of 0.375 mL. The small 0.5 mL tuberculin syringe can not accommodate this volume, but if a nurse selects a 3-cc syringe the patient will receive 7 times the intended amount. If the 2.7 mL is misinterpreted to be 0.27 mL the tuberculin syringe can be used, but the patient would receive only 72% of the dosage prescribed. Myra and Rickie (refer to section 3.3 above) made these types of errors. Myra reversed the order of the division in calculating 6.5/8. Rickie, who depends on the calculator for all of her calculations, misread 0.6 for 0.06 on a 1-cc syringe and consequently, would have administered ten times the correct dose.

Interpreting graphical information and correctly setting up an IV drip rate are difficult tasks for students who have learned mathematics as a disconnected set of procedures. Student nurses were able to solve proportional equations without significant difficulty. In a related nursing task, however, deficient conceptual connection resulted in student failure to accurately identify a patient's pulse rate from a 6 second EKG run. They were given a 15 cm strip, scaled at 0.2 seconds per 5 mm. Students with meaningful understanding used proportionality by inspection to determine that 10 beats were displayed in 6 seconds, a pulse rate of 100 BPM. Students without adequate relational understanding did not correctly determine this rate after considerable proportional calculation. The error rate was 24% for this problem. Calculation was not the problem for students who attempted the IV drip rate problems they were presented. However, proportional reasoning beyond the calculation was problematic. The importance of relational knowledge was apparent in the appropriateness of student reasoning. Using a 15 gtt/mL (drops per milliliter) infusion set to infuse 1000 mL over 5 hours, students recorded the calculator generated value of 0.8333… drops per second. This value is arithmetically correct but is neither meaningful nor practical. To set up the IV flow by counting 0.833… drops in one second would be impossible, since the rate must be set by looking at a watch while simultaneously counting the number of drops released, and then adjusting the flow so that over a specific time interval the exact number of drops necessary to fulfill the condition of infusing 1000 mL over 5 hours will be released. In this case an appropriate setting would be 5 drops per 6 second interval. Clearly, the conceptual disconnection that results from learning mathematics as a series of rote methods has serious negative consequences in attempts to apply mathematics to nursing.

5 Summary

The study revealed that nursing students who have learned mathematics as a series of discrete rote methods struggle with basic mathematical reasoning. That struggle is propagated with ever increasing negative consequences as these students encounter the need for conceptual connection in each new context they encounter, contexts of increasing difficulty and more directly reflective of nursing problems. The same conceptual disconnection that was evident in the responses to the betweenness questions negatively affected student thinking about rational numbers and scale in each of the other sections of the protocol. Students who had difficulty with basic mathematics used unnecessarily awkward and cumbersome approaches to otherwise simple problems. The lack of relational understanding between multiple concepts inhibited flexible thought and resulted in errors in clinical problems central to nursing practice.

Students who had a meaningful understanding of mathematics gave evidence of connected knowledge. This knowledge enabled successful use of estimation to confirm calculated values. Such students were not dependent on the calculator and made effective use of numerical information in a variety of ways. Because their understanding consisted of a well developed system of conceptual connections, they could correctly interpret graphs and tables and were resourceful in solving problems in applied nursing. For these students, the completeness, correctness, and connectedness of their conceptual understanding allowed for flexibility in their mathematical thinking and confirmation of their results.

Acknowledgements

Special thanks to the 24 student nurses who agreed to participate in this study. Their willingness to share their mathematical thinking in the hopes that this research might further efforts to improve the health care provided by professional nurses is commendable and most appreciated.

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MAPPING KNOWLEDGE FOR INQUIRY-BASED RESEARCH PROJECTS

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Abstract. This paper describes four techniques of mapping knowledge through concept maps for developing inquiry-based research projects. This qualitative study based on participatory action research focuses on identifying benefits and difficulties of research students in applying these techniques in their academic investigations. The background for this work is based on collaborative learning environments (CLE) for engaging students in learning mapping techniques and software tools together, and sharing ways in which they can apply knowledge mapping to elaborate their inquiry-based projects. Quantitative data is also presented to describe the fieldwork: an online course, which was organized by the author. The participants were lecturers and research students from different countries: Brazil, United Kingdom and Portugal. This research group is now interacting in the CoLearn community in the OpenLearn project. Findings based on qualitative analysis of their research maps, discussion forum and learning diaries show some benefits and challenges of using concept maps for developing research projects.

1 Introduction

The innovative use of technology has been promoting the free access to knowledge networks, communities of practice and social learning. New pedagogic approaches, based on the uses of technology to develop thinking skills and collaborative learning, are opening up new opportunities in online education. However the simple access to information does not necessarily mean acquisition of knowledge. "*In order to develop understanding, students need to be engaged in higher order thinking which operates beyond mere exposure to factual or conceptual information. Understanding means going beyond the information given to make inferences, connections and explanations*" (Okada et al, 2008:8).

The aim of this paper is to present the usage patterns of knowledge mapping in academic research for developing inquiry based research projects. This work describes a collaborative learning environment (CLE) that was designed for research students and lecturers to learn mapping software tools and apply mapping techniques to develop their research projects.
The methodology used was participatory action research, in which four kinds of knowledge mapping based on concept maps were applied by researchers to develop their inquiry based projects:

1. Profile Map for representing personal and professional path.
2. Research Map for designing a research project.
3. Theory Map for organising key concepts and definitions from the literature.
4. Writing Map for integrating key arguments for an essay.

In order to explain each technique above, this qualitative study analyses some concept maps developed by participants from a research community created during an online course organized by the author for postgraduate students and lecturers. This online community started their interactions using Moodle at the PUCSP University in Brazil from 2004 to 2005. In 2006, this group interested in knowledge mapping restarted their collaborations using the LabSpace OpenLearn Project developed also in Moodle by the Open University, UK. Some examples of maps and information about knowledge mapping techniques can be accessed in this Research Community – CoLearn (http://colearn.open.ac.uk).

2 Theoretical principles

Collaborative learning environments (CLE) means a cognitive system (Maturana and Varela, 1980) constituted by active participants (Freire, 1967) whose interactions produce and improve a network of knowledge (Levy, 1990) and collaboration in order to keep its existence A CLE is a space of common aims, collective interactions, contributions and production that are developed by social actors and their social networks (Okada, 2005).

In order to construct knowledge in collaborative learning environments, it is essential to foster thinking skills and inquiry-based learning as important strategies to avoid reproductive and passive learning. Learners should not construct their knowledge just by memorising and repeating the content offered in a course. Copying and pasting information in order to reproduce knowledge leaves students with lots of fragments disconnected, disintegrated and without meaning. Meaningful learning involves critical thinking (Novak, 1998; Jonassen, 2000).

As it can be observed, critical thinking is a complex process. It comprises several cognitive functions and mental skills resulting in a hard abstract process. According to all definitions above, thinking should not count as critical merely because it is intended to be. Thinking has to meet several requirements to be critical. In this context, knowledge mapping can help users to mediate the process of abstracting from the Latin "*abstractere"*, "take it from" the external world, to concreteness give it back to the world, mapped, interpreted, modified by critical thinking (Okada, 2006).

Jonassen (2000) points out several requirements for developing thinking skills which are very useful for inquiry-based research projects. Inquiry-based learning focuses on constructivist approach, in which knowledge is constructed through critical thinking, problem solving and community-based tasks. In order to develop thinking skills, it is necessary to integrate content/basic thinking, critical thinking and creative thinking.

- Content/Basic Thinking represents skills, attitudes and dispositions required to select and understand accepted information. It refers to declarative and explicit knowledge – basic academic content, general knowledge, common sense information.
- Critical Thinking represents the dynamic process of mapping knowledge in meaningful and usable ways though analysis, evaluation and connections. It integrates important skills such as evaluating the process by recognising fallacies, analysing understanding and interrelationships among relevant elements.
- Creative Thinking shows the ability to go beyond accepted knowledge to create and reconstruct new knowledge. It must be used to connected content and critical thinking in order to integrated existing knowledge with the skill of creating and innovating process and products.

3 Case Study

This study focuses on a community of researchers interested in learning and applying mapping techniques for designing inquiry-based research project. This community started their interactions during a semester-long course - Using mapping Software tool in Qualitative Research (USQR), offered in 2004 and 2005. During this course, participants produced a paper with maps, which was published in an electronic book (http://www.projeto.org.br/emapbook). Most of them finished their master and doctoral research using knowledge mapping techniques in 2006 and 2007. In 2008, most of them authored a chapter in the Brazilian book (*Cartografia Cognitiva*) and some of them in the *Knowledge Cartography*, book published by Springer.
The learning outcomes of the USQR course in 2004 and 2005 were:

- ✓ Understand concepts which underpin the uses of mapping for qualitative research.
- ✓ Be able to apply mapping techniques in a research project to collect web resources (web mapping), generate new ideas (mind mapping), organise concepts (concept mapping) and structure arguments (argument mapping).
- ✓ Be able to use different mapping software tools, depending on the context and interests, such as: Nestor Web Catographer, CmapTools, FreeMind and Compendium.

During these first two years, 52 people from Higher Education took this course. Some of them are now participating in the CoLearn Community that has currently more than 160 members. Participants in the online course were from different fields such as: Education, Business, Economy, Medicine, Psychology, Languages and Computer Science. They had different background (e.g. lecturers, scholars, educators, MA students, PhD students and researchers).

Community-based activities were planned to engage participants in exploring collectively mapping techniques in their individual research projects and also in reflecting and discussing about the uses of mapping techniques to develop academic projects. The methodology used in this research was participatory action research (Whyte, 1991). "*Participatory action research aims to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people*" (Reason & Bradbury, 2001:1)

The course was organized in two parts: (1) Mapping techniques with software tools and (2) Mapping techniques for inquiry-based project. In this participatory action study, the online instruments used to collect data were: discussion forums, knowledge maps and research and learning diaries developed by each participant.
Regarding to learning activities, in the first part, participants introduced themselves in the forum; they installed the software tools and explore different kinds of mapping technique such as concept maps, mind maps and webmaps. The second part, focused on principles to support the uses of maps in qualitative research. Its content was presented through a learning path map (figure 3). Its first activity was a "round table", where four authors (Moraes, Macedo, Cañas and Zeiliger) presented papers with discussion forums with questions related to authors' papers. In the second activity, participants should improve their research map based on teacher's

feedback and colleagues´ comments. In the third activity, they should work in groups in order to evaluate and improve their maps. Finally, they should write a map-paper, describing their maps.

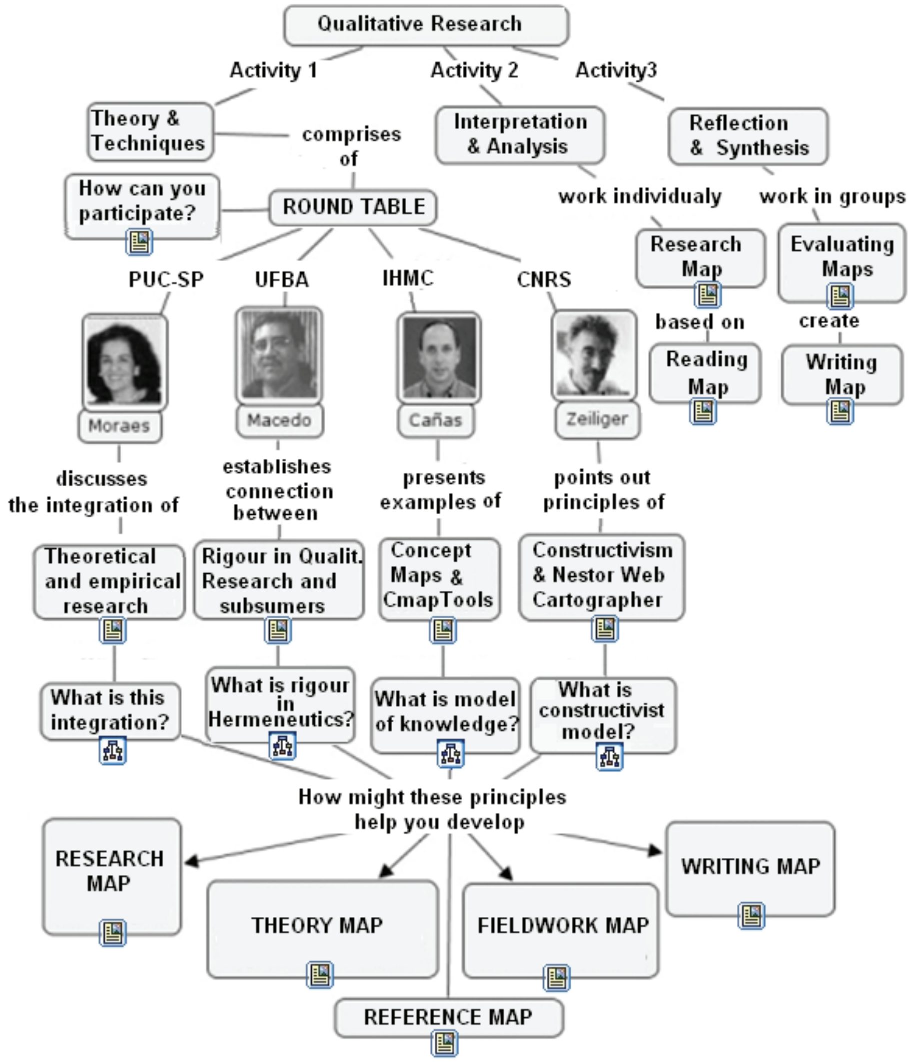

Figure 1: Learning Path Map created in CmapTools by Okada (2004).

Through a learning path map, participants were able to visualise a global picture of learning activities and identify groups to interact and give contributions. They were able to navigate through hyperlinks, select papers to read and choose groups to discuss based on their interests.

In forum, participants exchanged ideas about the papers, raised new questions and shared their reflections about new concepts (e.g. subsumer, theoretical and empirical research, models of knowledge and constructivism approach). Some participants registered in their blogs:

- *"The website of an online course is more attractive and objective through concept maps"*
- *"Maps allow us to visualize different options and select what we are interested in"*
- *"Maps help us identify relations between concepts while we are browsing the content"*
- *"Through maps, it is easier to connect our reading to activities and learning goals"*

4 CLE – Individual and Collaborative productions

4.1 Profile Map for representing personal and professional path

In the CLE environment, participants introduced themselves through concept maps created in CmapTools with a narrative describing their personal and professional life. Figure 2 shows an example of a MBA student's concept map created to introduce herself in the USQR community. The text shows some information about Laura's professional and personal life. The map presents content different from the text. It shows how she represents her reflection about herself. In this map, Laura shows that she has dichotomies in her life (body, mind

and soul). She indicates some of her skills (e.g. ability to connect ideas and concepts quickly) and difficulties (e.g. low ability to be focused). In this example, it is possible to see that introducing herself through concept map helped her to reflect and share personal aspects that were not described in the text.
When participants created and shared maps in the community, they started to know each other and themselves in different ways. Participants also registered in their diaries that profile maps helped them to think about their way of thinking, and also identify some similarities between their peers. They described that maps were very useful to see common interests and similarities in the community.

My name is Laura, I graduated in Business at PUC / SP in 1974 and I then start the Masters in Business Management at FGV. Unfortunately, I have not finished this course. I have been a consultant since 1974. Moreover, I have developing with my own company in the areas of marketing and strategic planning since 1990 and most recently, knowledge management. I am a lecturer at ESPM - School of Marketing and I am taking a MBA course in knowledge management at PUC / SP. I am glad to share my life with a wonderful partner and twelve wonderful cats, which were rescued from the street. Protecting animals is one of my current activities, so if someone would like a pet, let me know.

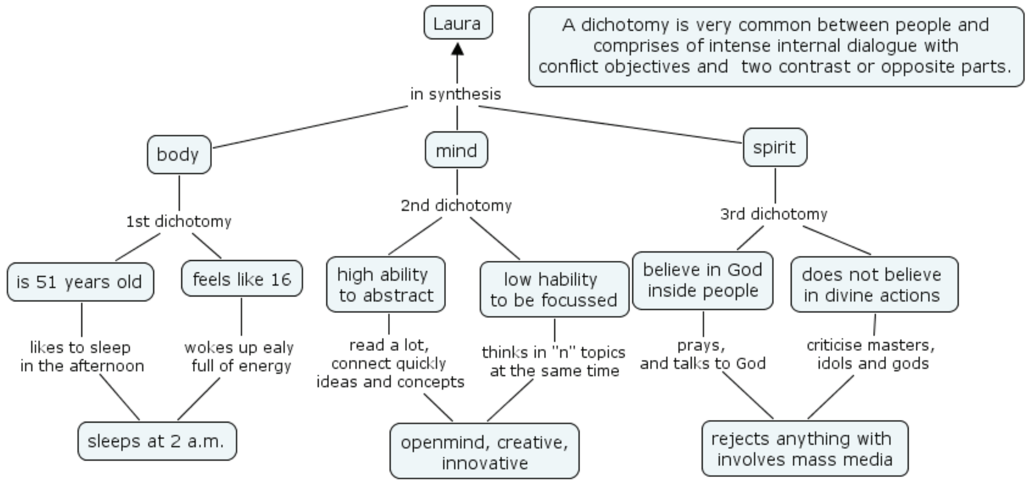

Figure 2: Concept map for introduction created by Laura.

4.2 Research Map for designing a research project

The research map in figure 3 shows the structure of a research project with main key concepts to generate a brainstorm: research questions or aims (*what is the meaning of partnership*…?), relevance of research (*why? …people needs*), contributions in the field (f*or what?... Research Organisations in the areas*), methodology of investigation (*how?... discussion of ideas and Consultation of Community*…) and work field (*where? …Social Economic Area*). Through a research map, participants described that they were able to select their key question and plan their investigation by establishing connections and visualizing important information. Good inquiry projects depend on significant questions.

However, initially, most of participants described that they had difficulties of using concept maps. They found hard to organise maps by facing lots of information. Others mentioned that they selected many questions but no significant references. Experienced researchers described that mapping the starting point in their project helped them visualize the main question. Conklin (2005) states mapping techniques can be used to frame the problem appropriately for tackling wicked problems; however, some skills must be developed in order to apply mapping tools to create good issue-based structure.

4.3 Theory Map for organising key concepts and definitions from the literature

This theory map shows three perspectives (context, key definitions and key concepts) to organise different meanings of "critical thinking". For that, 14 definitions from different authors were selected, grouped by context and ordered by date. From these definitions, 16 words were generated to capture the key ideas, which were integrated in a conceptual area. Researchers consider theory maps as a guide to help them to interpret different viewpoints, compare and combine different approaches to reconstruct their own interpretations.

Clarifying concepts is an important step to understand theories and for meaningful learning (Novak, 1998). Mapping several sources from different authors that explain the same concept helped researchers select and reconstruct maps from a wide and more significant perspective.

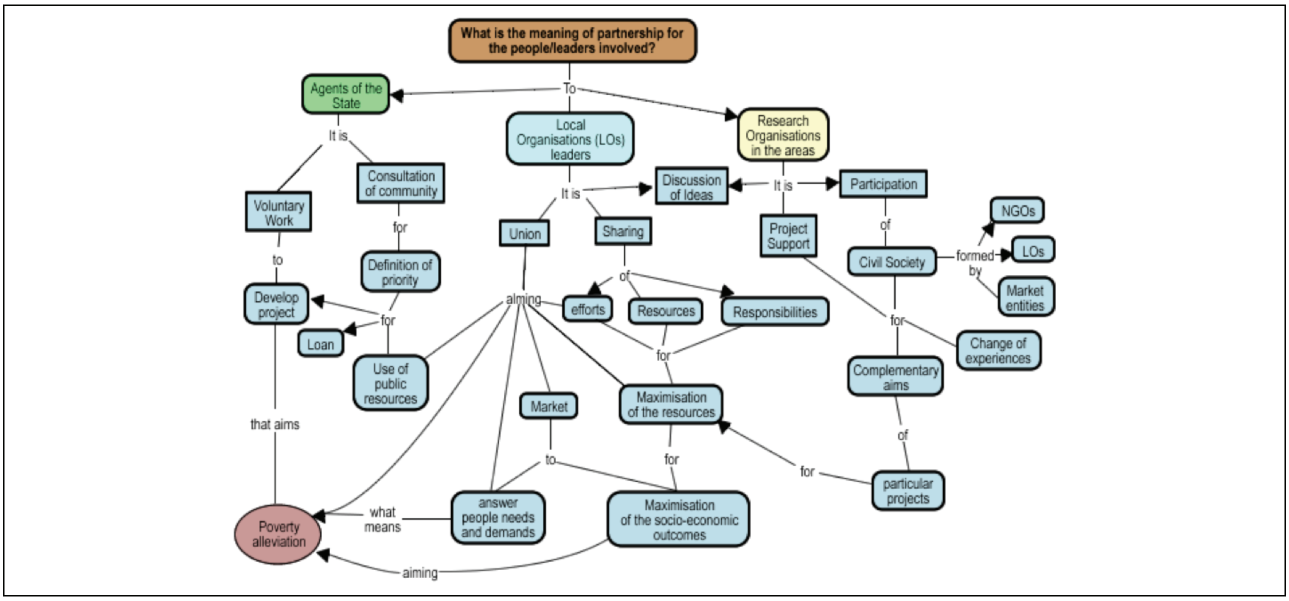

Figure 3: Research Map created by Mario

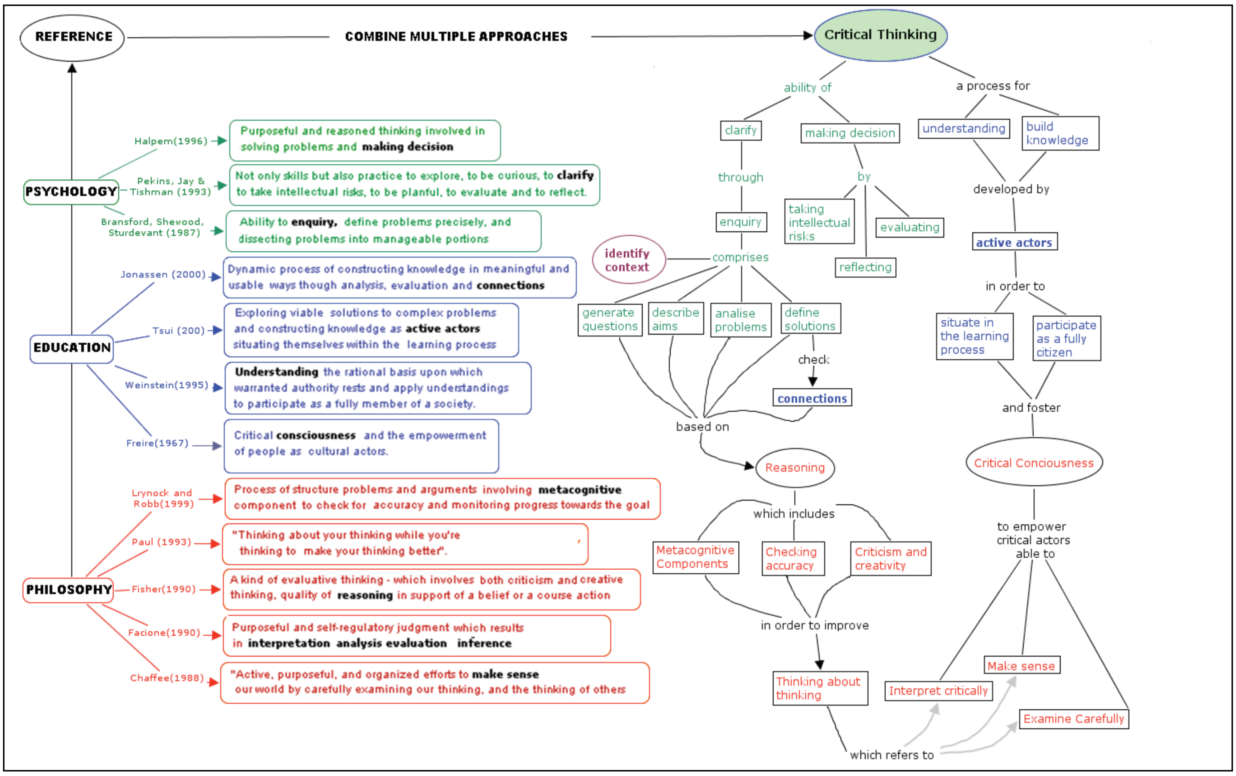

Figure 4: Theoretical Map about Critical Thinking created by Lila, Nely and Ale

Participants discussed in the forum that when concepts are well mapped, learners can compare, combine and reintegrate similar groups of references. Mapping theories are good exercise for reflecting. It helps researchers visualise gaps or misunderstandings that need to be investigated. They can identify new concepts that should be clarified. Through theory maps, researchers can represent and reconstruct semantic networks from their own perspective and reuse them in different research projects. Through theory maps, they can connect concepts, definitions and the original source by organising a graphical memory system of their research.

4.4 Writing Map for integrating key arguments for an essay.

After mapping theories and the fieldwork, another issue is to map the research's outcomes and synthesise a significant conclusion. It means integrating each relevant component to form a coherent whole. For that, a well-structured map is useful to organise ideas clearly and coherently. Researchers and learners can easily describe and visualise their line of reasoning from the maps instead of retrieved from memory (Andriessen, Baker, Suthers, 2003). Visualising argumentation help them to be actively focussed on the main issues. (Kirschner, Buckingham Shum and Carr, 2003). They can integrate all evidence including arguments that justify the conclusion. Through the writing map not only the outcomes can be understood but also how they were found and how the research problem was answered. This map below shows an example of a paper whose author created a concept map to analyse and write about the concept of partnership (figure 3 and figure 5).

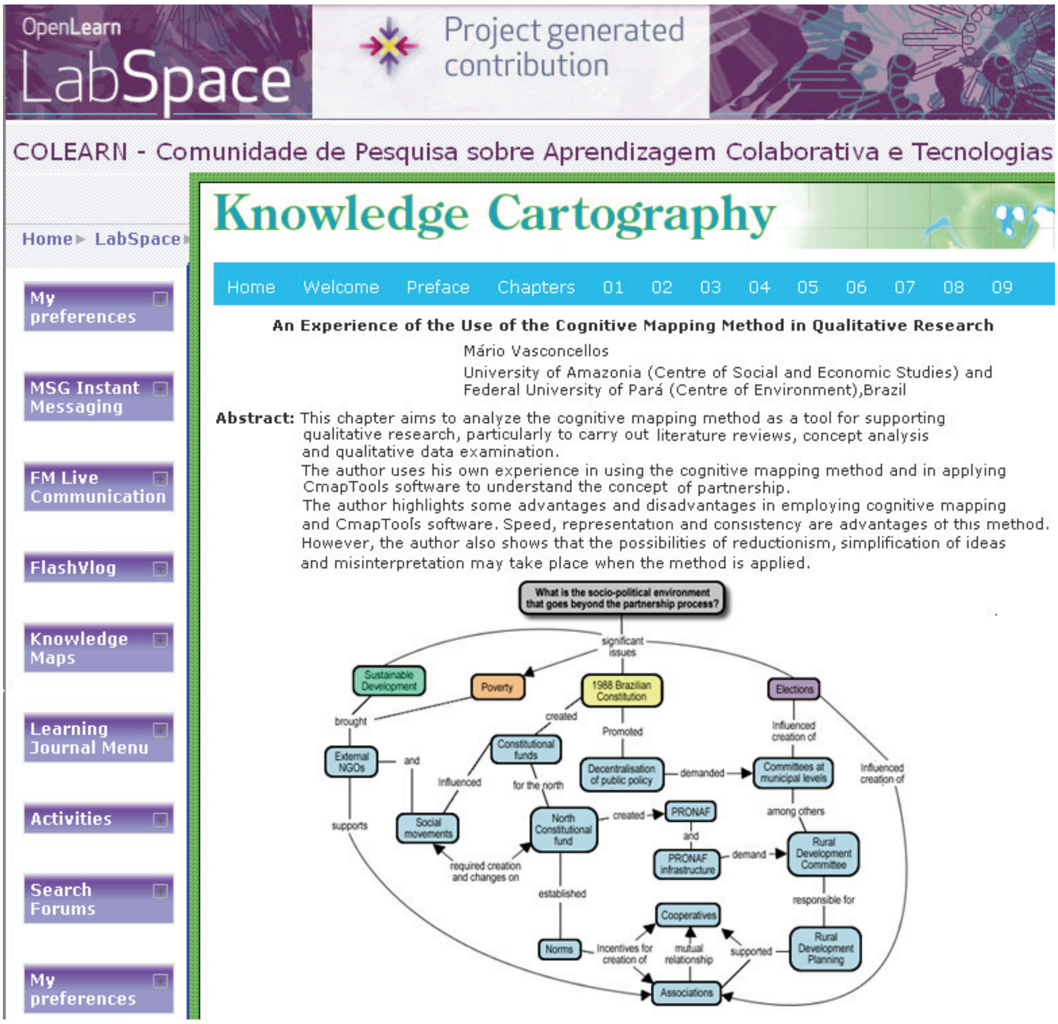

Figure 5: Map-paper develop by Mario (http://kmi.open.ac.uk/books/knowledge-cartography) & (http://mapweb.org/emapbook/)

5 Discussion

Knowledge integration environments (Bell et al, 1995) through knowledge maps seem to stimulate learners to develop and apply their thinking skills for inquiry-based research. Knowledge maps can guide them to find different spaces and groups to negotiate meanings, issues, claims and arguments with evidence and references When CLE stimulate learners to interact, contribute and develop productions together, they feel able to share cognitions and construct more knowledge that is significant together.

Knowledge maps can play an important role in CLE to represent collective construction of knowledge where all participants can access different spaces (figure 1) without feeling lost. They can negotiate meanings and add contributions connecting evidence. In this sense, these knowledge maps can help them develop and apply their thinking skills by analyzing and establishing more connections between referential space, argumentative space and questioning space in their maps and writing. Concerning difficulties with knowledge maps in CLE, this study shows that learners (10%) who faced problems with their computers, internet or software tools, gave up learning. Participants (14%) who were very busy with deadlines did not find time to interact and were not able to learn and apply knowledge maps in their academic projects. A few participants

(10%) who were not familiar with graphical representations with hyperlinks found difficult to understand the content through maps, however when they started to produce their own maps they mentioned that learning path and portfolio maps were very useful.

The second purpose of this study was to identify contributions of applying knowledge mapping techniques and software tools in academic projects. Participants point out that research map used to represent key ideas enabled them to find their key questions. The reference map helped them organise the literature review. The reading map was useful to interpret papers. The theory map facilitated the integration of different viewpoints about the same concept. The fieldwork map provided interesting ways to analyse data. Finally, the writing map was good strategy for summarising key ideas with arguments and evidence. Through these knowledge maps and their discussion in the CLE, teachers could also observe that participants were very engaged in applying these mapping techniques to develop their researches. Most of the participants (80%) in this course were able to create research maps, references maps and theory maps. Few participants (10%) who had already collected electronic data from their fieldwork were able to create fieldwork maps. In addition, some researchers (30%) who were interested in improving their writing skills elaborated reading and writing maps. In this study, participants did not apply six kinds of maps to develop all steps in their research, because most them were in different stages in their investigations with different interests and short time.

Regarding to difficulties with knowledge maps in academic research, several participants (60%) described that it was hard to explore different methods and technology. However, after get used to mapping techniques and tools, they could identify differences and apply different resources better. In order to illustrate some benefits of using knowledge mapping for inquiry-based research projects, Table 1 shows some researcher's comments from their learning diaries, which were selected and classified based thinking skills. Their messages describe how researchers observe the contributions of mapping for developing their academic projects.

Knowledge Map	**Thinking skills & Inquiry Based Learning**	**Researchers' comments**
Profile Map	**Designing**: formulate goals, draft outcomes, revise process.	*"Through the profile map I could see connections between my life and my research. By visualizing this integration I could identify important aspects in my academic project" Antonio*
Research Map	**Problem solving**: reformulate questions, find new alternatives, build acceptance **Evaluating:** define criteria, assess information, recognise fallacies	*"Through my research map I could find a focus of my investigation. After creating several maps of my key issues, I could visualise the main ideas and identify the key questions of my research." Claudio*
Theory Map	**Connecting:** compare and contrast, infer deductively and inductively, identify relationships **Analysing**: recognise patterns, classify main ideas, find connections**.** **Decision-making:** identify possibilities, generate alternatives, compare options.	*"Using maps to connect different perspective from the same concept is very challenging. Maps can reduce the meaning of concepts and it is hard to summarise in few words complex definitions." (…) "However, they help us to compare different approaches and identify connections to reconstruct new meanings" Mario*
Writing map	**Synthesising:** plan, hypothesise, summarise. **Elaborating**: reflect, widen and deepthen, update, concretise. **Imagining:** predict, speculate, visualize.	*"Maps applied to writing seems to be a great strategy because it help us visualize and integrate enough evidence to back up our claims, identify ideas to be deepened, approaches to be widened and plan a clear structure for presenting our thinking." Lila*

Table 1 –Fostering thinking skills through knowledge maps in research projects

6 Conclusions

In this paper, preliminary findings indicate some contributions of knowledge mapping applied in academic research for developing inquiry-based research. Results of this study also highlight the importance of collaborative learning environments to support researchers in exploring tools and applying mapping techniques in their academic projects.

This study has also identified some difficulties of participants in using different tools, representing thinking graphically and creating maps with lots of data. We will be investigating how participants can create these kinds of maps using the same tool; and how learning activities can help them manipulate graphical language to develop spatial ability and visual navigation (Chen & Czerwinski, 1997).

The emergence of social software and web 2.0 (Anderson, 2007) which create new scenarios for open learning (Willinsky, 2006) and collaborative construction of knowledge (Suthers, 2006) also highlights the importance of ongoing research. Knowledge maps may be considered strategic, speculative and heuristic tools to represent what is important, interpret and reconstruct meanings, record and share new structures of components and connections essential to foster critical thinking and make better decisions in social learning communities.

7 Acknowledgements

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MODELING A KNOWLEDGE DOMAIN FOR A MARITIME COURSE

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Abstract. Leveraging concept-mapping in a maritime course can lead to knowledge modeling and has the potential to change the traditional ways of teaching and learning with many constructivist components. The resulting knowledge model can maintain an updated knowledge-base system (KBS), which can benefit the learners. In the long run, the KBS can produce a dynamically enriching information repository, which has the potential to support the learners as well as practitioners in the subject domain. The paper relates the experience gained in a case study at the Singapore Maritime Academy (SMA), spanning a period of almost three years, and describes the processes followed for developing this knowledge model. The results so far have been successful in establishing a knowledge model, which is structured with classificatory (*object*-based) as well as explanatory (*event*-based) components. The paper further describes the plans for capturing the dynamic procedural knowledge from ships at sea, which is expected to enrich the present knowledge model incrementally.

1 Introduction

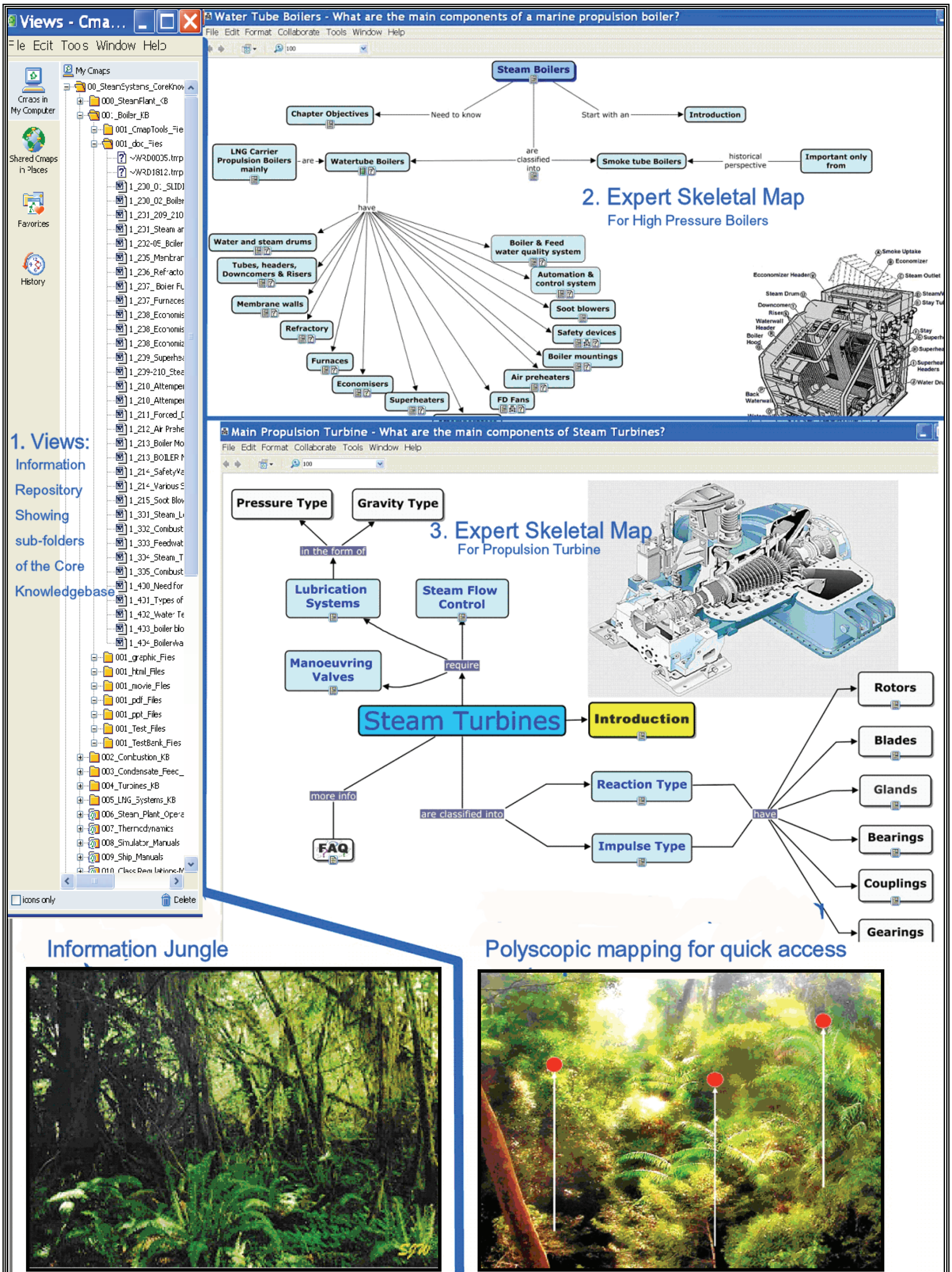
Keeping the content in-line with the competences required for operating engineers at sea is a challenge, which is ill-served by today's maritime training institutes (Chatterjea, 2008). The rate of change of technology at sea and the operational procedures for various ship types are taking place at an accelerating pace. It becomes difficult to incorporate these changes in the course structure of a maritime training institute when the content is based on published literature, which is out-of-phase due to the present rapid changes in technology and shipboard practices. In a case study at the Singapore Maritime Academy, a new course model is being used, which is based on concept mapping and proposes social constructivist methods of involving learners in developing and updating course structure. The learners develop concept maps from existing literature as well as from shipboard practices, which are captured, when the learners are on attachment at sea. Replacing lectures with active learning was made possible through the use of CmapTools and a classroom infrastructure, which is very different from traditional classrooms, where teaching and learning are mainly dependent on transmission mode. The paper describes the development of this course model, which incorporates content, assessment as well as course administration as part of the core knowledgebase all managed through the *Views* of a CmapTools project.

2 Knowledge Model for a Maritime Domain

The case study relates our experience at the Singapore Maritime Academy (SMA) with a group of senior engineers from ships. They are qualified to operate ships with diesel propulsion and are presently doing a conversion course at SMA for gaining proficiency in running of LNG carriers with steam propulsion. Presently, we just finished our 4th Cohort of trainees, who participated actively while going through this course and thereby contributed in improving the system. Over a period of almost three years we have been developing a CmapTools-based dynamic knowledge model to run and administer all aspects of this conversion course. The knowledge model includes learning content, formative assessment, knowledge creation and capture, summative assessment, feedback and general course administration, all stored in the *Views* of CmapTools. Thus CmapTools *Views* served as an information repository for the developing KBS.

In *Views* we created folders of (1) Core Knowledgebase, (2) Steam COC Course and (3) Cohort Assessment sections. Over this period of nearly three years, this repository has become a fairly large data source and it is virtually impossible to extract the desired information without some navigational interface. However, using Novakian concept maps, accessing through this digital information repository and exploring various concepts with embedded details (texts, graphics, movie clips etc) have been made relatively simple (see Figure 2). This method of graphical information lay-out and navigation is referred to as polyscopic modeling by Karabeg, (2004). Karabeg suggested "*mountain top view*" information design to handle information overload in a complex subject domain. Polyscopic Modeling is best illustrated by Polyscopic Information ideogram (Figure 1). The triangle in the ideogram represents a mountain, on which every point is a scope or a viewpoint. Polyscopic information (represented by the "i" inscribed in the triangle) consists of the high-level information (represented by the circle) and the low-level information (represented by the square). The high-level information provides the large picture of the subject domain, while the low-level information provides the supporting details, the foundation and the necessary rationale (Karabeg, 2004).

Figure 1. Polyscopic Information Ideogram
[Source: Karabeg, 2004]



[Source: Karabeg, 2007] [Source: Karabeg, 2007]

Figure 2. Information Jungle (***Views***) & polyscopic mapping (***Novakian Concept maps with resources***) providing access & relationship

Static knowledge is sometimes referred to as declarative and classificatory (Ferguson-Hessler and de Jong, 1990; Cañas and Novak, 2006). It is usually arranged hierarchically. On the other hand, the dynamic or evolving knowledge is referred to as procedural, cyclic or sequential knowledge (Safayeni, et al., 2005). This classification conforms to maritime practice, where we differentiate between knowledge (e.g. knowledge of thermodynamics) and skill (e.g. skill/ proficiency of operating a steam boiler). Hence, we organized the knowledgebase (see Figure 3), in our case study into two distinct areas. We called them (1) knowledge, which is meant to be classificatory and (2) proficiency which is explanatory and more dynamic in nature. The knowledge could be referred to as being *object*-based and proficiency to be *event*-based (Cañas and Novak, 2006). The *object*-based knowledge-section represents the accepted ontological structure of the subject domain, which is elicited from texts and existing literature and usually presented in an expert skeletal (Novak and Cañas, 2004) Novakian concept map. From our experience, we found these expert skeletal maps are more useful to the learners, when they had lesser number of concepts (say not more than 10 to 15). Otherwise, the learners, encountering so many of theses new concepts get overwhelmed with information overload.

So, we arranged the knowledge domain with a number of layers of expert skeletal maps and they were cross-linked for integration. As stated by Novak & Cañas (2008), cross-links facilitate seamless integration of concepts from one map to another in a large knowledge domain. Each skeletal map represents a set of byte-size information, which can be easily handled by the learners in a domain, where they are not familiar. Focus questions for the object-based concept maps shown in Figure 2 (e.g. *what are the main components of steam turbines?*), may appear trivial but to keep the self-directed learners engaged in these graphical exploratory interfaces, simplified expert skeletal maps were found to be more useful in introducing the basic ontological structure of the subject domain. It must be added that these structural arrangement of the knowledgebase was iteratively arrived at by the authors, who could be considered as domain experts. Further fine-tuning of the structure is done as we demonstrate the system to domain experts from various shipping companies. With our close association with the industry, we will be able to keep the KBS relevant to the present-day shipboard practices.

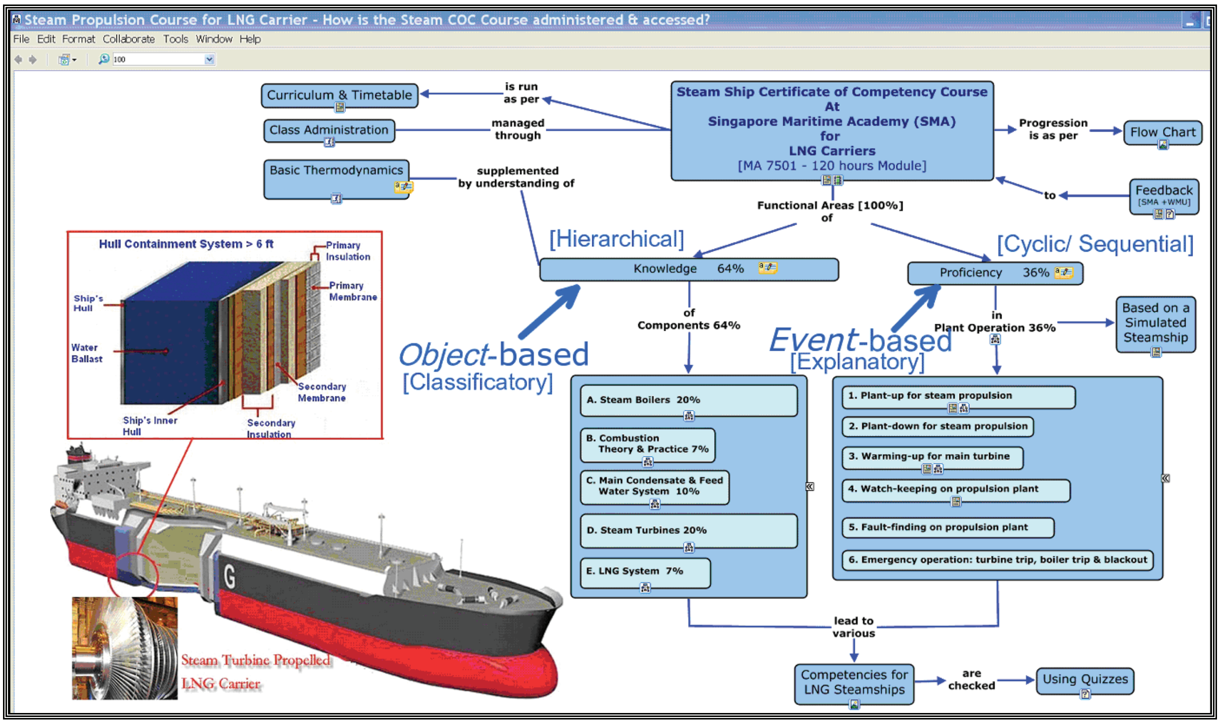


Figure 3 Object-based and Event-based division of the knowledgebase

2.1 Development of Expert Skeletal Maps

The idea of the expert skeletal concept maps, mentioned earlier, is to represent the established ontological structure of the subject domain, which should lead the learners towards practitioners' pathways to the knowledge segment. In our case study, these maps were developed by the learners themselves under the guidance of the course facilitator. Once a topic sub-folder is populated with digital files of texts, graphics, etc from the available literature, the learners, who were paired for collaborative work, were asked to develop these maps. The maps were iterated for improvement and finally socially validated for acceptance by the group under the guidance of the facilitator.

The process followed the recommended guidelines suggested by Novak & Cañas (2008) of parking of the concepts. Given the existing literature in the knowledge segment, the learners were asked to pick up the important issues or concepts after going through the information repository in the CmapTools *Views*. The concepts were then kept aside in a parking bay on one side of the Cmap. Critical issues missed by the learners are appended to the list by the facilitator.

Subsequently the learners drew the Cmap, taking the concepts from the parking bay and by choosing the appropriate connecting phrases as they saw fit. The resulting Cmap is not merely a reflection of the existing literature but a combination of the existing literature as viewed by the participants, who have diverse exposure in the field of engineering. Once they were finalized after a number of iterations by the group, the Cmaps were presented to the whole class for social validation. Hence, sometimes the existing literatures were partly disagreed with by a certain group and if the suggested Cmap could be accepted by the class and the facilitator, the created Cmap was put inside the core knowledgebase.

Some of the groups also worked on knowledge extension on the expert skeletal maps, digging out further information from the Internet and books from the library. Thus, each cohort will substantially improve the core knowledgebase and as we dealt with mature students with substantial industrial exposure, significant contributions were received from a number of participants in each cohort.

2.2 Development of the Skill/ Proficiency Path of the Knowledge Model

Based on suggestions by Safayeni et al. (2005) and Cañas & Novak (2006), we based our proficiency path of the knowledgebase on sequential concept maps (see Figure 4), which became a *learning organizer* for the simulation exercises.

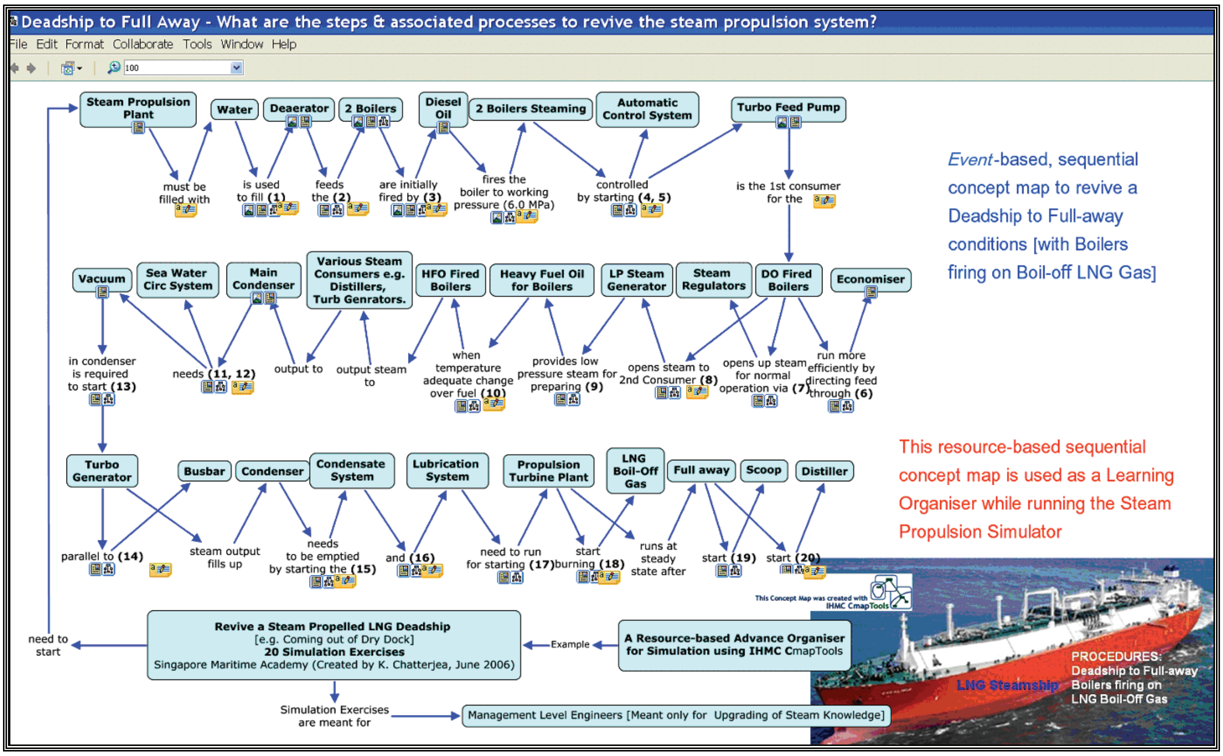


Figure 4 A Learning Organizer: *Event*-based sequential concept map to assist learners while running the Steam Propulsion Simulator

The concept map traces the steps required to revive a LNG carrier with steam propulsion from the deadship conditions (plant in *dead state* as opposed *running state*) to full-away conditions at sea (running at full *sea-speed*) with the propulsion boilers firing on LNG boil-off gas. These *event*-based procedures of 20 simulation exercises (represented by the numbers in Figure 4 above) are well depicted in the sequential concept maps. For each exercise, embedded resources provide the knowledge support. The maps serve the purpose of a *learning* *organizer* (Ausubel, 1960; Willerman & Mac Harg, 1991) and it provides spatially distributed context-base resources to support individual knowledge management. This *learning organizer* provides support while running the steam propulsion simulator, which forms the main instrument for gaining proficiency in operating the steam propulsion machinery of an LNG carrier.

2.3 *Infrastructure for the Knowledge Lab*

We had to device a new arrangement in our knowledge lab as the traditional classroom arrangement with predominantly transmission mode of learning (see Figure 4.) was considered unsuitable for learning tasks of knowledge creation, knowledge sharing, cooperative learning, social validation of knowledge and finally knowledge capture and additionally, online assessment. We based on a collaborative arrangement with two students per station. This arrangement allows for teamwork and peer level support. Support from one's capable peers or adult guidance could lead to higher levels of achievement in learning (Vygotsky, 1978) as compared to learning through independent efforts. Additionally, the arrangement as shown in Figure 6, led to the development of self-directed learners, who enjoyed learning without much intervention from the facilitator.

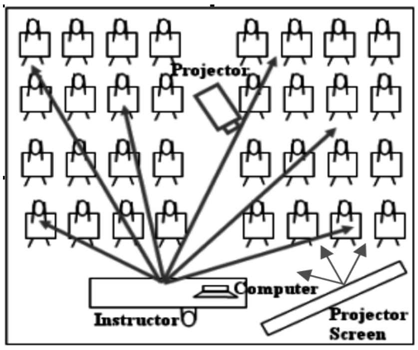


Figure 5 Traditional Classroom with Transmission Mode of Learning

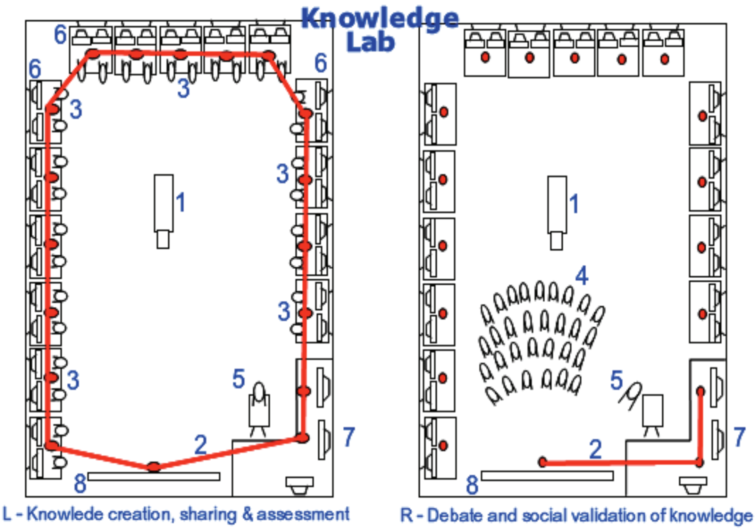


Figure 6. Two scenarios of Knowledge Lab arrangement [L – for facilitating knowledge creation, knowledge sharing and online assessment; R – for debating and social validation]

Legend: 1 – Projector, 2 – LAN with knowledge nodes, 3 – Students (in pair) connected to KBS, assessment & simulation servers, 4 – Students debating to validate shipboard procedures, 5 – Facilitator, 6 – Student computers on LAN, 7 –Knowledge, simulation & assessment servers, 8 – Cambridge-Hitachi knowledge-capture screen (FX77).

Each learning station has a pair of learners and there is connection to the knowledgebase, simulation and assessment servers. A Cambridge-Hitachi interactive knowledge-capture board (Starboard FX77 – Item 8 in Figure 6.) is used for presentation, for running of the simulator and social validation of the newly created knowledge. Figure 7 shows the classroom discussion captured on the FX77 board and the formalized Cmap using equipment images as concepts. This approach of including background graphics, makes the concepts in concept map more in context and for the novice user it becomes easier to relate to the actual system flow.

FX77 is an active board, which supports projection as well as touch-screen activity. Hence, the propulsion simulator can also be operated directly from this board. While running the simulator, comments and remarks from the learners are also captured on a simulator page and the same is then converted into an image file. These captured image files are subsequently embedded on the learning organizer (see Figure 4) to enhance performance support to the learners as they operate the simulator.

Once a Cmap is finalized by a group, it is then presented to the whole class for debate and social validation (see Figure 6). This is the crucial stage of the knowledge creation, where final changes are made to the concept map after a debate. With the FX77 board, we could capture all the discussions when the Cmap is presented by a group. Based on these discussions, Cmap is modified and stored at the appropriate folder of the core knowledgebase (in *Views*).

2.4 Knowledge Capture at Sea & Course Assessment

While shipboard technologies and particularly procedures evolve rapidly with changing times, the changes in content at the maritime training institutions lag behind due to the content being generated, mainly from books and published literature and consequently the learners do not get the updated knowledge at the shore-based training centres. Most of the trainers at these institutes are lacking the updated shipboard operational knowledge as they leave sea early in their sea career to settle down ashore with their families and rarely get the opportunity to sail again. Perhaps, the easiest channel of capturing updated operational knowledge from the practitioners is when these engineers come to the institute for further training. In maritime practice the practitioners come regularly to the training institutes to revalidate their certificates or to get additional endorsement to their existing certificate.

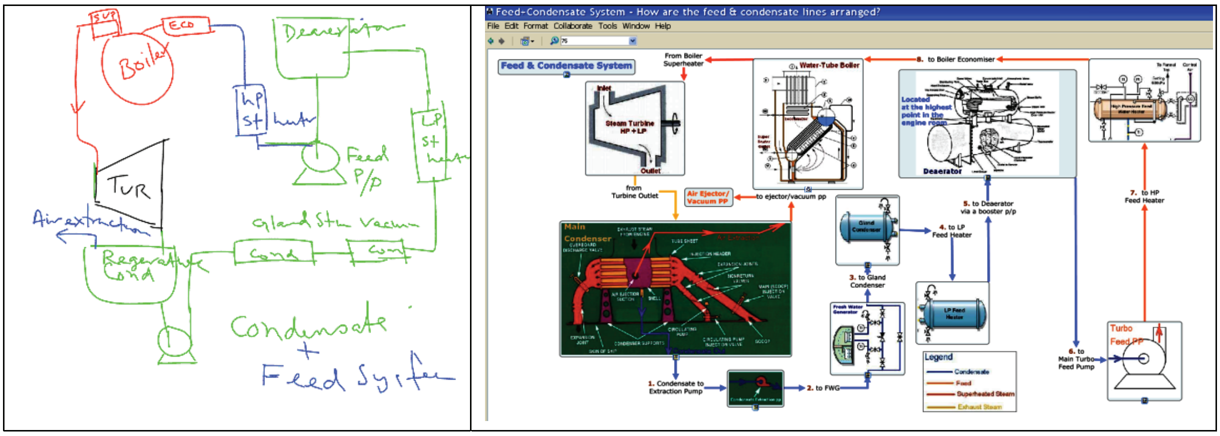


Figure 7. Left: Knowledge capture of the discussion on FX77; Right: Formalized Cmap using figures as concepts

Normally, we make no effort to capture their recently acquired rich shipboard experiential operational knowledge. The age-old institutional practices of catering unidirectional knowledge-transmission towards the learners are difficult to moderate. We had the experience of capturing such knowledge using CmapTools in a pilot project earlier (Chatterjea, 2006). In this steam conversion course, we are creating an avenue to tap this rich experiential knowledge of practitioners through shipboard assignments. The process should plough back the latest procedural knowledge into the core knowledgebase, thereby keeping the course content dynamically updated. The core knowledgebase will grow incrementally and over time has the potential to become a large source of knowledge with logical concept-map-based access points, which could be tapped by both learners and practitioners. As the learners go on board LNG carriers after completion of this course, they are urged to capture the shipboard procedural knowledge as part their course assignments (see Table 1, last row). The assignments are given on the course Blog: http://lngsteam.blogspot.com, so that these could be updated regularly and can be directly accessed by the learners when they are away from the institute. An extract from the course Blog is shown in Figure 8.

Assessment Components	Type of Assessment	When Conducted	Weightage %
1. Coursework A (*Formative*)	60 Computer-based on-line assessment	Continuous (*In-course*)	15
2. Coursework B (*Collaborative Knowledge Creation*)	12 Assignments – 2 for main areas of coverage (*Individual Portfolio*)	Continuous (*In-course*)	15
3. End of Course Assessment (*Summative*)	1 Computer-based on-line assessment	End of Course at SMA	55
4. Shipboard Assignments (*Dynamic Procedural Knowledge Capture at sea*)	6 Assignments – 1 for 6 main areas of coverage. (Appending *Individual Portfolio*)	During steam ship attachment at sea.	15

Table 1. Assessment plan for Steam Certificate of Competency Course at SMA

Table 1 shows the components of the assessment for the course and highlights the various aspects of interactive teaching and learning as well as knowledge management plan. Dynamic procedural knowledge capture will start when the 1st and the 2nd cohort students return to SMA towards end-2008/ beginning-2009.

3 Conclusion

The paper described the development process of a knowledge model in a maritime subject domain. It was shown how a CmapTools-supported knowledgebase could be developed involving students through social constructivism. The four cohorts of students (a total of 37 participants) developed a course structure with guidance from the course facilitator. Even though the learners came with limited IT exposure, they learned to use CmapTools within a period of few days using mainly the *Help* files provided with the CmapTools program. It was surprising how quickly the learners accepted the use of CmapTools as the vehicle for learning and started contributing in the development of the knowledgebase. However, in general, the younger learners were more productive than their senior counterparts, who needed a lot more support and encouragement from the facilitator.

According to Novak and Cañas (2008), knowledge creation by individuals facilitates the process of learning for the learners. It is expected that this new course model will impart a more *meaningful* learning for the learners and they will practice knowledge management using CmapTools in their own workplace. A longitudinal study is required to establish the true usefulness of this approach of constructivist learning.

1.1 Sunday, 6 January 2008

1.1.1 Assignments at Sea

Shipboard Assignments:

++ These are meant for those of you at sea doing steam-time now!
++ You need to complete six assignments at sea.
++ Either do six assignments from the suggested list below -- one from each topic -- or you may suggest your own assignments (in that case you need to check with me first...just send me a mail at Kalyan@sp.edu.sg).
++ Table below lists the suggested assignments. Please note the submission should be based on your shipboard plant and NOT reproduction of information from books.

Assignments for STEAM BOILERS
a) Boiler shut down and start up procedures followed on board.
b) Safety valves on drum, superheater and desuperheater: construction, setting and operation.
c) Line drawing of the steam distribution system and rationale for the same.
. . . .
Assignments for COMBUSTION THEORY & PRACTICE
e) Boiler combustion control and management: Faults encountered in practice and actions taken.
f) Fuel oil to gas and gas to fuel oil change over: precautions and practices on board.
. . . .

Figure 8. Extract from the course Blog showing the items for procedural knowledge capture

4 Summary

The paper describes the development of a CmapTools-based knowledge model, which includes learning content, formative assessment, knowledge creation and capture, summative assessment, feedback and general course administration for a maritime course titled "Steam Certificate of Competency for LNG Carriers". A knowledge-based system was created in the CmapTools *Views*, which served as an information repository for this course. In *Views* we created folders of (1) Core Knowledgebase, (2) Steam COC Course and (3) Cohort Assessment sections. Over a nearly 3-year period, this repository has become a large data source for this course. Using Novakian concept maps, accessing through this digital information repository and exploring various concepts with embedded details (texts, graphics, movie clips etc) have been made relatively simple. In the case study, these maps were developed by the learners themselves with the guidance of the course facilitator. Once a topic sub-folder is populated with digital files of texts, graphics, etc from the available literature, the learners, who were paired for collaborative work, were asked to develop these concept maps. The developed knowledgebase was split in to two sections: (1) *object*-based, which is classificatory and (2) *event*-based, which is explanatory. The *object*-based section covered the knowledge from the existing literature, while the *event*-based section covered the proficiency or the skill aspects of the knowledgebase and created learning organizers. A learning organizer provides support while running the steam propulsion simulator, which forms the main instrument for gaining proficiency in operating the steam propulsion machinery of an LNG carrier. There is also plan for dynamic knowledge capture using student assignments, when the learners are sent for industrial attachment at sea after completion of the course. The paper also describes the class infrastructure used to develop concepts map and for social validation of the new knowledge, generated by the learners.

5 Acknowledgements

The authors wish to thank Singapore Maritime Academy for supporting the project, for providing the funds to upgrade steam learning facilities at SMA and to undertake this research work. We also want to thank World Maritime University (WMU) to support this project and for providing assistance during the period when for a month the research work was undertaken at WMU, Malmö, Sweden. We also want to thank the Maritime Port Authority (MPA) of Singapore for supporting the project and for providing technical assistance in formulating the steam engineering curricula and the assessment system. MPA has now submitted this model as a novel model of education in maritime training to the Sub-Committee on Standards of Training and Watchkeeping, International Maritime Organisation, London (MPA, 2007). A number of countries have provided positive feedback for this proposed model. We need to acknowledge Aalborg Industries Singapore for their continuing support in providing expertise and also for providing funding for the project. We also acknowledge the contribution made by the MPRI Ship Analytic team at Singapore for supporting the project by providing professional support during the running of the Steam Propulsion Simulator for LNG Carriers at SMA. Finally, we must thank our participating students, who supported the trials whole-heartedly and contributed generously to improve the system knowledgebase.

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Tallinn, Estonia & Helsinki, Finland 2008

NEXT STEP: CONSOLIDATING THE CMAPPERS COMMUNITY

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Abstract For more than three decades, the refinement and use of the concept map tool has been evolving, with new applications to improve school teaching and learning, new ways to capture and use of expert and tacit knowledge, better ways for searching and organizing information from the Web, and better tools for collaboration locally as well as internationally. While we anticipate this utilization "growth phase" will continue, we seek in this paper to present some ways to move toward building collaborative communities of users who will work to provide guidance to new users and mechanisms for evolving better organized sets of concept maps. We also seek to develop new Web sites to facilitate the latter developments.

1 The Origins

Concept maps, as we define them, were first developed in 1972 as a tool to study changes in children's conceptual understanding of basic science concepts (Novak & Musonda, 1991). We faced the challenge in our research program of trying to find a way to illustrate clearly what cognitive changes were taking place in the 6-7 year old children we were working with, providing instruction in the particulate nature of matter, energy and energy transformations. While we found modified Piagetian interviews appeared to probe children's knowledge, it was difficult to see clearly what changes were occurring in their cognitive structure that was leading to their manifest better understanding of basic science concepts. Novak's research group at Cornell University revisited key ideas in Ausubel's (1963, 1968) cognitive learning theory on which their research and instruction was based, and decided to try to represent the concepts and propositions put forward by their students in the simplest possible form, namely concept labels in boxes linked with a line and "linking words' to form a proposition. In keeping with Ausubel's ideas of hierarchical structure of cognitive structure, concept maps were drawn with the most general, most inclusive concepts at the top and most specific, least inclusive at the bottom. Working from interview transcripts, concept maps were drawn, using pen or pencil and paper, representing the concepts and propositions the child held for a given domain of science. The team found it relatively easy and reliable to represent children's knowledge in this way. Figure 1 shows and example of one of these early concept maps.

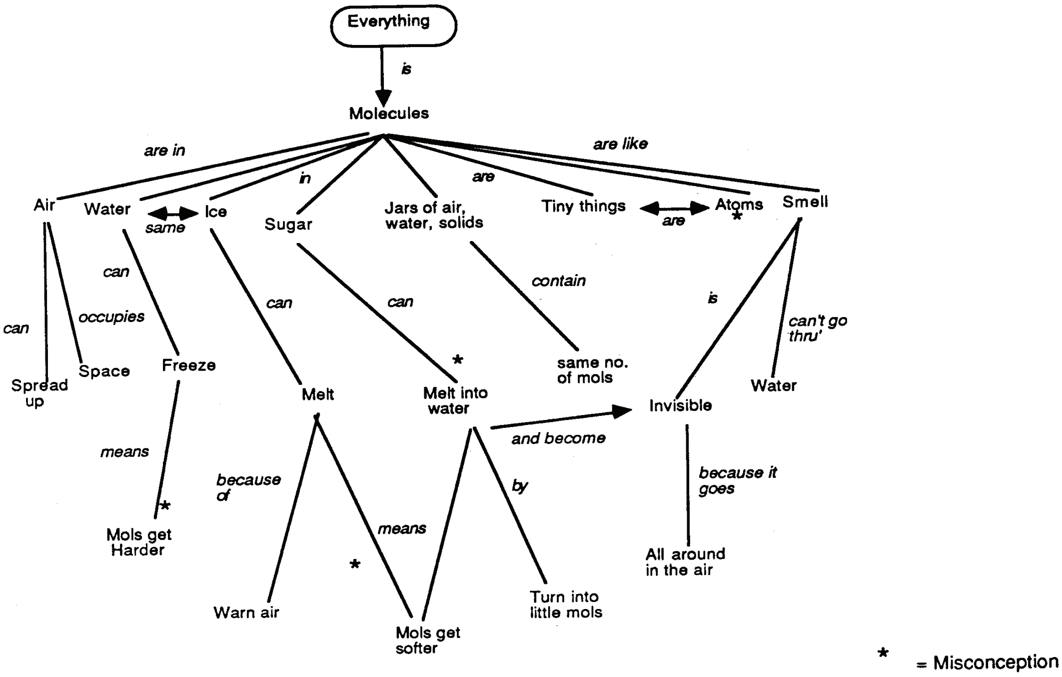

Figure 1. An example of a typical concept map drawn from an interviews with a children at the end of second grade (age 8), from Musonda (1986, p. 118).

We soon found that concept maps were also effective in helping students to organize and better learn subject matter. Six-year-old children could begin with a short list of related concepts and organize these into very meaningful concept maps. Figure 2 shows an example from our early work.

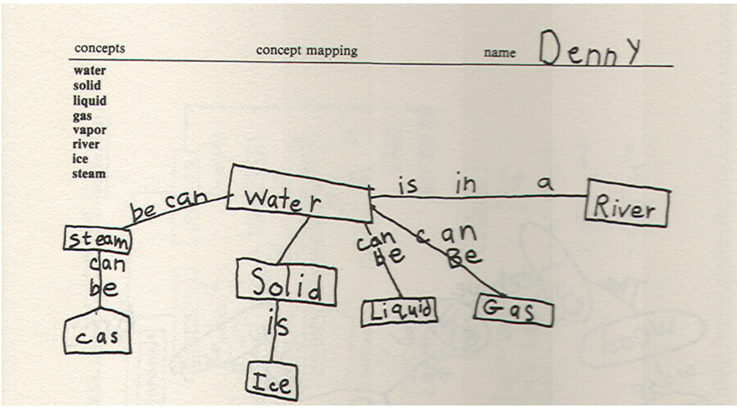

Figure 2. A concept map drawn by 6-year old children using the concepts provided on the left side. These were the first concept maps made by this child after a class demonstration drawing a sample map about plants. (From Novak & Gowin (1984, p. 177)).

By the mid 1970's, Novak and his colleagues were using concept maps as a tool to facilitate meaningful learning in every subject matter area, and at all age levels. Moreover, they found that students working with concept maps were also *learning how to learn* (Novak & Gowin, 1984).

2 In Memory of David Ausubel, 1918-2008

For most of the 20th Century, North American psychology was dominated by behavioral psychologist who held that only manifest behavior can be observed scientifically, and it was unscientific to speculate on the inner workings of the brain in describing learning processes. The behaviorists so dominated North American psychology, and psychology in many other countries, that other viewpoints had difficulty getting published or presented in classrooms. Piaget's monumental works on children's mental development, while popular in Europe were rarely presented in American classrooms until the 1960's when his work was "rediscovered" (Ripple & Rockcastle, 1964). It was the pioneering efforts of Ausubel and his students that helped to turn the tide to what is now the widely popular cognitive psychology. Ausubel's *The Psychology of Meaningful Verbal Learning* (Ausubel, 1963) and his *Educational Psychology, A Cognitive View* (Ausubel, 1968) led the way to what became the "cognitive revolution" in the 1980's.

Perhaps Ausubel is best known for his idea of *advance organizers*, i.e., a small segment of instruction that is more general and more abstract than related instruction that followed. Research studies by Ausubel and others showed that advance organizers when well planned can significantly enhance subsequent related learning. Advance organizers were an instructional tool, but they also related to a fundamental principle in Ausubel's assimilation theory of learning, namely that new learning proceeds best when it deliberately builds on the learner's prior relevant knowledge. In fact, in the epigraph to his 1968 book Ausubel stated:

> *If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.*

Figure 3. David and Gloria Ausubel touring wineries in Upstate New York, 1989.

It was the challenge of ascertaining what relevant concepts and propositions the learner already knew that was the driving problem that led Novak and his students to develop the concept map tool. This also became an important tool for helping students and teachers build on what the learner already knows. While we hear and read today a good deal about the importance of *constructivist* teaching and learning approaches, many of these fail to recognize the critical and explicit role that the learner's relevant concepts and propositions play in new learning. To fully understand how and why to use concept maps to facilitate learning, it is useful to read some of Ausubel's writings on the nature and role of meaningful learning to build powerful knowledge structures and powerful learners. Figure 3 shows David and his wife Gloria on a happy tour of wineries in Upstate New York in 1989.

3 Concept Mapping reaches Maturity

Concept mapping proliferated throughout the educational community during the 1980s, as reflected in the translation of *Learning How To Learn* (Novak & Gowin, 1984) to 9 languages. It was, however, during the 1990s that concept mapping's popularity as a knowledge representation tool began spreading into domains beyond education and started making its appearance in organizations and corporations (Novak, 1998). The development of concept mapping software further facilitated the construction of concept maps, but it was the integration of concept mapping with the Internet and the Web that took concept mapping to new levels of applications. The spreading of concept mapping to all domains and throughout the world is demonstrated in the variety and breadth of papers presented at the First (Cañas, Novak, & González, 2004) and Second (Cañas & Novak, 2006) International Conferences on Concept Mapping as reported by Daley *et al.* (2008), and at this Third International Conference on Concept Mapping (Cañas, Reiska, Åhlberg, & Novak, 2008). In this section we discuss some aspects of how this maturity was reached.

3.1 Making Tacit Knowledge Explicit, or Making Private Knowledge Public

When Michael Polyani (1958) first introduced the idea of *personal* knowledge in 1958 he was speaking primarily to how scientists reason, not only using the hard data from their research but also subtle and unarticulated ideas based on their years of experience. In 1966 he expanded on his ideas and labeled this personal knowledge *tacit* knowledge (Polyani, 1966). The importance of tacit knowledge is now recognized as very important not only in sciences but in every field. Nonaka and Takeuchi (1995) argued that tacit knowledge was essential to recognize and capture, if possible, for the successes of any business. Today most corporate executives recognize the importance of tacit knowledge, albeit many lack the tools and ideas to help make workers' tacit knowledge explicit.

When Novak and his colleagues observed young children working with science materials in guided instruction, it was evident that they appeared to have more knowledge than they were able to express. This private or tacit knowledge, if it could be captured, would help to explain why some learners appeared to grasp quickly specific scientific ideas, whereas others did not. It was this challenge that was part of the motivation to create a new tool to represent the children's concept and propositional knowledge. We soon found that the concept map tool not only could capture the explicit statements made by students to explain how some event or object behaved; it also could reveal more subtle knowledge that was not evident in simply listening to a child talk or interviews with the child. However, it took some years before we came to fully appreciate this power of the concept mapping tool.

In 1986-87, Novak spent a sabbatical year at the University of West Florida and began collaborating with Cañas and colleagues who formed what is now the Institute for Human and Machine Cognition (IHMC) in Pensacola, Florida. In the early 1990s, this collaboration lead to the development of ICONKAT (Ford et al., 1991), a software tool to aid in the elicitation and representation of experts' knowledge. ICONKAT was used with Dr. Andrews, a local Pensacola cardiologist interested in better ways to train cardiologists to use a technology that permitted a non-invasive way to assess cardiac functions and abnormalities. Concept maps were used to represent Andrews' knowledge and an expert system was developed (NUCES) that aided in the diagnosis of coronary problems and trained new users in interpreting the images used in the technique (Ford, Coffey, Cañas, Andrews, & Turner, 1996). NUCES used concept maps as an explanation/help component (Ford, Cañas, & Coffey, 1993), as shown in Figure 4. It was in NUCES that we first used icons under concepts to link other resources that contained information related to the concept, as shown in the Figure.

The success of NUCES led to new projects, including, El-Tech, a collaboration with the Department of Navy to capture the expertise needed to repair electronic equipment on ships (Coffey et al., 2003), and other similar systems (e.g., Hoffman, Coffey, Ford, & Carnot, 2001). This attracted funding not only from the Navy but also NASA, Department of Defense, and other agencies for the development of the CmapTools software (Cañas, Hill et al., 2004), described in next section. Geoff Briggs at NASA Ames lead the development Mars 2001 (Briggs et al., 2004), which showed how concept maps could be used to organize large amounts of resources and conform an easy to navigate Website. These efforts together with work by other colleagues at other places helped demonstrate the value of using concept mapping in organizations and corporations, at a time when "knowledge management" was in its infancy.

Friedman in his book, *The World is Flat* (Friedman, 2005), presents a compelling case that we have moved from the Information Age to a new world where virtually anything can be made anywhere and shipped anywhere primarily because there are virtually no boundaries on knowledge and knowledge utilization. His case is illustrated in recent work by Procter and Gamble reported by the Vice President for Knowledge and Innovation, Larry Huston together with N. Sakkab (2006). When it was suggested that printing popular pictures on Pringles™ might increase sales, they searched the literature and found a researcher/baker in Italy had developed a method for printing pictures on bread. Working with this baker, it was relatively easy to adapt the technology for use with Pringles, and this led to double-digit growth in sales of Pringles. Procter and Gamble now routinely searches the literature for research relevant to their interests, saving millions of dollars in R&D development costs. Currently Huston is working with researchers in India and other countries to prepare comprehensive concept maps dealing with diabetes, eye care and other areas of health care. We similarly find innovative ways in which concept mappig is being used in organizations and corporations worldwide.

3.2 Concept Mapping Meets the Internet & the Web

Early concept mapping software facilitated the construction of concept maps but did not provide any additional features. When a new generation of concept mapping software appeared that took advantage of the facilities offered by Internet and the Web, (e.g., Alpert & Gruenberg; Cañas, Hill et al.; Gouli, Gogoulou, Papanikolaou, & Grigoriadou, 2003; Simón, Estrada, Rosete, & Lara, 2006), concept mapping was shown to be useful for applications that we didn't even dream of when concept mapping was developed decades earlier. Concept mapping software like CmapTools greatly expand the power of the concept mapping tool, enabling easy collaboration between individuals either locally or remotely via the Internet, and either synchronously or asynchronously. In addition, the software allows the user to easily create knowledge models –collections of concept maps and attached resources about a domain of knowledge– and publish them on the Web. These and other capabilities provided by this new generation of concept mapping software tools confer a whole range of new opportunities for facilitation of learning, creating, archiving, and using knowledge.

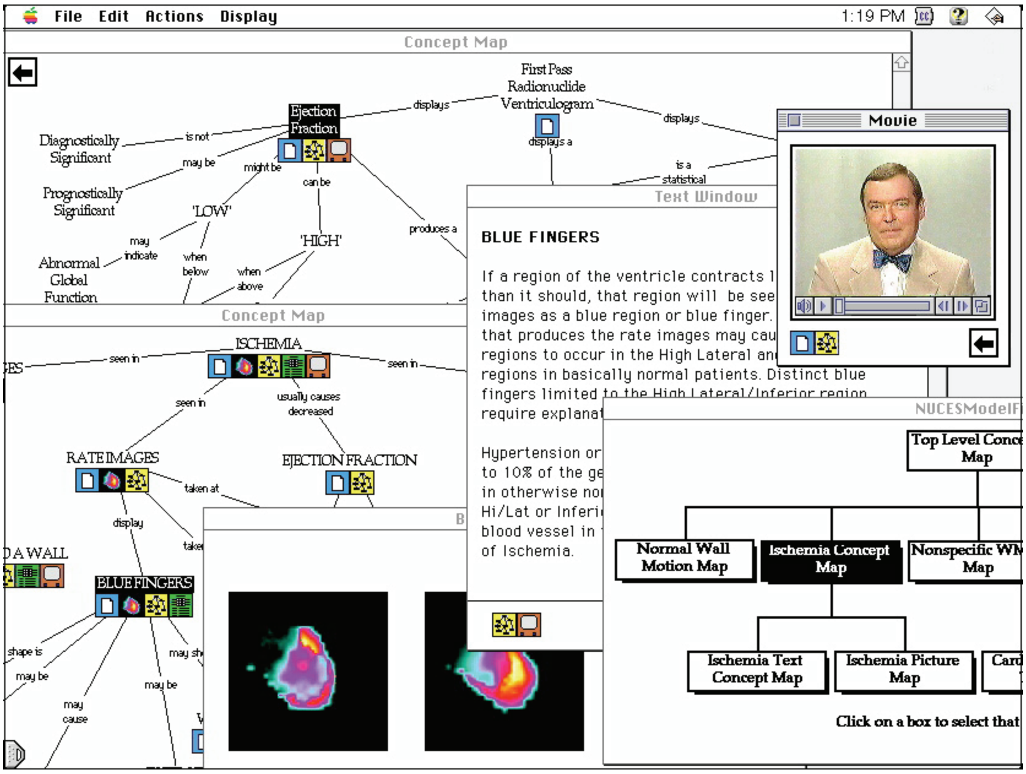

Figure 4. The development of ICONKAT and NUCES demonstrated the use of concept maps beyond education.

3.3 *From Learning by Individuals to Collaborative Learning*

As the Pringles example illustrates, knowledge creation and knowledge utilization is increasingly becoming a collaborative effort. The powerful collaboration tools included in CmapTools can greatly enhance collaborative knowledge building and knowledge sharing. We have proposed a New Model of education based on a concept map-centered learning environment (Cañas & Novak, 2005; Novak & Cañas, 2004) where the concept map is used throughout the development of units or projects to show the increase in understanding as students progress, creating a knowledge models that are incorporated into the students' portfolios, and where collaboration at the classroom, school, national and international level is encouraged (see, for example, Figure 5). As an exemplar of this idea, in Panama we are engaged in the *Conéctate al Conocimiento* project (Tarté, 2006), a nationwide effort lead by the President through the Secretary for Governmental Innovation that aims at incorporating meaningful learning through concept mapping into the elementary public schools in the country. Over 6,000 classroom teachers from over 700 schools have been trained and are using concept mapping, CmapTools, and collaborative projects to transform the way learning takes place in the classroom. Elsa Sanchez et al.'s (2008) "Who Am I?" project demonstrates the sense of community and the power of collaboration, publishing and sharing in *Conéctate*.

The methodology proposed and being implemented in Panama is particularly effective when used in environments with high density of laptops per child, whether its 1:1 ratio (one laptop per student) or through sharing of laptops. Otto Silesky's keynote presentation at this conference is a clear, documented, example of the results that can be obtained.

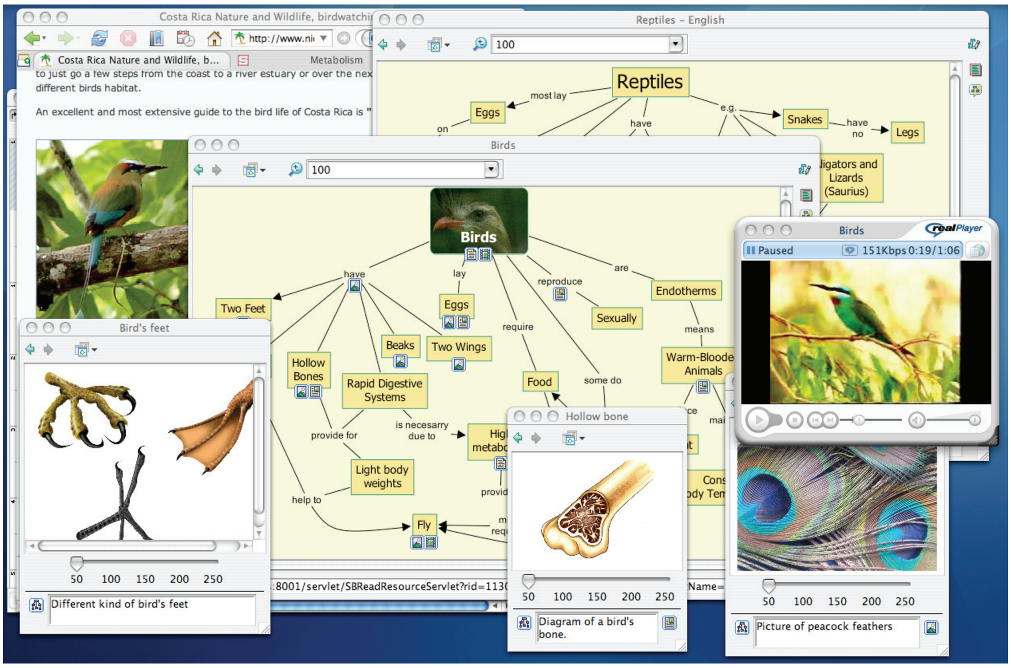

Figure 5. A Knowledge Model on birds shows the concept maps and linked resources.

4 Consolidating the Cmappers Community

After years of spreading throughout all types of organizations and domains of knowledge, we feel confident in stating that concept mapping is used all over the world. The realization of a Third International Conference on Concept Mapping, with many of the participants repeating from the previous two conferences, is proof of the existence of a strong concept mapping community. Papers from all continents and in a large variety of domains further demonstrate the worldwide breadth of the community. From our standpoint, the extended use of CmapTools throughout the world is one more evidence of the far-reaching use of concept mapping. Figure 6 shows the CmapTools clients and CmapServers that connected to IHMC's Directory of Places (DOP) during

2007.[1] Clearly, concept mapping users cover the whole world. Additionally, the *Conéctate al Conocimiento* project is a clear example that concept mapping is growing not only in extension but also in "intensity": in many organizations and countries it's not only a few isolated users that use concept mapping, it's a constantly growing number of users.

We feel that the Cmappers community has grown and matured to the point where we need to further organize and help and collaborate with each other to continue growing. We are involved in three efforts that we open to the community as a means to share and collaborate in a continuing effort to support concept mapping.

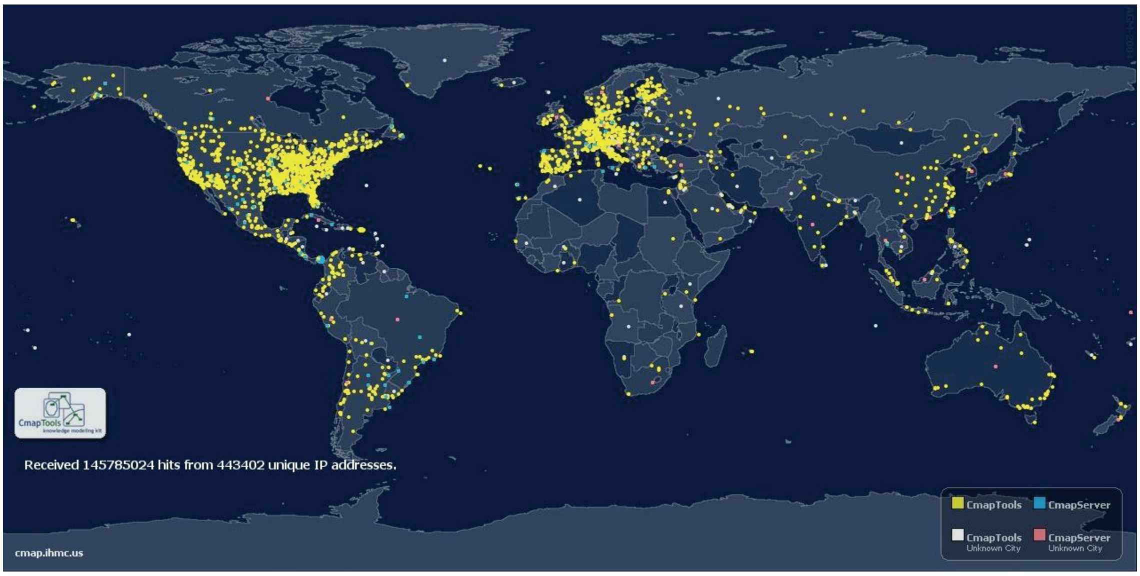

Figure 6. Locations of CmapTools clients and CmapServers that connected to IHMC' Directory of Places (DOP) during 2007.

4.1 A Concept Mapping Training Website

In a collaborative effort, IHMC and Microsoft Corporation are developing a Website aimed at facilitating learning about concept mapping and its applications. The Website will consist of a repository of resources (documents, videos, papers, Webpages, concept maps) about all topics related to concept maps (theory, applications to education at all ages, business, science, engineering, etc.) organized in numerous ways as non-linear *itineraries* by means of concept maps, in such a way that users with different expectations and interests can find an *itinerary* that will fit their needs. This Website will be open to anybody anywhere. We want to invite the concept mapping community to add resources and create *itineraries*. For example, a faculty member in nursing could create an *itinerary* that consists of the resources and activities that he/she considers his/her students should follow. This *nursing itinerary* could then be made public and could be used by people interested in concept mapping in nursing from other parts of the world. Users will rank *itineraries*, and thus those that are well received by students will be ranked high and will show as such on the site. Since learning to construct good concept maps generally requires the learner to receive feedback on the quality of the map, we propose that through forums users will be able to request from the community a volunteer that will help him/her improve his/her concept mapping skills. Through a joint effort, we could together take concept mapping to anybody who is interested with quality training.

4.2 A Student Collaboration Website

Concept maps have been shown to be an effective collaboration tool. While jointly constructing concept maps, students need to negotiate meaning and reach an agreement on the propositions that are included in the map and their organization. Additionally, the concept map is an "artifact" over which the students collaborate, and is itself the result of the collaboration. Teachers and students all over the world use concept maps in the classroom,

[1] The map actually shows the location of the Internet Provider, not the CmapTools client or CmapServer, and therefore does not really correspond to all locations where the software is run. CmapTools clients and CmapServers not connected to the Internet, behind restricted firewalls or configured not to connect to the Directory of Places are not shown.

and many are particularly interested in establishing collaboration with other classrooms. Efforts like Tifi and Lomardi's WWmaps (2006) further demonstrate that through some structure and coordination, collaborative concept mapping projects can be established between schools in different countries, even when there is no common language between the students. In a collaborative endeavor between IHMC, Microsoft Corporation, and UNESP university in Brazil, a Collaborative Projects Website for teachers and students is being developed, that will be open to teachers and students from schools all over the world. By proposing new projects or registering for pre-established projects, teachers will be able to link to other teachers and get their students involved in collaborative projects. We invite teachers from around the world to get involved, with their students, in collaborative concept mapping with students and teachers from other parts of the world through this site. We see teachers first participating in the Training Website and moving on to participate in collaborative projects.

4.3 Publishing and Searching for Concept Maps

Concept maps are an effective way of sharing knowledge among humans. As such, having a good concept map about a subject is an effective way to learn about the domain. A search mechanism that will retrieve "good" concept maps would therefore be a useful tool. There are hundreds of thousands of concept maps constructed using CmapTools and stored in CmapServers that are indexed and therefore searchable (Cañas, Hill, Granados, Pérez, & Pérez, 2003). Concept maps on all subjects are available, but there is no easy way to automatically rank these concept maps to make the searching useful. At IHMC we have created a Website (http://www.cmappers.net) that allows users to "rank" concept maps, in the same way as users rank videos in YouTube or photos in photo sharing websites. We open this Website to the community to collaborate in the sharing and ranking of maps. Through a joint effort, we can provide the community with high quality concept maps on any topic and search mechanism by which to find them. Through publishing and ranking, this collection of high quality maps could grow to cover all domains of knowledge.

5 Summary

Since the early development of the concept mapping tool in the 1970's to represent children's understanding of science concepts, the concept mapping tool has evolved with new computer software permitting easy map construction, incorporation of Internet resources, collaboration in developing and using knowledge resources, and a growing community of users with multiple interests. We see the need now for building new Web sites to facilitate the training of new users, collaboration by students and in refinement of existing maps to improve their quality, and to provide forums for all users to "publish" their maps and receive critical feedback from colleagues, much as exists in the field of literature. The goal is both to expand further the worldwide use of the tool, and to develop mechanisms for improving users skills and the quality of concept map archives.

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PHYSICS CONCEPTS AND LAWS AS NETWORK-STRUCTURES: COMPARISONS OF STRUCTURAL FEATURES IN EXPERTS' AND NOVICES' CONCEPT MAPS

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Abstract. A characteristic feature of physics knowledge is the high degree of coherence and connectedness of its concepts. To large degree physics concepts and laws can be viewed as organized, network-like structures. Consequently, learning can also be seen as the working with and the building of the conceptual networks. It is argued here that a useful viewpoint on learning physics conceptual structure can be developed on the basis that physics concepts can be seen as networks, where the formation of such structures is guided by the meaning coherence of concepts, related to the deductive coherence of concepts themselves and their explanatory coherence with respect to experiments. From this viewpoint, we compare here how experts and novices represent their physics knowledge by drawing concept maps of such networks. By analyzing the topological structure of the concept maps it is shown that experts' maps are characterized by conceptual coherence and hierarchies inbuilt in the network-structures. In novices' concept maps similar features are found in the best cases, but many novices produce maps with poor coherence and a lack of organizing hierarchy. Finally, applications and advantages of the viewpoint emphasizing networked structure of concepts in physics teacher education are discussed.

1 Introduction

Experts' abilities to think and solve problems depend strongly on a rich body of knowledge about the subject matter. The "usable knowledge" of expert is easily recovered and applied, because it is not the same as a list of disconnected facts, instead it is connected to and organised around the most important concepts of the subject (Bransford et al. 2000, Mestre 2001). In education the goal is first and foremost tutoring students to achieve and master knowledge, which is well organised and which has inherent hierarchy. Hierarchically organised knowledge structures make both the deployment of knowledge and the integration of new knowledge as a part of the network easier (cf Novak & Gowin 1984; Mestre 2001). Therefore, instructional strategies that help students to create a hierarchy are advantageous to learning (Trowbridge & Wandersee 1989).

Experts view physics concepts as an entangled web, which links concepts to other concepts, as well as embeds the basic laws of the structure to these concepts. The basic laws are here taken as basic models, which frame certain phenomena so, that phenomena become identified and defined in terms of pertinent concepts. For example, phenomena which belong within Newtonian mechanics are framed out of all possible phenomena by application of the basic law **F**=d**p**/dt (Newton's II law), where all acceptable forces **F** need to be defined in terms of additional auxiliary models of forces, as well as linear momentum **p** being expressed in terms of kinetic models in order to be tractable or even recognizable. Finally, force and linear momentum need to be embedded in a common system of coordinates. In such conceptual systems concepts are far from being independent; instead, they are fundamentally entangled and can be used only with an understanding of their interdependency. In framing out and recognizing phenomena, which can be described and understood in terms of such conceptual systems requires a set of concepts and laws, which are coherent enough to allow coherent explanations, coherent deductions, and coherent analogies within the system (Thagard 1992, 2000). Following the coherentists views (Thagard 2000) we can say that seeking such *meaning coherence* is the guiding principle in constructing acceptable and usable scientific theories, and when found, it gives the satisfaction of understanding.

Learning is also working with and building of the network. In learning, the conceptual systems are, however, acquired rather through instruction than research. When a conceptual system is constructed or acquired one must "*first through instruction and use build up an integrated set of concepts and rules, and second through argument to come to see its explanatory coherence*" (Thagard 1992). It should be noted, that then the explanatory coherence of most importance is the coherence of concepts with respect to experiments. Within the network view such conceptual structures can be represented as concept maps, where connections between concepts are formed through the requirement of meaning coherence consisting of deductive and explanatory coherence. In this study, we have examined the structural features of such concept maps drawn by experts in physics and by novices (students). The structural features are analysed by using graph theoretical methods to find characteristic topological features of the maps and the hierarchical structure of the maps. It is shown that experts' maps are characterized by conceptual coherence and hierarchies, which are inbuilt in the network-structures. In novices' concept maps similar features are found only in best cases. Many novices produce maps with partial coherence and severely fractured organizing hierarchy; in some cases there is no structure at all. The notion, that structural features of the concept maps are so closely connected to expertise has interesting implications for physics education. Finally, we discuss the applications and advantages of the viewpoint emphasizing the networked structure of concepts in physics teacher education.

2 Coherent knowledge structures in physics: Networks of concepts

In physics the structure of knowledge has a certain hierarchy built in it, although the hierarchy is not necessarily a strict one. Traditionally the organisation of knowledge in physics its laws - relations between concepts - is also seen as hierarchical; the uppermost level contains the major principles, and the lower level laws are subordinated to these more general principles (cf. Duhem 1954, Campbell 1920). In more recent views, this idea of hierarchy and connectedness is inherited by the model structures, which are thought to form the basic knowledge structures of physics (Giere 1999).

2.1 Coherence of knowledge

In the coherentist account of knowledge (see e.g. Thagard 1992, 2000) explanatory coherence is central for the epistemic justification of knowledge. Explanatory coherence is obtained when hypothesis and propositions are made to cohere what they explain, also those hypotheses that together explain something, cohere Such coherence is obtained as constraint satisfaction (Thagard 1992). The concept- and theory-structures get their epistemological credentials mainly from their explanatory coherence. In conceptual systems there are usually different possibilities for the use of concepts and models to understand certain target phenomena. In this it is possible to find different mappings between a source and target, and the found coherences in mapping hypotheses. This is referred to as analogical coherence. Analogical coherence, when achieved, enhances explanatory coherence. Finally, there is deductive coherence, where the cohering elements are mathematical propositions, axioms and theorems. Deductive coherence has a close resemblance to explanatory coherence, because some explanations are deductive (but not all). The coherentist account of knowledge leads naturally to the idea that the connections between concepts and the nature of the principles linking the concepts is of central importance in establishing the meaning of the conceptual system. Thus, attempt to establish coherence is the driving force behind the evolution and modification of conceptual systems (Thagard 1992, 2000).

2.2 Conceptual hierarchy as network

Based on the coherentist view of knowledge, Thagard suggests that concepts are complex network-like structures, where a special role is given to interrelations between concepts. This viewpoint emphasises concepts as parts of ordered knowledge structures or networks; they cannot be defined semantically or in isolation of other concepts; '*rules connected to concept are parts of them as well concepts are part of the rules*' (Thagard 1992). These kinds of systems can be analysed as a network of nodes where each node corresponds to a concept and each link corresponds to a relationship between concepts (Thagard 1992, diSessa & Sherin 1998). A conceptual change can then be seen as adding or deleting new nodes or creating new links between the nodes. Within these structures it is possible to distinguish part and kind hierarchies, which organize the whole system. Most notable changes involve changes in the hierarchies, and this change is associated with the restructuring of the links. According to Thagard, the most important feature of the hierarchies is that they not only organize the structures, but they create and define ontologies by specifying the constituents of world and their relation to each other. This entangled web of concepts and rules also makes it possible to apply concepts in different situations for providing explanations and making predictions. The meaning of concept emerges not only when learning the definitions and rules but also in the ways of applying the concepts and rules when solving various problems (Thagard 1992).

In the formation of the conceptual network the rules of formation or the rules used to attach new concepts and laws in the network acquire a crucial role. This is largely a methodological question and should not be overlooked, because in physics certain methodological principles need to be acknowledged in order to justify the knowledge. One central method of physics is to integrate new concepts in the framework through experiments, where the concept is operationalised and made measurable through the pre-existing concepts in the network. These experiments are quantifying experiments where quality is transformed to quantity (c.f. Duhem 1954). Quantifying experiments also form new relations between quantities in network and thus new experimental laws (Duhem 1954, Campbell 1920). It is through these quantifying experiments that the hierarchy of network is constructed. Therefore such experiments acquire an important methodological and epistemic role in physics education and they actually contribute to constructing the meaning of concepts (Koponen & Mäntylä 2006). This view, which puts weight on the logic and methodology of physics knowledge formation also forces an unavoidable hierarchy on physics knowledge. Such a hierarchy is quite often taken to be an unquestionable and characteristic feature of physics knowledge (see. e.g. Thagard 1992, Giere 1999).

3 Constructing the concept networks

Learning is also working with and building networks. It becomes a continuous conceptual change where new systems are obtained by addition and deletion of nodes, agglomeration of branches of the network, or restructurisation of the network as a whole (Thagard 1992, diSessa & Sherin 1998). The elements and rules, which are used to construct the networks are summarized below as the *nodes* and *edges* the network is made of.

Nodes. The structural elements, which are nodes of the network can be:

1. Concepts or quantity.
2. Laws, i.e. particular laws or law-like relations.
3. Fundamental principles.

Of these elements, laws could be taken as particular experimental laws or law-like predictions in specific situations (derived from theory). Fundamental principles are the highest-level principles or axioms of theory.

Edges. The rules to make connections create edges. Each edge is a well-defined procedure and can be:

4. A Logical procedure, which are definitions or logical deductions.
5. An experimental procedure, which is operational definition or demonstration.

These procedures are represented as links connecting concept and create edges (links) on the representation. Adopting these rules for the construction of the graphs restricts the possibilities of what kinds of knowledge can be represented in these graphs. However, the experts agreed that although this is a restriction, it is not too severe and does not prevent us from displaying essential and useful information in the graphs. In addition, it should be noted that the adoption of any rules for the construction of structures always forces on these structures a certain order or even hierarchy. However, if the rules are not alien to the knowledge we want to represents, such structures and hierarchies may well be truthful enough for the structure of knowledge we want to reveal. The most severe restriction of these representations is that our conceptual structures will be limited to laboratory phenomena and experiments. Such structures will at best have explanatory coherence only for those experiments, which are included as procedures. However, without extending the conceptual framework to provide explanations for real phenomena, we cannot actually show how the explanatory coherence on a larger scale is acquired. In addition, the logical procedures provide the deductive coherence. In what follows, we will use the term *meaning coherence* to describe this combination of explanatory coherence, which is restricted to laboratory experiments and deductive coherence.

4 Applications of network-view: Expert's and novice's knowledge structures compared

Three experts, who are physics instructors, were given the task to represent connections between concepts of electrostatics. The experts were familiarized with idea of representing the concepts and laws as a connected network-like structure. In effect, they were asked to produce a concept map collaboratively of the pertinent knowledge elements. In order to have representations which could be evaluated and analysed as unambiguously as possible, the experts were introduced to the use of rules for connections (links or edges) and rules to make distinction between different entities in map. Because the experts were familiar with the idea of concept mapping and had used it in their teaching to some degree before, the methods and ideas for drawing such representations was familiar to them. In what follows, it is important to note that although the rules adopted to construct the maps are restrictive, they do not prevent the display of relevant physics knowledge. This means representing that part of the expert's knowledge, which has the meaning coherence allowed by logical and experimental procedures coded in the edges. Novices' maps are then compared against the expert map, and then similarities between the expert map structures can immediately be taken hallmarks of good content, and severe deviations as hallmarks of deficient content. In this way, structures and comparison of structures also give us information about the quality of the content. Of course, more detailed content analysis, which is independent of the structure, would give more information about the quality of knowledge represented by the maps. However, at present we are concentrating only on the structural aspects only.

4.1 Structure and meaning coherence of expert's map

Following the rules outlined above, experts produced a preliminary map, which they then after discussions modified over several stages. The final version which they agreed on and which they thought contained the essential elements of electrostatics is shown in Figure 1. In this representation, following rules for nodes and edges is shown concepts (boxes), laws and principles (boxes with thick borders), definitions (D) and logical deductions (L). In addition, a conceptual (geometrical) model is shown as ellipse, and entity like objects as rounded boxes. Of the procedures, only the operationalising experiments are shown (E), and in most cases the demonstrating experiments are similar ones, but the directions of the arrows are reversed. The detailed content of the experiments is not important here, it is sufficient to know that they are mostly standard student laboratory experiments done in the context of electrostatics. The interesting feature of the expert map is the high connectivity of concepts and the tendency of some concepts to attract edges. However, a more detailed analysis of the maps is difficult without methods to analyse the topology of the maps.

The previous study by Reichherzer and Leake (2006) of the structure of a concept map as it relates to the content of the map have shown that the relevant information of a central concept can be extracted from topological information, even from average measures like the root distance and the connectivity of nodes characterizing the topology (Reichherzer & Leake, 2006). Topological taxonomy has been used also by Cañas et al. (2006) to classify concept maps and to evaluate their quality. However, whereas Reichherzer & Leake use metrics emphasising connectivity of nodes, Cañas et al. pay attention to measures related to branching. In what follows, we propose a topological analysis which simultaneously takes into account node connectivity as well as branching. Moreover, global topological features are in focus, and possibility to transform maps from one layout to a topologically equivalent layout for better recognition of central features.

The topology of the expert map can be examined more closely by using the methods of graph theory. The steps followed to analyze the structure are:

- coding the map to a connectivity matrix
- using the matrix to redraw the map as a hierarchically ordered tree

The coding of the map nodes and edges is done by using only the binary values 0 and 1, so that no other qualities but the existence of connection and its direction are coded, but no other qualities. In fact, the information of the directedness is not taken into account, because it is not needed in order to show the primary features of the topology. Of course, in more detailed analysis, when also type of the edges is considered, the directedness of edges is of central importance. However, in this works only the primary features of topology and the possibility to transform the maps in different topological forms and the advantages of these transformations are of interest.

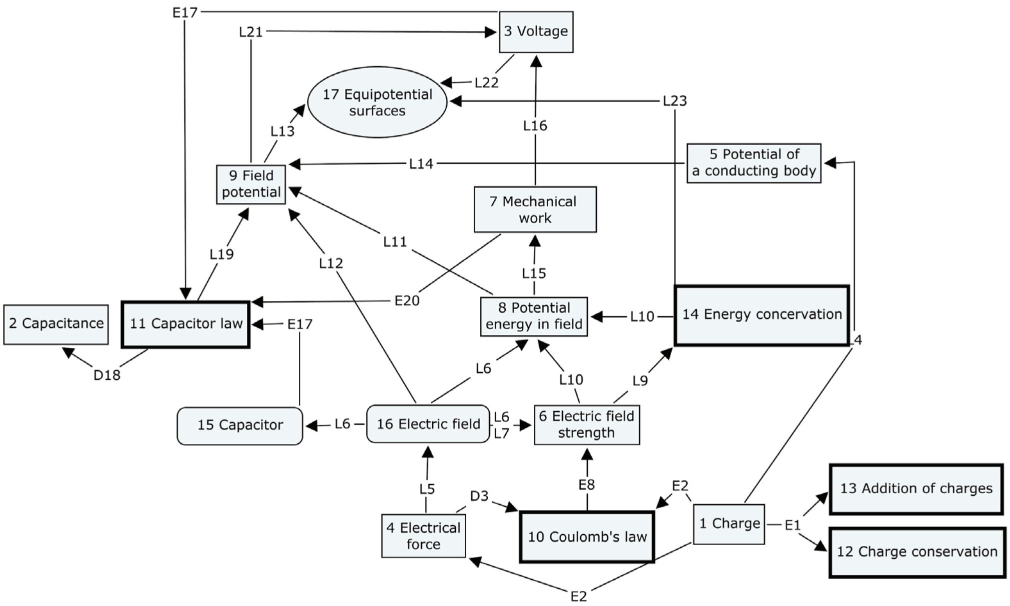

Figure 1. The experts' map for the concepts and laws in electrostatics. The map is shows concepts (boxes), laws and principles (boxes with thick borders), definitions (D) and logical deductions (L), and operationalising experiments (E). Conceptual (geometrical) model is shown as an ellipse, and entity like objects as rounded boxes.

The redrawing and transformation of graphs was done using COMBINATORICA (Pemmaraju & Skiama 2006), which allows using different rules to redraw the maps and to compare their topological features. Using well-defined rules to represent maps removes the ambiguity associated with personal styles for doing the layout of the maps. In addition, the transformation of maps in different forms to detect hierarchical structures hidden in the connections becomes much easier. The advantage of COMBINATORICA is that it is based on well defined and established graph theoretical concepts, and it is freely available.

In analyzing and redrawing the concept maps we used two different graph-embedding methods, which produced webs- and tree-like structures.

Webs. Maps are redrawn as undirected structures but so that the “energy” of edges (edges taken as springs with tension) is minimized while “entropy” (nodes are located as far from each other as possible) of the structure is maximized. This reveals how tightly certain concepts are tied together. The coherent map should not then break up into distinct loosely connected branches or chains instead it should resemble a web-like structure.

Trees. Maps are redrawn as an ordered hierarchical tree, selecting a certain node as a root. Then nodes and edges are rearranged so that nodes that are equidistant from the root are on the same hierarchical level. The coherence of the structure is now reflected as distinct hierarchical levels, with many interconnections within each level. It should be noted, that a hierarchical tree without intra-level connections is not coherent and meaningful.

The expert map redrawn as a web and tree-like hierarchical structure is shown in Figure 2. From these redrawn maps we can see that the expert map contains hidden hierarchies when a physically relevant concept is chosen as a root concept. This, of course, is as expected, because the map is drawn following physically meaningful rules, where concepts and laws follow either from well defined experimental procedures or from logical procedures. Therefore, it is important to understand, that the organized structure and with a well-defined hierarchy with clearly recognizable hierarchical levels is a direct consequence of physically meaningful and coherent content. The rules build on the structure the meaning coherence and meaning coherence is thus recognized through structural characteristics and through hierarchy.

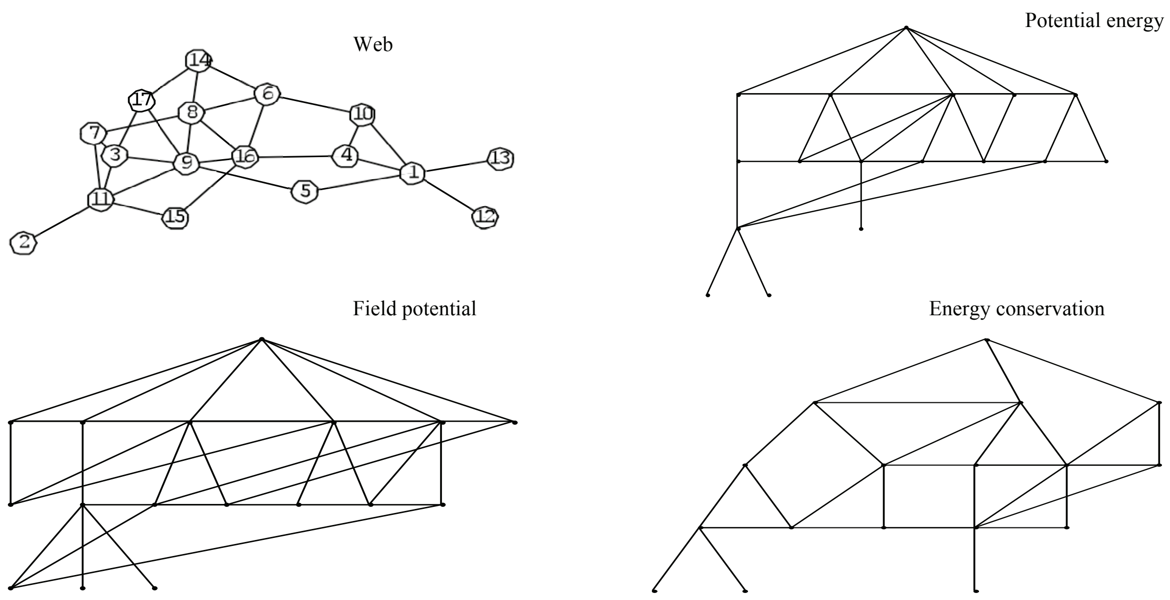

Figure 2. Web-structure (upper left) and tree-structures and hidden hierarchies in expert map

4.2 Structure and coherence in novices’ maps

The students’ map are analysed following the same principles as expert’s map. The students who produced the maps had studied the standard first year university courses on electricity and magnetism and electromagnetism, but they had not done any advanced studies. Therefore, the student maps are expected to be more like novices maps. The students drew maps for the connections between concepts of electrostatics in a teacher preparation course (third year studies). The students were given a list of concepts and laws that contained all the same concepts and laws as our expert map. On the basis of the list, the students were asked to represent the connections and also to define the nature of the connections, i.e. whether they were experimental procedures or logical procedures. All the students were already familiar with concept mapping and the use of concept maps.

Students produced the maps in groups and we got a total of 20 maps. The maps were analysed using the same methods as used for expert map. First a connectivity matrix was produced, which was used to redraw the webs and trees using COMBINATORICA. On the basis of their structure the maps were classified into three classes according to their structure. In this classification, the overall structure (connected webs, loose webs and chains) and hierarchy was used as the basis of classification. In these three classes, we can see the typical features of student maps.

Connected webs. In case of connected webs the topology of redrawn maps as webs is rather similar to that of the expert map. The web seems to be tightly connected and there are no clearly separate branches. Looking more closely at the hierarchies contained in the maps, it becomes evident that there is number of relevant hierarchies, where concepts are coherently connected. One example is shown in Figure 3 (I). In comparison to the expert map we can however see that the hierarchies are not as well defined as in the case of the expert map, and the hierarchies are partially broken. This reveals that not all possible coherent meanings are contained in the map. This kind of map, although not yet as comprehensive and coherent as the expert map, shows already a mature understanding of the structure of a concept web and it allows many coherent meanings to be represented. The map has significant meaning coherence.

Loose webs. In some cases student maps have a topology that consists of connected webs as subsets, but the subsets are loosely connected. These kinds of webs shown in Figure 3 (II) we have called loose webs. The fragmentation of map to subsets reveals that some important connections are missing. This deficiency is also seen in tree-like redrawn maps, where hierarchies are now severely broken, as can be in lower panel in the example in Figure 3. In comparison to connected webs, these loose webs thus have significantly less inbuilt meaning coherence inbuilt than connected webs.

Chains. In some cases, the structures are not webs, but rather consist of linear branches that resemble chains or weeds, as shown in Figure 3 (III). In these structures, there is very little connectivity. Hierarchies in these cases are trivial branching hierarchies, with no intra-level connections. The missing connections are directly connected to poor relatedness between concepts and weak coherence between concepts. These structures lack the meaning coherence and are not adequate representation of conceptual structure.

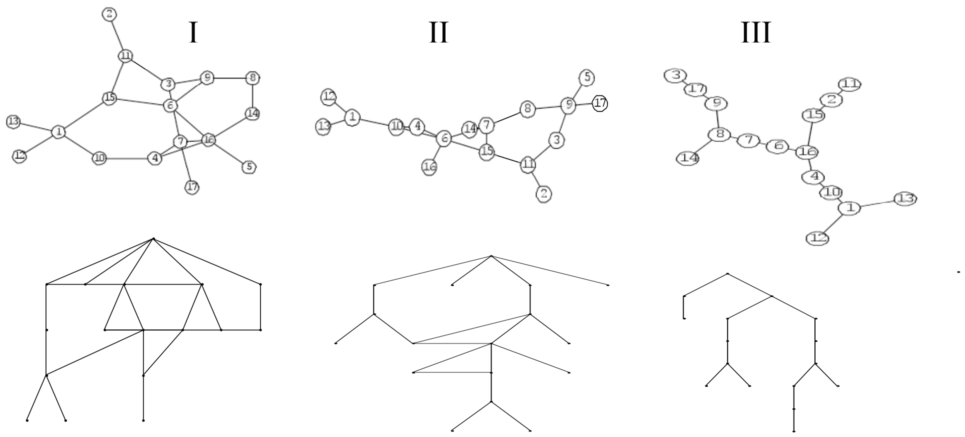

Figure 4. Connected webs (I), loose webs (II) and chains (III). An example of a typical tree-structure corresponding each type of map is given in lower panel. Only for connected web hierarchies can be found, for other structures the hierarchies are severely broken.

The classification of structures in connected webs, loose webs and chains brings forward the notion that meaning coherence inbuilt in the structures is reflected on the overall topology. This connection comes from the fact that meaning is constructed through the creation of edges (creation of links), which we required to have a specific meaning: either experimental or logical. In absence of these meanings, it is not possible to establish the connections. This simple notion underlines the importance of attributing a definite meaning to each link. Just drawing a line without specified meaning is void of meaning, not interpretable and ambiguous. It should be noted, that now the attributes attached to edges are not simply verbs or expression making it possible to form a sentence, as in case of ordinary concept maps. Instead, the links represents procedures, which we can perform. Therefore, links contain essential knowledge about the methods of physics concept formation.

The differences in expert's map and novices maps can also be seen by calculating some characteristic measures for the maps. First, we can classify the nodes as hubs, junctions and outliers. **Hubs** are important connecting nodes, which tend to collect edges, and have more than two incoming/outgoing edges. **Junctions** are nodes that have at least one incoming and one outgoing edge to two different nodes, so that the removal of junction will break the network in two pieces. **Outliers** are simply terminal nodes, which have no role in connecting parts of the network. In Table I is listed the relative fraction of hubs, junctions and outliers in the expert's map shown in Figure 2 and in the novices' maps shown in Figure 3. In addition, we have calculated the degree of hierarchy as an average number of hierarchical levels per physically meaningful root concept.

	Expert	Novice I Connected web	Novice II Loose web	Novice III Chain
Hubs	0.7 (12)	0.6 (9)	0.4 (7)	0.2 (3)
Junctions	0.2 (3)	0.3 (5)	0.4 (7)	0.3 (5)
Outliers	0.1 (2)	0.2 (3)	0.2 (3)	0.5 (8)
Hierarchy	4.4	2.6	1.6	1.0

Table I: Relative fraction of different types of nodes and the degree of hierarchy of the expert's map and novice's maps I-III. Total number of each type of nodes is given in parenthesis.

The results in Table I show that there is clear correlation between the connectedness of the map and its degree of hierarchy. By classifying all the novice's maps we found that in class of connected webs, the hierarchy degree is on the average 2.5, loose webs have 2.0 while chains score only 1.5. So there is a correlation between the topology of networks and their inbuilt hierarchies.

5 Discussion and conclusions

The notion that there is a clear connection between the contents of the maps and their structures may seem rather trivial and just agree with our most obvious expectations. However, if we ask how a good structure can be recognized, and on what aspects we need to pay attention to, the situation is not so simple. An often used criterion in traditional analyses of concept maps an often used criterion is the number of cross links and the requirement that links have some verbs or attributes attached to them (see e.g. Slotte & Lonka 1999 and references therein). In our case, these requirements are simply insufficient and could not lead to meaningful evaluation of the maps. On the contrary, just increasing the cross links would not improve the meaning coherence, if there are no reasonable and physically sound procedures for the creation of links. It is essential to note, that in our case nodes are not connected on basis of associations but rather on basis of well defined procedures. Similarly, the requirement that edges make the connected nodes as propositions, which can be verbalized (Ruiz-Primo & Shavelson 1996), is not appropriate for our purposes of representing physics concepts and laws, because it would mean diminishing the meaning content of the link.

The analysis we have done here suggests that if we have rules to create edges and the rules which are based on procedures, we will have representations, where content and structural aspects are strongly coupled. The structural and topological characteristics of maps have a resolving power, so that three qualitatively different types of networks can be distinguished from novices' maps, and these can be compared with an expert's map. It is found, that the topological connectedness and richness of hierarchical structures organized by physically meaningful root concept are hallmarks of rich meaning content. The hierarchy, on the other hand, is seen to be connected to the general topology and appears only in structures that are connected webs. These notions can be easily embedded and made understandable within the framework of the coherentist view of knowledge, as advocated by Thagard (1992, 2000). In this view, knowledge and concept and principles associated with the knowledge obtain their credibility, reliability and truth from the coherence of the structures. In that explanatory coherence is of central epistemic importance, because it connects the structures to reality. In our case, the networks contain explanatory coherence in a restricted sense; only with respect to experiments and experimental procedures (the standard student experiments used in teaching) connected to the links and in addition deductive coherence connected to logical procedures. Together these coherent features provide the map what we have here called meaning coherence.

However, the meaning coherence defined in that way is much reduced form of all possible forms of coherence (c.f. Thagard 2000) found in scientific knowledge. In the present case we have deliberately restricted the scope of explanatory coherence in order to make the structures here more tractable and yielding to detailed analysis. In future, of course, in order to extend the conceptual structures to cover broader areas of phenomena and not only laboratory experiments and laboratory phenomena, we should make a similar representation of concepts and laws as applied in giving explanations of real complex phenomena. However, it is evident that such an attempt would be far more demanding than the case studied here. Nevertheless, the analysis given here and the way the connections are build in show there is a direct connection between the topology and hierarchy of the maps and their meaning coherence; maps with good meaning coherence have rich internal hierarchy and well connected topology. The analysis carried out here has taken into account a certain minimal meaning content of edges, and more thorough analysis of meaning content is needed to make further progress. A promising combination is a structural analysis combined with e.g. semantic analysis of content (see e.g. Cañas et al 2006).

An interesting possibility contained in network view is its potential for uses to monitor conceptual development. Within the network view conceptual development takes place through addition and deletion of nodes and edges in the structure, and the driving force behind this is the acquisition of a better meaning coherence of such structures. Thagard (1992) has applied the network-view to understanding the historical conceptual change or historical conceptual revolutions, and it seems that in this case the network view leads to a deepened understanding of how explanatory coherence guides the evolution of the conceptual structures. In Thagard's work the focus is on addition and deletion of nodes and in restructirization of links, both processes being driven by constraint satisfaction for better explanatory coherence. It is quite evident, that similar description also could be possible in learning and in monitoring the learning, and in finding typical features of the conceptual change during learning. The directions seem to open up promising ways to improve traditional physics teaching and instruction, and to develop concept mapping and concept maps which are truly useful representations for expressing physics knowledge, its structure and the relation of structure to methodological procedures. Such an extended view on concept maps escalates the maps from tools of thinking and reasoning in the personal cognitive realm to a more inter-subjective level, where they begin to share more and more structural aspects and contents of physics knowledge itself. In this form they can eventually begin to function as effective learning tools also for learning the real content knowledge of physics in higher education

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PICTORIAL SCAFFOLDING IN THE CONSTRUCTION OF SCHEMA OF CONCEPTS

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Abstract. The learning obstacles experienced by community college students in the Bronx in mathematics classes have been reported in several issues of the online Teaching-Research Journal on Line. (MTRJoL, 2006-2008) Over the course of the teaching research studies utilizing the Teaching-Research/NYC model, it was found that students absence of assured success is caused by absence of independence of learning, difficulty getting started, absence of procedural skills such as multiplication facts, all of which contribute to weak problem-solving skills which in turn create obstacles in students' capability to adopt a problem-solving approach to learning the very basic mathematics in question. The Discovery-based Instructional Sequences utilized in our classrooms are designed from the point of view of facilitating the construction of a schema among students, with a steady emphasis on the Zone of Proximal development of Vygotsky as the theoretical framework. Concept Maps can be useful in several different ways as are described in this paper. The use of concept maps in the TR-NYC approach are for the construction of the schemas of concepts that either students' or teacher-researchers are trying to grapple with, and this two-fold use of the concept map illustrates a part of the way the TR-NYC methodology works, from theory to practice and practice to theory, a bidirectional route.

1 Introduction

Understanding of concepts is a common theme of study across disciplines. In particular, the study of how concepts are understood is undertaken in mathematics education, mathematics, cognitive psychology, artificial intelligence, pattern recognition, and man-machine cognition. This article describes such a cross cutting approach that learns from each of the disciplines in the pursuit of increasing understanding of mathematics among students of remedial classes in the community colleges of the Bronx. The concept of fractions has unfortunately become a topic which students' young and not-so-young love to hate. A large-scale study (PROMYSE, 2006) consisting of 200,000 students in 60 districts across Ohio and Michigan reporting on the low passing rates of third through twelfth graders on a fractions test points out to some of the sources for the troublesome situation.

While mathematics in general and particular mathematics topics, including fractions are intriguing puzzles, their intrigue might remain inaccessible to students given their prior experiences in mathematics. Moreover, this "deficit" is detrimental as the PROMYSE study continues to draw our attention to: "*They are not learning enough to prepare them for the world they will face. They are not getting a chance to do all that they are capable of. In important ways, they are not making the grade even while they make their grades.* " (PROMYSE, 2006).

The role of the instruction in remedial mathematics courses at community colleges in this situation is to help students to re-construct, or in many cases, to construct the new schema of fractions. Generally, the schema is the network of the relationships between different components of the relevant concept, in this case, of a fraction. Once students are aware of the connections and of the procedures which participate in making these connections their knowledge can acquire a robust character, they "see" the fraction in its many manifestations.

In the NSF-ROLE #0126141 study (2002-2006), Introducing Indivisibles into Calculus Instruction, concept maps were envisioned as assessment tools, and this was based on the use of concept maps in science education as a research tool in the original work by (Novak and Gowin, 1984), although they were also seen before as chapter guides to some mathematical monographs written in the Bourbaki spirit. They are intended "as a graphical representation of the psychological structure of knowledge within the subject producing the map" (Novak and Gowin, 1984).

Concept maps discussed in this article represent a ready-made schema of general arithmetical relationships (Fig. 1), of Place Value (Fig. 3) or of the decimal fraction (Fig. 4). Our instructional task is to help students to understand these relationships and to make them their own, "to own them", to interiorize them. The question is how to do it?

In terms of the theory of instruction of Bruner, what one needs here is the outline of "how what one wishes to teach can be best learned, with improving rather than with describing learning." The theory of instruction needs to specify the ways in which a body of knowledge should be structured so that it can be most readily grasped by the learner, and it should specify the most effective sequence in which to present the material to be learned. We employ here Vygotsky's concept of the Zone of Proximal Development (ZPD) defined as the conceptual distance between what the student can understand by herself alone and that what she can understand with the help of the mentor, or peer discussions. The boundaries of student ZPD's are outlined by the spontaneous concepts of the learner, and the scientific concepts established by the profession, and the role of instruction is to create the conditions when the two can integrate with each other. The role of the instructor here is to choose the problems and questions, which, by a proper cognitive challenge help students to grasp needed relationships.

Hence, our attention has been focused on utilizing the power of concept maps, as ways of assisting learners in the construction of the schema of concepts from the bidirectional route:

- From spontaneous to scientific
- From scientific to spontaneous

Further, our use of concept maps is also to alleviate the difficult gap between procedural and conceptual understanding, which must be developed hand-in-hand.

In this article, the use of concept maps is demonstrated in the following ways:

1. as a means by which to provide students a snapshot or big picture,
2. as a way for teacher-researchers to design the problems in the instructional sequence (The structure of the concept map representation of the schema outlines the pedagogical design which will be taken in the course.)
3. as an environment within which analysis of word meaning can begin and progress toward a shared understanding (Bruner, 1990)

2 Facilitating Schema Development

In each case the process of meaning-making is facilitated by the use of the concept maps as pictorial scaffolding. Organization of mathematical knowledge which for students in college-level basic mathematics courses has been difficult is enhanced via the pictorial scaffolding of the concept maps. The concept map of the course in Figure 1 below serves as the organizing element for students throughout the semester. The concept map in Figure 2 serves a different purpose. Its aim is to aid the teacher-researcher in the design of the instructional sequence. Figure 3 has the aim of clarifying and reinforcing the process of working with numbers that involve decimal points.

The best way to discuss the schema development here is in the context of the procedural/conceptual divide known in mathematics education. There is a break between learning the procedure and understanding the concept this procedure relates to. Vygotsky's (1987) theoretical perspective offers clear solutions. All learners, especially students in remedial classes possess intuitive or "spontaneous" concept knowledge, which contains elements of different arithmetical procedures. On the other hand, the teaching environment has as its focus, the creation in the mind of the student, an understanding of the mathematical or "scientific" concepts. These latter concepts are those used by the profession as the working knowledge. Vygotsky's theoretical viewpoint as used in the TR-NYC methodology of Teaching-Research projects in the Bronx colleges takes on the investigation of creating the needed scaffolding from the diagnosed spontaneous knowledge to the required scientific via the Discovery approach (Czarnocha, Prabhu 2007a). Hence the possibility of integrating the spontaneous procedures with the mathematical, scientific concepts they are related to.

A Discovery-based development of instruction that progresses from spontaneous to scientific with clearly articulated conventions or embedded concepts used as basis by the mathematical community allows students to construct the desired concepts with validation at each stage of the mathematical truth of the concept in question, while one that misses the important middle step might lead to deep misconceptions that are difficult to clarify and which leave scars that have multiple repercussions. An example of such a mathematical concept is that of irrational numbers. An important hallmark of the irrational numbers was proposed by (Dedekind, 1901), viz., the Dedekind cuts. A Dedekind cut is

> *"If all points of the straight line fall into two classes such that every point of the first class lies to the left of every point of the second class, then there exists one and only one point which produces this division of all points into two classes, this severing of the straight line into two portions."*

The concept is difficult, often considered "higher mathematics" and as such out of scope of most elementary books of mathematics. However, many of those same expositions assume Dedekind's construction and a corollary, which while not explicitly stated is also not stated to be an assumption. The corollary states that there is a one-to-one correspondence between points on the geometric line and the set of real numbers. This assumption is difficult for students to comprehend. Hence, there appears in the exposition a jump or gap in the reasoning process. A logical step is missed and when this is not clarified, it creates in the mind of the learner a difficulty in navigating towards the conclusions that follow. Student schema of rational numbers contains then an unnecessary break in its structure. However, in the TR-NYC approach, when the appropriate connections, are explicitly articulated, students difficulty with the navigation of the concepts and understanding of the numbers of the number line significantly improve (Prabhu, Czarnocha, 2007).

Such an approach, integrating theory and practice on a continuous on-going basis requires that the failures/inadequacies in the constructions we had imagined would occur but did not, are open to our scrutiny and this scrutiny is quick, since the classroom of students needing attention, shortage of time, etc., continues without respite. So, if the needed help to students in their learning has to be provided then it is imperative that the teacher-researcher knows what to do, and knows what to do in short amounts of time. It is this blending of theoretical and practical perspectives that concept maps are very useful. The concept map provides a mediating tool with the help of which a student can be helped to develop the full concept she is studying. The analysis of meaning of words/concepts and of their connections to each other helps to create the model of the "scientific concept" in the student's mind. Creation of such mental models is particularly suggested by ZPD framework of the Vygotskian theory; it forms the upper level of student ZPD's, which, with the help of careful analysis of word meaning, and Bruner's theory of instruction, explains all the mathematical conventions present in the map, to anchor that "scientific concept" in students' minds.

Such a model is important in the context of students in community colleges of the Bronx because they are missing many components of the mathematical knowledge and linguistic knowledge and that absence makes it especially difficult to traverse the full developmental path by themselves.

3 Instruction

In the middle of the semester, close to the early part, a very bright student with a learning disability, questioned on seeing the concept map shown in Figure 1 below. "This is our syllabus"? After a few moments, in a very disbelieving voice, he asked again, "Are you serious, this IS our syllabus?" When enquired why he would have this question, he replied he had never imagined a syllabus as a picture. Cliches about pictures are well-known, however, the concept map serves an important role for students. It brings bring back the belief that Mathematics is not overwhelming, that it is not "a bunch of stuff to be memorized", but rather that Mathematics is about big ideas deeply rooted in us which have stood the test of time, and are being scrutinized. Students and teacher-researchers together take up the concept map syllabus as a tool by which they

- navigate their teaching throughout the semester, altering the concept map as needed should such a need arise
- test their developing understanding
- communicate with each other in meaningful ways across a non-intimidating medium where words are few and sense can be made easier and quicker of what the other is trying to say.

The concept map in Figure 1, which appears on the first page of the Instructional Sequence, Story of Number (Prabhu, Czarnocha, 2007), serves the purpose of providing a snapshot of the schema of the concepts in question in the course. Knowing that a fraction is a number is an important new realization for some community college students. Understanding a fraction as division, as part of a whole, as decimal and percent asks a lot of the student, and such a map can help in grasping that concept through its many representations. The concept map is repeatedly visited throughout the semester. Thus, students used to seeing no connection between fraction, percent and decimal now have the capability of creating and seeing the created connections through classroom instruction. The underlying proportional reasoning inherent in the interrelated concepts takes on new meaning as a mechanism or tool whose use can be extended to situations where students would have had difficulty knowing how to begin the process of attempting a solution.

The concepts maps in Figures 2, 3, and 4, are utilized explicitly as schema building tools, directed primarily to students as conceptual scaffolding, and are examples for the development of students' schema of thinking. According to Skemp (1987), schematic learning provides a triple advantage over rote memorizing in that we are:

1. learning efficiently what we are currently engaged in
2. preparing a mental tool for applying the same approach to future learning tasks in the same field
3. when subsequently using this tool, we are consolidating the earlier content of the schema.

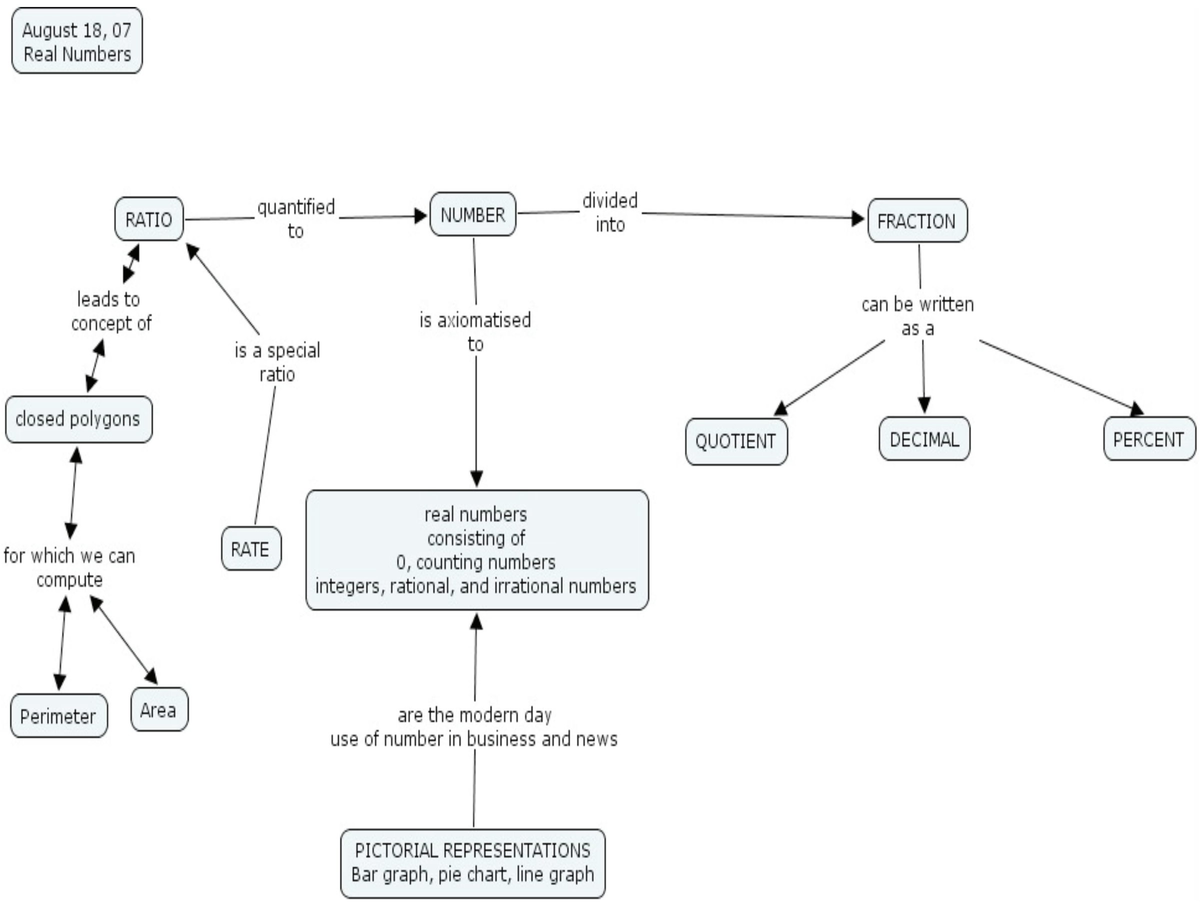

Figure 1. Concept Map that provides students a snap-shot of the course

The pictorial nature of the concept map as illustrated below assist in accomplishing all three points. Furthermore, the importance of learning based on the schema is stated by Skemp (1987) as follows:

A schema more than a concept, greatly reduces cognitive strain. Moreover in most mathematical schemas, all the contributory ideas are of very general application in mathematics. Time spent in acquiring them is not only of psychological value (meaning that present and future learning is easier and more lasting), but of mathematical value as well.

The concept maps below are thus to be viewed as the seeds of schema formation.

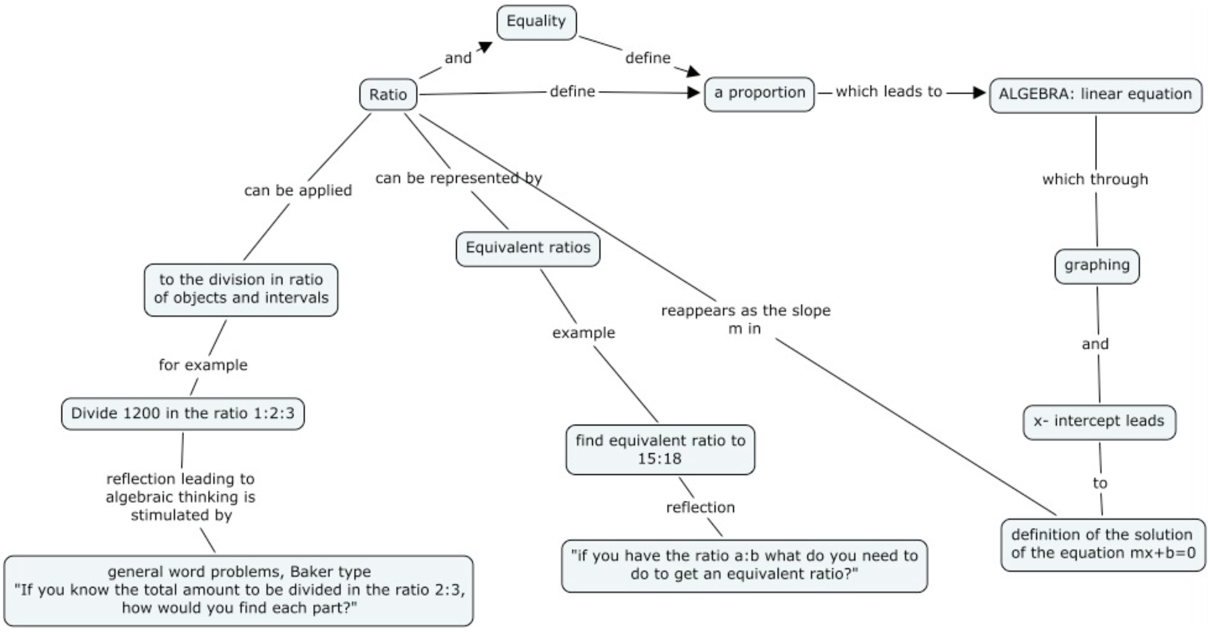

Figure 2. Methods of algebraization of the concept of a Ratio.

In the concept map above, the concept of the ratio, changes its role from a basic concept in the schema of a number (Fig.1) to its own subschema in (Fig.2), which indicates steps of fine level approaches to the algebraization of an arithmetic problem – one of the central themes of the arithmetic/algebra divide, which cause many problems both in schools and community colleges. Also a guide for the development of the instructional sequence, here it indicates the need for the separate concept of equality to be introduced, while at the same it is re-asserting its central position by reappearing at the end of one of the branches of algebraization process as the slope "m" of the line inherent in the equation. Its inner two branches provide a good scaffolding support for students developing their algebraic base of thinking. Can be used both as the scientific concept, that is its structure given to be explained by students or as the facilitator of relevant spontaneous concepts, which need to be developed through problem solving before they can be smoothly integrated with the scientific ones. In either case, conclusions can be drawn from students' responses about the process of schema development in an individual student's mind. Understanding of the details of that development can be helpful in refining the instructional approach for the mathematics classroom.

The Place Value concept map shows the connections between three different aspects of the Decimal System Notation: cycles of units, tens, hundreds, the powers of ten and place value. Color differentiation between the three concepts enhances the concepts differentiation while focusing attention on the connections between them wherever the color is changing. Designed especially for student use as the instructional tool around which to build the system and lead a class; it is very concrete and explicit in its content.

A third approach of the use of the concept map is when we wish to focus on the process of working with decimal points, another dreaded and misconception-laden topic. The following concept map in Fig. 3 below was found useful by students in two consecutive semesters.

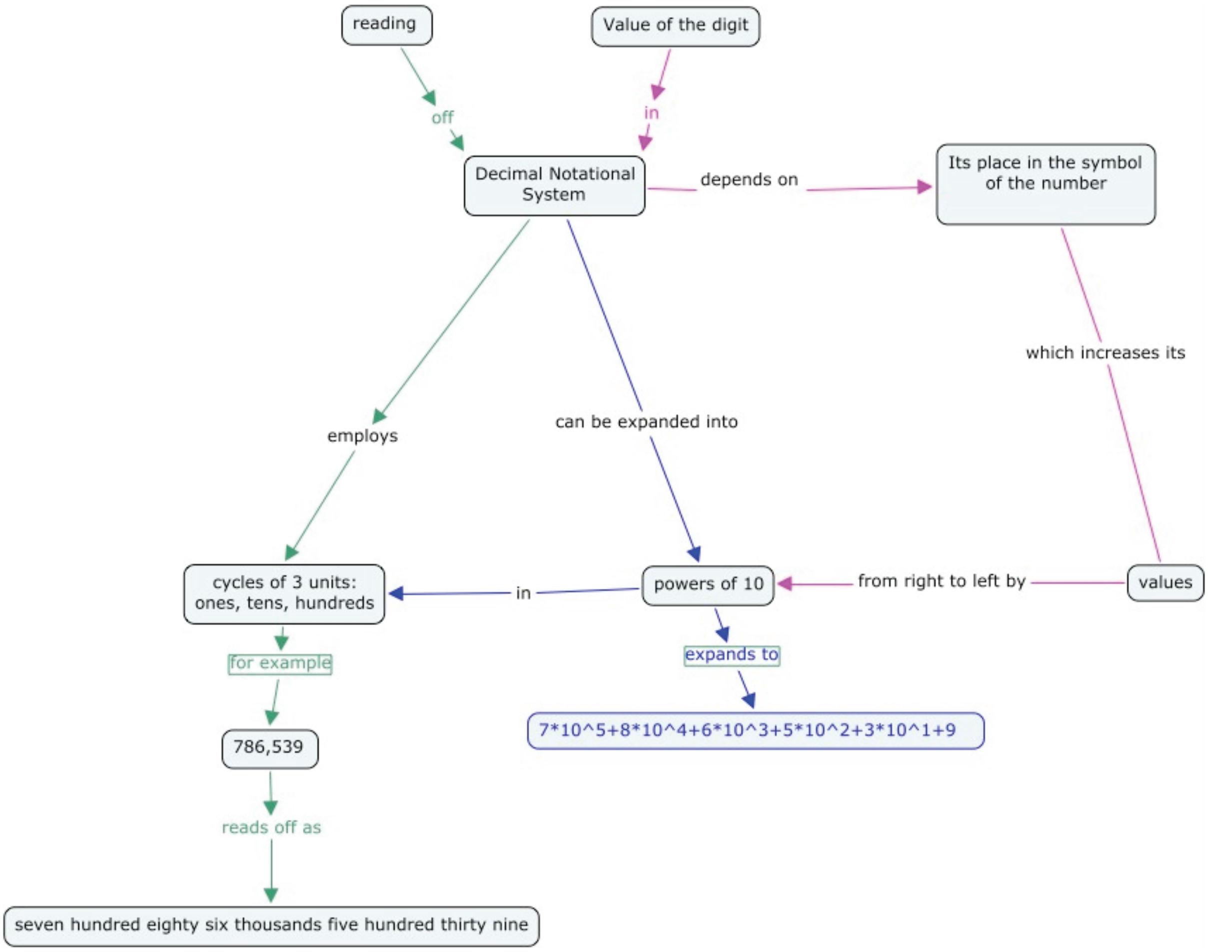

Figure 3. Place Value Concept Map

The Decimal Fraction concept map is designed in the similar style showing three different aspects of the decimal fraction: the decimal point, decimal expansion and the decimal alignment in addition or subtraction processes. General multiplicative technique of positioning the decimal point is absent since the understanding of its meaning is on a higher level of abstraction than its motion due to multiplication of the decimal fraction by powers of 10.

A fourth completely different approach appears in the creation of instructional sequences by the teacher-researchers of the team. It is known that students in the transition course from Arithmetic to Algebra have a high rate of attrition, i.e., about 67% of the students in community colleges at the City University of New York, who are registered in the Arithmetic course will not pass the following Elementary Algebra course. The needed transition, which assumes that students themselves can see how the algebra evolves from the arithmetic cannot be made. Hence, once again a scaffolding is required in which this transition is made explicitly clear, its explicitness is a regular discussion theme between teacher-researchers paying careful attention via language and other means, viz., concept maps to the transition points between Arithmetic and Algebra. The Instructional Sequence, Story of Number in Abstract (Czarnocha, Prabhu, 2008), in its evolving stages has utilized the following concept map in Figure 5. In the design of the instructional sequence, the concept map serves the purpose of being the mathematicians' palette similar to the artist's palette. Further, given the cyclical teaching-research methodology (Czarnocha, 2001), the concept maps used from semester to semester or from one Instructional Sequence version to another, demonstrate in their evolution the researchers' refinements in understanding the source of students' difficulties and their means of resolution via the appropriate mathematical intervention.

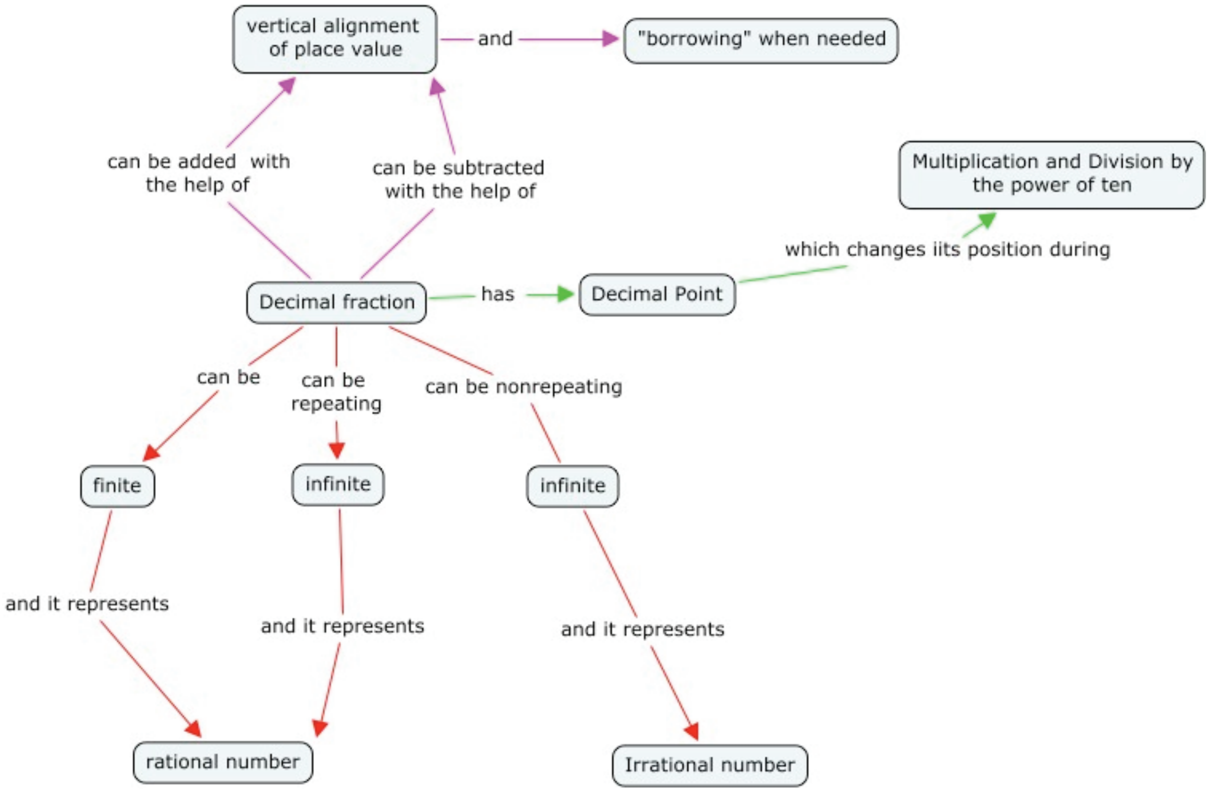

Figure 4. Decimal Fraction Concept Map

Given that (i) the concept map in Figure 5 below summarizes the entire course, (ii) arithmetic, the basis of algebra has been very troublesome to students in the past, (iii) English, the medium of instruction may not be the first language of many students, the concept map provides an opportunity to create meaning from analysis of a word or few words. Teacher-researcher and students can engage in a discussion of the few words within the concept map to establish understanding or to ferret out misunderstandings. Analysis of word meaning thus becomes an ongoing feature of the mathematics learning in question, and its starting point is the concept map.

4 Summary

Concept maps as used in our work accomplish the following

- facilitation of learning, via the integration of theory and teaching practice in the TR-NYC methodology of teaching-research;
- eliciting, capturing, archiving, and using "expert" knowledge, via the cyclical creation and refinement of instructional sequences for known to be difficult concepts;
- planning instruction via the use of the instructional sequence in actual classroom teaching;
- assessment of "deep" understandings via the periodic standard assessment instruments such as quizzes and tests and also the regular questioning in the classroom discourse;
- research planning via the cycles of teaching-research extending over several semesters and colleges.

Acknowledgements

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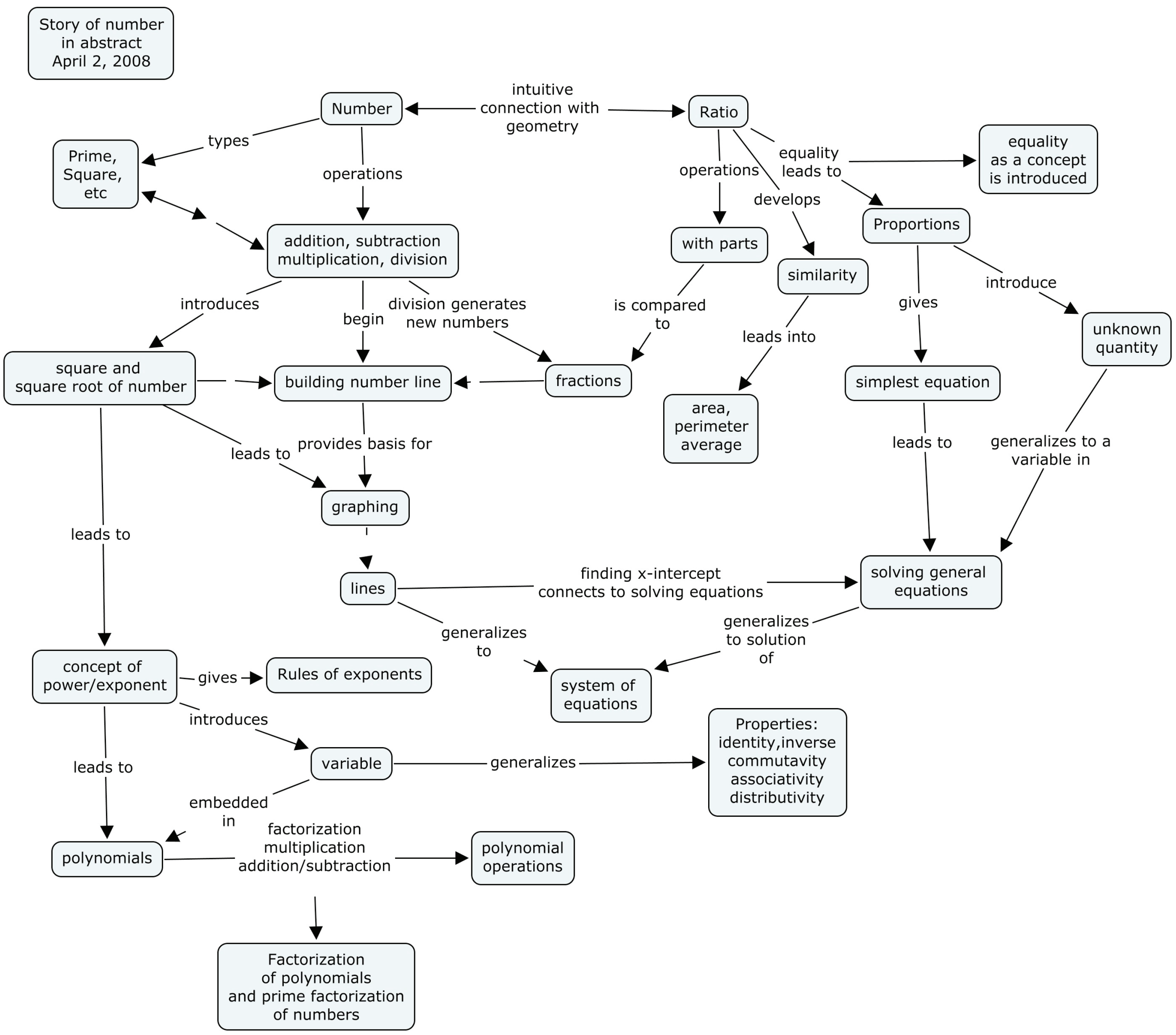

Figure 5. Preliminary Concept map to envision the design of the instructional sequence integrating arithmetic and elementary algebra.

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PRACTICAL TEXT CONCEPT MAPPING: NEW PEDAGOGY, NEW TECHNOLOGY

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Abstract. Previous experimental studies have indicated that young people's text comprehension and summarisation skills can be improved by techniques based on text concept mapping (TCM). However, these studies have done little to elucidate a pedagogy that can make the techniques adoptable within the context of typical secondary school classrooms. This paper explains how a collaborative research approach has developed a new pedagogy, named TCM/4, for text concept mapping, along with new technology that supports this pedagogy in practical ways. Case studies indicate that pupils enjoy their lessons and share their teachers' opinion that TCM/4 is helpful in learning to comprehend texts.

1 Introduction

Development of literacy skills is a major goal for education in all countries. According to the UK's National Literacy Trust (2006), one in four adults in the developing world is illiterate. In England, 16% of the adult population has reading skills at or below the level expected of 11-year olds in the National Curriculum. Poor basic skills cost UK industry more than £4.8 billion a year and also represent a personal tragedy for individuals. About 50% of jobs are closed to someone who only has the minimum level of basic skills. Shifting economic trends will increase the disadvantage, with forecasts suggesting that by 2009, only 21% of UK jobs will fall into the 'elementary and operative' categories.

For children in school, a high proportion of information is presented in the form of text and hence weak literacy is a major barrier to learning. This project is focussed upon an important area of text literacy skills, specifically the area of text comprehension, and upon the use of concept mapping to support learners' summarisation of texts. The paper is in six parts. In part 2, we explain why this type of work seems to be promising in the light of previous research. Part 3 explains how the present research was stimulated by the perception of a wide gap between research and practice in secondary schools in our local area. The core of the paper is part 4, which describes our research goals and methods, including reports of case studies that we have undertaken to develop and evaluate new pedagogy and technology. Part 5 discusses some key issues that seem to be raised by this project and finally, part 6 provides a conclusion.

2 Previous research

2.1 Seminal

The seminal book by Novak and Gowin (1984) discussed the use of concept mapping as a learning activity. Among the applications identified was that learners could use concept mapping as an aid to comprehending a text. Nowadays, a recognised shorthand for this overall approach is 'text concept mapping' (TCM). The rationale for TCM seems straightforward: a learner faced with the task of transforming a text into a concept map is necessarily engaged in the selection of main concepts, organisation of these concepts into related categories, and their reintegration into a structure of meaningful propositions. This amounts to summarising, and hence presumably comprehending, the text. Because it can make important relationships explicit, concise, and memorable, the concept map that emerges from the text may act in several ways to support learning — it provides a salient record of work done, an organiser for parts of the text not yet processed, and a tool supporting communication with teachers and fellow students.

2.2 Experimental studies

Experimental studies have tended to endorse the value of TCM and significantly, some have demonstrated that the benefits can transfer beyond the learning of the specific texts that are mapped. An example is Chmielewski and Dansereau's (1998) study of 60 undergraduate students. This study concluded that training in TCM improves a person's *underlying* information-processing strategies and skills, a result that its authors observe to be "encouraging given the sparsity of far transfer effects that has been documented in the literature over the past 50 years" (op. cit., p412).

A second example comes from the study by Chang, Sung and Chen (2002) who compared three different versions of TCM. In a seven-week course, 126 Taiwanese fifth-grade pupils (mostly aged 10) were formed into three groups and each provided with the same set of specimen texts. The first group corrected maps that had been wholly preconstructed but in ways that deliberately included errors; the second group completed maps that were partly and accurately preconstructed; and the third group generated maps in *tabula rasa* fashion. This study found that children in the first two groups improved their comprehension and summarisation skills in ways that were manifest beyond the completion of the course, even in situations which made no explicit use of TCM. The third group showed no more improvement than a control group, a finding that was attributed to the over-demanding nature of *tabula rasa* map generation and the inadequacy of the children's initial training.

A third study, conducted by Nathan and Kozminsky (2004) in Israel over one entire school year, repeatedly tested 112 eighth-graders (age 14) on their language, concept mapping, comprehension, and writing skills. In the first semester some students used a TCM technique while others did not. In the second semester all students conducted collaborative research projects. Results indicated an advantage for the TCM students both after the first semester and at the end of the year. The version of TCM adopted in this study was notably elaborate: it contained five stages of activity, from pre-mapping prior to reading the text through to review of final maps. Perhaps unsurprisingly, the researchers observed that the method "may tax students with learning difficulties, or less skilled mappers".

3 From research to secondary school practice

The present study originates in an informal network of Scottish teachers and researchers who shared an interest in concept mapping, in particular TCM. The network has a core of about a dozen individuals, with peripheral participation that at various times has been much greater. Teachers from MEd (Chartered Teacher) courses, teachers from local secondary schools who are engaged in teacher education roles, university staff from education and informatics faculties, and students on BEd and PGDE teacher education programmes, have all played active parts. Our research agenda has three parts: to demonstrate a practically effective pedagogy for TCM within our local contexts, specifically those of Scottish secondary schools; to develop technology that would support classroom use of TCM; and to begin to explore some of the factors which seemed to have been neglected in existing research.

Such a research agenda acknowledges that TCM is not part of the current practice of Scottish classroom teachers. In fact, one of our earlier studies found that within a large and well-regarded local secondary school, concept mapping was hardly used for any purpose whatever and only some very limited use of mind-mapping was identified (Conlon & Bird 2004). The gap between research and practice is clearly wide. Unfortunately, almost all existing TCM studies have been conducted not by teachers but by academic researchers. They were also based in curricular and cultural contexts that are, to us, unfamiliar. Thus, the teachers in our network faced a large challenge in discovering how TCM might be successfully adopted in their typical classrooms, assuming the approach was practically adoptable at all.

A particular challenge to our project was that there existed no standard technology for TCM. Although numerous software tools for concept mapping are available, few if any have been designed to match the specific needs of TCM and its associated pedagogies. A weak relationship between technology and pedagogy is not unusual, unfortunately: one influential review of UK school technology initiatives concluded that 'ICT in the curriculum has been broken-backed without a pedagogical spine to provide the necessary structure and support' (Reynolds et al., 2003).

4 Research methods and implementation

The research agenda outlined above shaped our main project goal: to investigate ways in which TCM might be practically adapted towards, and sustainably adopted within, Scottish secondary schools. Our emphasis on practical and sustainable development is influenced by Hargreaves' (2003) advocacy of curriculum development as something that must be led by 'professional learning communities' as opposed to 'performance training sects'. The rationale for our project is not to repeat existing experimental studies, nor merely to 'transfer' them, but rather to support teachers in transforming the knowledge from those studies in a process of shared enquiry based on their own specific contexts, with a view to developing new pedagogical practice where that seems to be justified by emerging evidence.

Our underlying research methods are correspondingly practice-oriented and collaborative. They are based on a theoretical research approach known as PCM (Persistent Collaboration Methodology; Conlon & Pain

1996), a hybrid of traditional action research with a participative-design approach to the development of pedagogy and associated technology. PCM is similar to action research in that it employs an iterative cycle containing phases of reflection, design, implementation and observation. It differs from much of action research by its assumption that, if the aim is to generate well-integrated and well-theorised pedagogy and technology, then what is required is a well-organised collaboration of researchers, teachers and technologists. PCM identifies the roles and outcomes of such a collaboration. We were fortunate in having access to a network that made this research approach feasible.

4.1 Stage 1: Framing the problem

In the first stage of research, discussions were held with a group of experienced secondary teachers, all of whom were working on a specialist concept mapping course that contributed towards their 'chartered teacher' qualification. For curriculum focus, an initial target group was suggested of Higher Grade (age 16-17) students using texts accessed from the government-sponsored Scholar website (http://scholar.hw.ac.uk). Scholar provides numerous study texts for a variety of subjects and it is widely used by teachers in Scotland to promote forms of independent learning, including home learning (Livingston & Condie 2004). The teachers in our group believed that students' weak text comprehension skills limited the usefulness of Scholar, making this a relevant (as well as fairly safe) initial testbed for TCM.

In terms of pedagogy, the various strategies for TCM as documented in the research literature were considered by our group to each combine possible strengths with weaknesses. Table 1 summarises the lengthy discussions that took place. In general, the documented strategies were regarded as too contrived or elaborate for adoption in normal classrooms. The overall preference that emerged from discussion was for a relatively simple strategy comprising four phases, as shown in Table 2. For convenience of referencing, we have named this strategy 'TCM/4'. Although essentially a map generation approach, TCM/4 is relatively novel in combining concept mapping with explicit phases of skim-reading, colour highlighting, and reflection: these were elements of pedagogy with which teachers were already familiar and which had proved successful in their previous experience. This embedding of concept mapping within an overall pedagogy that included other, already trusted, methods seemed to increase teachers' confidence, boost the prospects of the strategy, and mitigate the risks associated with a new approach to learning.

TCM strategy	Reference	Possible strengths	Possible weaknesses
Correction approach: students correct maps that have been preconstructed, with errors introduced	Chang, Sung & Chen (2002)	• Closed task, easily managed by teachers • Easily assessed • 'Problem-solving' approach	• Extensive teacher preparation required • May undermine aim of truly independent student study • Too little challenge for stronger students
Scaffolding approach: students complete maps that have been partly (and accurately) preconstructed	Ditto	• 'Scaffolding' idea is familiar to teachers • Adaptable to suit learners at different stages	• Extensive teacher preparation required • May undermine aim of truly independent student study
Generation approach: students generate maps from scratch	Ditto	• No prior maps required, easing teachers' preparation • Consistent with aim of independent study • Flexible — can be applied to any text	• Too much challenge for weaker students • Open task, may be difficult for teachers to manage • Difficult to assess
Multiple-stage approach: pre-mapping, drafts, final maps with reviews	Nathan & Kozminsky (2004)	• Starts from what students already know	• Requires extensive teacher input • Highly effortful for students — some resistance anticipated

Table 1 **Evaluation of documented variants of TCM strategy**

Phase	Activity	Aim
1	Skim-reading	Quickly browse the text for gist
2	Highlighting	Close-read the entire text, highlighting key words and phrases using colour markup
3	Concept mapping	Build concept map using highlighted words and phrases
4	Reflecting, reviewing and refining	Compare concept map's contents to original text and refine as necessary for an accurate summary of the required length

Table 2 **TCM/4: The four-phase strategy for TCM favoured by our research network**

4.2 Stage 2: Developing technology

At an early stage, formative trials of TCM/4 were undertaken with BEd and PGDE students using technology based on our existing Conception mapping system. These identified the need for at least two technology developments. First, in order to support phases 2 and 3 of the TCM/4 strategy, a new text markup tool was specified that would be fully integrated within Conception. This tool would enable colour highlighting and also provide a command for copying marked-up text into list windows, from which phrases could be transferred into a concept map window by drag-and-drop. Second, to support phase 4, a sentence generation tool which extracted sentences from the concept map window seemed necessary. Such a tool could encourage learners to ask of themselves questions useful to formative assessment, such as: Do these sentences represent an accurate summary of the original text? Do they capture the text's most important ideas?

We implemented these tools (which are now part of the Conception package, available from www.parlog.com — see also http://www.parlog.com/pub/files/Appendices1-8.pdf for screenshots and other illustrative project material) and tested them in further laboratory-based trials. Significant refinements followed. For instance, observations of students showed that they tended generally to over-markup their text, leading to dense concept maps and, in many cases, to summaries of text that did not necessarily select the most important elements of content. To address this difficulty, we implemented a status field that continuously indicates how much of the text has been marked up, together with limits on the quantity and length of markups that will be permitted before the software protests. These markup parameters are user-settable: in practice we hoped that teachers would recommend values to suit the particular target text and the required length of summary.

4.3 Stage 3: Classroom case study — upper-school Computing

The first episode of classroom-based research was located within a Scholar-using Computing department in a local comprehensive school. This department's teachers had been using concept mapping and Conception software with pupils for several years. Adam Caldwell, the teacher of the Higher Computing class (comprising seventeen pupils from secondary fifth-year, ages 16-17), volunteered to lead a case study that would contribute to an evaluation of TCM/4. In an initial interview, he made clear his disappointment in pupils' typical levels of learning from Scholar texts hitherto.

In a seventy-minute lesson observed by a researcher, Adam presented the class with a previously unseen Scholar text on Computer System Performance, a topic that they had been studying as part of their Computing Higher course. The text was technical and descriptive, 1180 words long, and measured at grade 11.2 on the Flesh-Kincaid readability scale. Almost all pupils had used forms of concept mapping (but not TCM) in previous classes. Adam had introduced to them the phases of TCM/4 and the associated Conception technology in a one-hour lesson a week prior to the observed lesson.

The observed lesson began with Adam explaining that the pupils' task was to read the Scholar text and create from it a concept map summary containing no more than 30 nodes, refining the map until they were happy that it generated sentences that comprised a valid summary. It was evident to the researcher that pupils mainly understood what was involved in the TCM/4 process and they were highly attentive to their task throughout the lesson. In line with Adam's normal practice, pupils worked individually and with only occasional interaction. All were still working on their 'first-draft' concept map when the lesson ended. The next day they worked for a further hour in refining and reviewing their maps, by the end of which time about half of them considered that they had completed the task. Table 3 summarises the researcher's and teacher's shared observations.

Phase	Ave. time spent	Observations
Skim-reading	10 minutes	Direct reading of the text from a Scholar web page. All pupils were attentive.
Highlighting	15 minutes	A file containing the text in a Conception markup window was created without difficulty. Some pupils highlighted only concepts, others highlighted both concepts and relationships.
Concept mapping	45 minutes (to first draft map)	Transfer of highlighted text to list windows caused no problems. Drag-and-drop from there into the concept map window was normal practice. Pupils frequently cross-referred between the markup window, the list window(s) and the concept map window, managing this process well.
Refining and reviewing	60 minutes	Sentence generation seemed an effective stimulus to map review, but weak expressions were sometimes not improved in the redrafting.

Table 3 **Higher Grade pupils' progress through the phases of TCM/4**

In discussions that followed, Adam said that he was encouraged by this first experience of TCM/4. He predicted that further work would confirm TCM/4 to be a valuable complement to Scholar and one that his departmental colleagues would be keen to adopt. When asked to predict obstacles to adoption by other departments in his school, Adam suggested that the two main ones would be teachers' lack of access to technology and their lack of available time to learn the new methods.

A review of pupils' completed concept maps was conducted. Some demonstrated impressive performances in the task, but others clearly revealed a restricted grasp of subject matter, poor comprehension, or in a few cases, weak skills in concept mapping. Pupils' own written feedback mostly indicated agreement that TCM/4 had helped them to learn the information from the Scholar text and they concurred that the strategy should be adopted in other subjects too. However, a few said that TCM was too time consuming, not enough fun, or suited only to people with particular learning styles.

4.4 Stage 4: Classroom case study — lower-school English

The above case study of a Higher Computing class demonstrated the practicality of TCM/4 within the particular context of technically-oriented pupils who were upper-school, relatively high-achieving, and well-motivated. In our second trial, we aimed to test the approach within a very different, and in some ways more typical, context for learning in literacy: specifically, lower-school, mixed-ability classes within the English department of another comprehensive school.

Iain Petrie, an English teacher who had recently completed an MEd (Chartered Teacher) course in concept mapping, agreed to lead this part of the project with case studies undertaken in his first- and second-year English classes. His pupils had been working on their 'close reading' skills using factual texts and Iain was hopeful that TCM/4 might boost their learning in this area. His overall approach deliberately mirrored that of the earlier trial but with some variations to match the needs of his different contexts.

In this paper, we outline only the experience of the first-year class. This class comprised 14 pupils aged 12-13 years whose attainment levels in the Scottish 5-14 Language Curriculum ranged from A to D (the highest achievable level is F; see SOED, 1991). Iain's pupils had been using Conception, mainly to explore imaginative writing, since the start of the year. They normally worked in friendship pairs and did so throughout the lessons described here.

In the first lesson, Iain used an interactive whiteboard to demonstrate the newly developed Conception tools for text markup, list creation and sentence generation. Pupils were informally introduced to the TCM/4 process and were then allowed to explore the software freely with various, mostly factual, types of text. In the lessons that followed this introduction, pupils were asked to build a concept map that summarised an unseen factual text. The text contained 156 words and had a Flesh-Kinkaid grade of 7.1. Iain's observations on these lessons are summarised in Table 4.

Phase	Ave. time spent	Observations
Skim-reading	10 minutes	Pupils found the text reasonably accessible.
Highlighting	20-25 minutes	All pupils tried to highlight both concepts and relationships. Some software problems were noted; e.g. where highlighting areas touched, two markups become one. Increasing font size helped.
Concept mapping	60-80 minutes (to first draft map)	Transfer of highlighted text to list windows caused no problems. But pupils generally neglected drag-and-drop (and even copy-paste) from those windows into the concept map. Despite demonstration and reminders of drag-and-drop, they mostly re-keyed text instead, sometimes introducing spelling errors. Occasional software crashes caused frustration.
Refining and reviewing	80-100 minutes	Some pupils added colour to their maps as an additional means of organising information. The sentence-generation tool was mostly helpful in assisting concept map review, but some maps remained weak.

Table 4 **First-year English pupils' progress through the phases of TCM/4**

In reflecting on pupils' collaborative behaviour, Iain observed that a pattern had emerged in the pairings where the higher-attaining individuals (in terms of their pre-assessed 5-14 levels) came to dominate phases 3 and 4. Partners seemed to accept this readily, but remained active and focussed on the task. In fact all pupils were keen and eager to participate throughout and, unusually for this class, they sought and used dictionaries as they went about the task. Lack of familiarity with the software caused some problems but pupils soon reached the point of requiring little or no teacher assistance, although the time required to complete the task was longer than anticipated.

Pupils' maps varied in quality and those with weaker expression or comprehension skills tended to produce weaker maps, as Iain had expected. Pupils' own written evaluations of the experience (see Table 5 for a small sample of unedited comment) mainly confirm their enjoyment of the process and also their belief that it was helpful in understanding the text. Most pupils expressed willingness to make use of the strategy in other subjects, and also for homework, and they affirmed that it could be applied (albeit less conveniently) even without use of computer systems. Iain noticed that these lessons created interest among wider school staff, including History department members who came to observe.

	Pupil #	*Pupil's comment (unedited)*
Did the Conception mapping system help you to learn the information that was contained in the text you were asked to study?	1	Yes it helped me learn the information.
	2	Yes it did help me learn more stuff because i've never used it before
	3	Yes! Because it told you the words and you just had to type them
	4	Yes because the text was helpful on what we were going to do.
Was the software easy to use?	1	Yes I enjoyed using it.
	2	It was quite difficult at the start but when me and my partner got all the work together we started doing it easy like i would tell her ideas and she would tell me ideas and wee both would get it all together
	3	It was easy and fast
	4	It was ok opening was ok to.
Do you think the techniques used in this exercise could be completed without the use of a computer?	1	Yes because it's very simple and you could do it on paper.
	2	I think i would be able to do it but it would take longer to make it all be neat and tidy
	3	Yes ! Because you could use highlighters
	4	No

Table 5 **First-year pupils' comments**

5 Discussion and future work

In this section, we raise issues on three areas that seem central to the project: the TCM/4 pedagogy, the associated learning technology, and the research methodology.

As to the first area, evidence from the case studies suggests that TCM/4 does provide a practical pedagogy that is enjoyable for many (but not all) pupils at different stages of secondary schooling and in different subjects. However, it is both demanding on teachers' skills and time-consuming. The latter point was frequently commented upon by teachers and pupils alike. Although completion times will surely fall as pupils gain familiarity with the process, any investment of classroom time needs to be justified by learning benefits; and of those that are potentially on offer here, it is the transferable benefits (rather than the benefits of learning the specifically mapped text) that seem most promising. Unfortunately, we do not yet know what pattern of classroom episodes of the strategy is required to optimise transferable learning.

A large part of this project was concerned with the development of technology that would integrate well with the pedagogy. The extensions that we developed to the existing Conception mapping software included new tools for text-markup; for phrase extraction from marked-up text into list windows; for drag-and-drop support for transfer from list windows into a concept map window; and for sentence generation from the concept map. A clear risk in this development was that the resultant software could be too difficult for pupils to use. However, the evidence from classroom studies is that most pupils actually found it to be usable and even enjoyable. Problems certainly remain: the comments from teachers and pupils about lack of robustness, and various interface issues, need to be addressed.

In fact, there is considerable potential in our technology that has not yet been exploited. Conception has always been capable of constructing not only concept maps, but also other, more specialised types of information map, such as argument maps, decision maps, and swot maps. Previously we have justified this capability as affording a 'repertoire for teaching and learning' (Conlon & Gregory, 2007). When we designed the system's new tools, we ensured that they would accommodate other types within the repertoire beyond concept maps. The implications are promising. For instance, a discursive-type text can be marked up using the specialised semantic categories of an argument map ('claims for', 'claims against', 'grounds', etc) and summarised accordingly. Applications of this capability await investigation and, especially in this area of new opportunity, we would welcome collaboration with other researchers.

Our project is also suggestive of answers to some interesting questions about research methodology. One such question was hinted at earlier: how should the development of learning technology interact with the development of pedagogy? The PCM strategy (described previously) aims to develop the two *concurrently,* with technology emerging in the service of a coherent enriched pedagogy. Thus, the Conception-based software tools emerged synergetically with the TCM/4 pedagogy. This is a tricky research strategy but it can produce good results. Critical to its success is the right kind of collaboration between technologists, researchers, teachers and learners. Unfortunately, such collaborations (certainly in the case of UK education) are rather rare.

There remain many questions about TCM/4 that we would hope to address by future research. One already mentioned concerns the applicability of the strategy to text genres other than factual texts. Other questions that have been raised within our research network are summarised below (Table 6).

Phase	Problems and issues
Skim-reading	▪ How can teachers best support this phase, which at present has no 'visible trace'?
Highlighting	▪ Should relationships as well as concepts be marked-up, or concepts only? ▪ How much highlighting should be recommended for each particular text? How should Conception's 'markup limit' parameters be set? ▪ What can be done to ensure that highlighting entails 'close reading'?
Concept mapping	▪ How important are generic concept mapping skills in this phase and how best can such skills be developed?
Refining and reviewing	▪ The sentence generation tool is not always effective in stimulating learners to self-assess their summaries. How can this type of formative assessment be improved, for instance by the use of prompts or analysers?

Table 6 **Questions for TCM/4 research and practice**

6 Conclusion

This project has focussed on ways in which secondary school pupils might develop text comprehension and summarisation skills through concept mapping. The main contributions of the project are a new pedagogy, named TCM/4, and an associated new technology that is currently implemented by extensions to the Conception mapping system. The technology and pedagogy have been demonstrated to make text concept mapping enjoyable and, probably, practically adoptable across a range of curriculum contexts. Although more research is needed to refine and evaluate both pedagogy and technology, the evidence from our case studies clearly points to a promising addition to the repertoire of practical approaches to teaching and learning in literacy.

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PROFESSIONAL LEARNING OF MIDDLE SCHOOL AND PRESCHOOL TEACHERS USING CONCEPT MAPPING

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Abstract. The purpose of this paper is to describe the professional learning of teachers as they acquire the knowledge and skill to use concept mapping for instructional planning, as an instructional strategy, and to assess children's conceptual knowledge. The professional learning involved middle school mathematics and science teachers as they used concept mapping to develop a summer camp program and preschool teachers as they designed and implemented the *Young Florida Naturalists* and *Healthy Habits through Literacy* projects which embedded concept mapping in the lessons. We found that it is important to immediately use concept mapping in real-world, concrete ways and to provide feedback during the process. In our work with the preschool teachers, we accomplished this by using the professional development workshops to develop specific lessons/curricula the teachers would subsequently use in their daily practice. This is in contrast to providing concept mapping skills at professional learning workshops and then assuming teachers, on their own, would overlay concept mapping strategies in their practice. Additionally, we found on-site scaffolding and organizational support were critical to implementation of the preschool projects.

1 Introduction

Over the past several years, advancements in cognitive and learning science have begun to inform both learning and instructional design (Carver & Klahr 2001). Thus, research findings are used to both inform teachers' professional learning and to structure students' learning experiences. Novak and Gowin (1984) suggested that learning is an active process that involves acquiring, creating, and using knowledge. Furthermore, learning takes place on a continuum ranging from rote to meaningful. For learning to be meaningful, three conditions must be present: the learner must possess some prior relevant knowledge to which the new information can connect, the new information must contain significant concepts and propositions, and the learner must consciously and deliberately choose to relate in a meaningful way the new knowledge to the existing knowledge. Through this process, learners build knowledge by making a growing network of connections. The purpose of this paper is to describe the professional learning of teachers as they learn how to use concept mapping as a visual representation of the structure of their knowledge, as a process for building content knowledge, as a method to assist in designing curricula and lessons, and as a form of assessment.

1.1 Concept Mapping

In this paper we report on the professional learning of preschool teachers as they designed and implemented preschool curricula incorporating concept mapping and middle school teachers as they designed summer camps and implemented concept mapping in their everyday practice. Concept mapping has been widely used to assess the structure of learner's knowledge especially in science. However, concept mapping is used across many domains and across a considerable age span of learners. Novak and Cañas (2008) stated that concept maps are graphical representations of knowledge. Concept maps visually depict separate but related concepts by showing the relationship between the concepts with a line, or directional arrow. The words on the linking lines represent the relationship between the concepts. Two linked concepts are called a proposition, and propositions form meaningful statements when read. Concept maps generally represent concepts in a hierarchical fashion with the most general or overarching concepts at the top and subordinate concepts and examples towards the bottom. Concept maps can also have cross-links which connect concepts in different segments (branches, domains, or strings) of the map. Novak and Cañas contended that the two features of concept maps that indicate *leaps of creative thinking* are the hierarchical structure of the map and the use of cross-links.

1.2 Professional Development and Change Theory

In discussing the effectiveness of the professional learning of our teachers, we use Gusky's (2000) framework that links professional development to improved student learning. In developing the framework, Gusky recognized that student learning will not automatically follow professional development and that successful professional learning engages five levels which are hierarchical in nature with success at one level depending on success at the lower or preceding levels. The five levels as described by Gusky include the participants' reactions to the professional development, the participants' learning, the organizational support and change, the participants' use of the new knowledge and skills, and the intended student learning. First, the participants must consider the professional learning experience time well spent. Positive reaction facilitates participant learning. Participants' learning represents the extent to which participants increase their knowledge, acquire new skills, and possibly change their attitudes/beliefs. If participants are to apply what they have learned with fidelity, they first must learn what is expected. Implementation of the professional learning requires that individual change occurs and, in addition, that organizational support for the learning occurs. Organizational support can include but is not limited to providing the resources and time necessary to implement the new learning and collegial support for and recognition of the change. The participants' use of the new learning involves recognition that change is a dynamic process rather than static event. The personal aspects of the teachers' change process typically reflect levels of concern about their ability to implement the required change (George, Hall, & Stiegelbauer, 2006). In all of our professional learning activities, the desired outcome was improved student learning and the teachers functioned as designers, implementers, and/or evaluators of students' learning experiences.

Scaffolding can be embedded in professional learning to increase its effectiveness and facilitate the change process (Harris, 1991; Moll, 1990; & Vygotsky, 1978). Scaffolding can be involved in the participants' learning, the organizational support and change, and the participants' use of the new knowledge and skills by establishing shared goals, asking probing questions to identify current levels of understanding, providing support that is tailored to the identified needs, mediating organizational support, and providing regular feedback. Thus, scaffolding helps teachers move through the change process both in terms of their stages of concern regarding the implementation, their developing expertise using concept mapping, and implementing concept mapping strategies with their students.

2 Professional Learning and Concept Mapping at the Middle School Level

Our first attempt at using concept mapping in conjunction with professional learning involved middle school teachers serving low-income neighborhoods in two counties, one urban and one rural. The participants were middle school mathematics and science teachers primarily participating in the professional development to prepare curriculum materials for mathematics and science summer camps. The focal content of the workshops was mathematics, specifically Algebra I. Professional development activities included four, all-day Saturday workshops designed for the teachers to learn to use IHMC CmapTools™ (Institute for Human and Machine Cognition) and to use concept mapping for lesson planning, instruction, and assessment of student progress in mathematics. Additionally, during the late spring and early summer, teachers worked to plan activities for the summer camp held at their school. The purpose of summer camp was to motivate the selected students toward mathematics, science, and technology (MST) careers and toward enrollment in college preparatory mathematics and science courses. The development and delivery of activities for summer camp provided further concept mapping experiences for the middle school teachers.

The professional development workshops progressed from a general introduction of concept mapping, to making concept maps from a *parking lot* of concepts, making concept maps of provided mathematical concept, and concept mapping a textbook unit. Professional development time was also allocated for teachers to examine an existing set of *expert* concept maps developed by university faculty and high school mathematics teachers. The amount of time spent on developing the teachers' mathematical content precluded researchers from providing a thorough introduction to the use of concept maps for student assessment. It was hoped by the research team that the teachers involved in the professional learning would continue to use CMap Tools™ as an instructional planning tool, to strengthen their own understanding of key mathematical concepts and the connections between them, and to assess students' knowledge. Subsequent follow-up discussions with the teachers and school partners showed that this was not the case.

2.1 Lessons Learned

1. Conducting professional learning for using concept mapping with all of the original design components (concept maps for planning, instructional delivery and, assessment) was too much information to introduce through one professional learning experience even though it was spread over several weeks. There was no guided practice between the professional development workshops. Subsequent workshops demonstrated that *incremental learning* followed up by supported practice was necessary to improve teachers' knowledge and use of concept mapping.

2. In the initial concept mapping workshop experience, teachers worked individually. Collaboration could have provided suggestions for improvement and feedback. We incorporated *team learning* in subsequent professional learning.
3. Stand-alone professional development/training is necessary but not sufficient to produce desired change. Ongoing support is necessary if teachers are to adopt new methods and change their practice.

3 Professional Learning and Concept Mapping at the Preschool Level

The preschool curricula were designed with concept mapping embedded in the lessons and concept mapping was used in the planning stages. Researchers used concept mapping combined with *Understanding by Design* (Wiggins & McTighe, 2005) to form an intentional and explicit instructional planning framework. Wiggins and McTighe's backward design begins by identifying specific understandings and skills desired for learners and then specifies learner behaviors that provide evidence of the outcomes—all prior to the development of the learning activities and/or experiences. Concept mapping was used in the preschool curricula development process to help teachers focus on the essential content addressed, identify important concepts related to the content, and make explicit the connections among the important concepts. Developing and sharing concept maps during the professional learning experiences clarified the teachers' thinking (including misconceptions) about the content and made the instructional design more coherent. Finally, teachers used concept maps to reflect upon their learning, to see how concept mapping could help children increase their conceptual understanding, and how the children's concept maps could be used to assess the extent to which the complexity of their knowledge increased over the implementation of the lessons.

3.1 The Young Florida Naturalists Curriculum

The *Young Florida Naturalist* curriculum was developed and implemented for use in three preschool classes in an urban professional learning demonstration preschool center that primarily enrolls low-SES, African American children. This project provided the opportunity to incorporate and test the lessons learned from the middle school teachers' professional development. The *Young Florida Naturalists* curriculum focused on increasing the background knowledge and concept development of 3-year-old preschool and prekindergarten children. Learning experiences involved plants and their role in the environment. Building background knowledge was emphasized as children engaged in concrete experiences, and vocabulary development was emphasized through read-aloud activities. Concept mapping was used to document the hierarchical relationships described by the children before, during, and after the learning experiences. The curriculum was implemented in two classes of prekindergarteners and one class of 3-year-old preschoolers. Moreover, one or two of the project researchers were on site most of the time during the project's implementation. During implementation of the concept mapping preschool curricula, the research team provided initial instruction, modeled expected behaviors, and provided support as teachers developed their own concept maps as well as when teachers began using concept mapping with their children.

After the initial concept mapping introduction and demonstration, professional learning at the preschool center continued with multiple opportunities for teachers to practice building concept maps as a team as they planned the instructional unit. It was through this process that teachers began to develop an understanding of the hierarchal nature of concept maps and were able to make their own thinking explicit. The initial pre-instructional concept map developed by the teachers is shown in Figure 1. From this map, teachers identified some essential questions critical to the lessons developed using the backward design process.

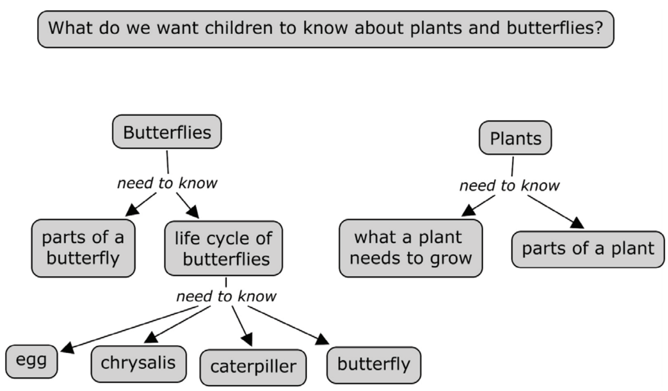

Figure 1. What do we want children to know about plants and butterflies?

After the development of the curriculum concept map, project researchers modeled for the teachers the process of creating concept maps with preschool children. The first concept map developed prior to instruction was constructed by soliciting from the children their current understanding about plants and butterflies. After assessing the children's prior knowledge, teachers began implementing the lessons. The teachers created a team concept map at the conclusion of the 8-week unit. The resulting concept map, shown in Figure 2, indicates an increase in complexity, cross-links and levels in the represented knowledge structure. The *Young Florida Naturalist* project demonstrated that professional learning can help teachers make connections among concepts and can substantiate for them the value of concept mapping in making children's thinking explicit.

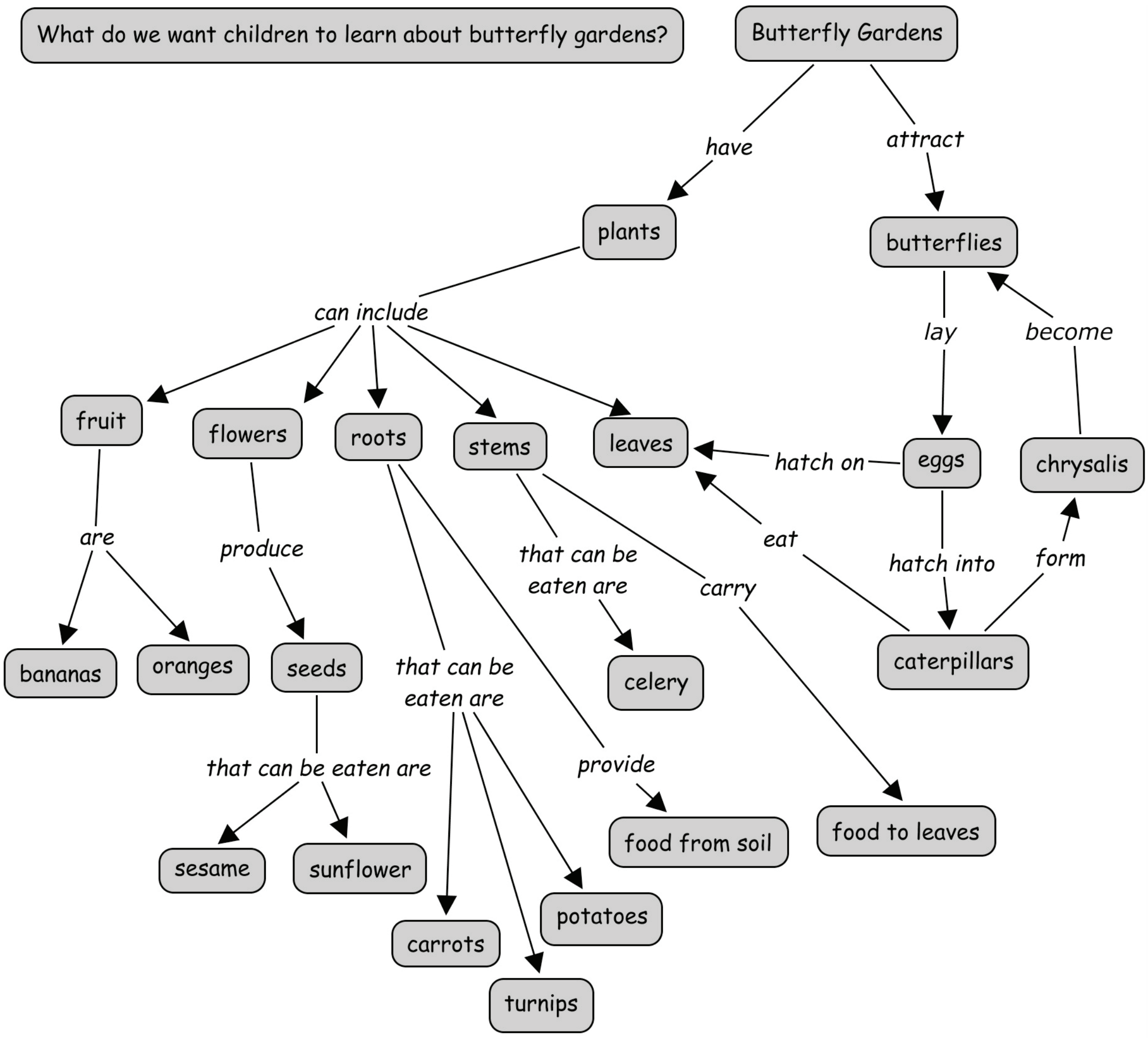

Figure 2. What do we want children to know about butterfly gardens?

3.2 The Healthy Habits through Literacy

The *Healthy Habits through Literacy* curriculum provided a third opportunity to investigate the use of concept mapping as an instructional and learning tool, the second opportunity involving teachers of preschool children. *Healthy Habits through Literacy* was designed to combat the rise in childhood obesity by building children's knowledge and concept development of health-related topics. The curriculum supports the goal of improving school readiness outcomes for preschool children by utilizing strategies that help young children develop thinking strategies. This project was implemented at same preschool enter as the *Young Florida Naturalists* project and the professional learning included one returning teacher and one returning teacher's assistant.

At the initial professional development session, the returning teacher and teachers' assistant shared testimonies concerning the positive effect concept mapping had on their personal understanding of the butterfly and plant concepts and the connections between them. The first professional development session also included a video capturing preschool teachers and their children engaged in class concept mapping during implementation of the *Young Florida Naturalist* project. Using instructional materials gathered for the *Healthy Habits through Literacy* curriculum unit, teachers worked as a team to develop a concept map that would guide their teaching of the unit. The concept map is shown in see Figure 3.

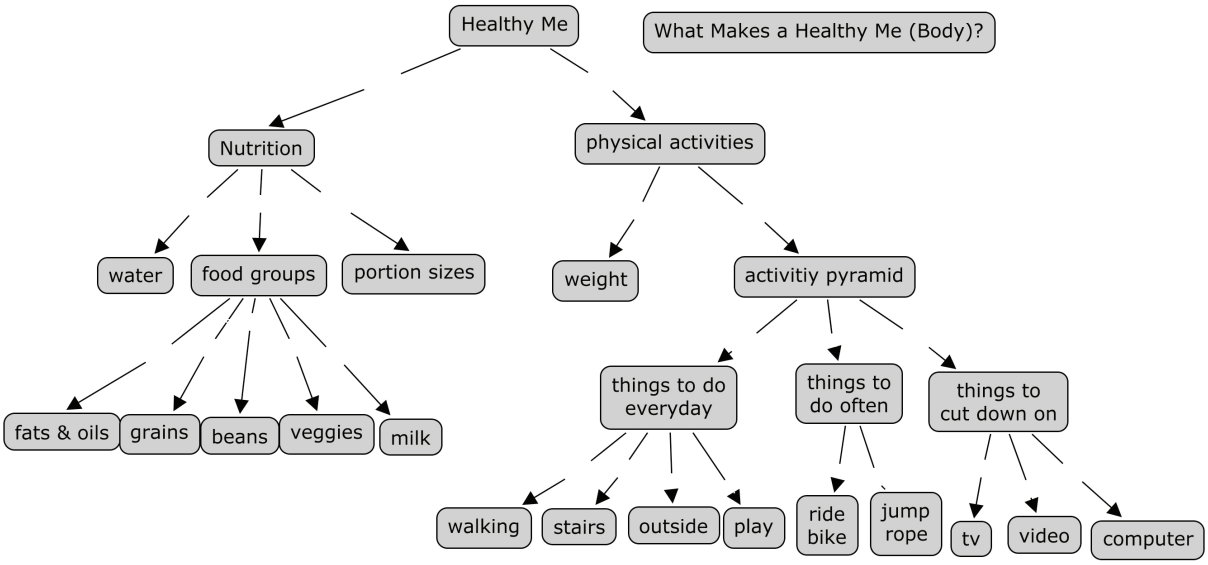

Figure 3. What makes a healthy me (body)?

Members of the research team are on site meeting with the teachers weekly to model the process of making concept maps with children and to help them modify the class concept map as their children's knowledge increases. The *Healthy Habits through Literacy* project will last for 12 weeks.

4 Discussion

The discussion of the effectiveness of the three professional learning experiences will use Gusky's (2000) five levels as a framework. The five levels are hierarchical in nature and include the participants' reactions to the professional development, the participants' learning, the organizational support and change, the participants' use of the new knowledge and skills, and the intended student learning.

Teaching staff involved in all three professional learning experiences expressed satisfaction with the workshops and thought that learning about concept mapping as a visual representation of knowledge was time well spent. The middle school mathematics and science teachers met on Saturdays in the library of an involved school. The preschool professional learning occurred at the center during the school day which, in our opinion, provides the optimal context for the professional learning.

Teaching staff involved in all three professional learning experiences gained knowledge about concept mapping. In working with the middle school teachers, we overestimated the extent of their content knowledge and thus we underestimated the time required to teach them to use concept mapping for planning, instruction, and assessment. Using the lessons learned from this experience, we more narrowly focused the preschool teachers' professional learning of concept mapping. The first preschool professional learning involved teachers who helped design and implement the *Young Florida Naturalists* project, an 8-week curriculum. In this instance, the teachers were totally immersed in the project in contrast to the middle school teachers who were asked to overlay concept mapping strategies on an existing state approved and county mandated mathematics curriculum. Additionally, the preschool teachers, working as a team with the university researchers, immediately used concept mapping to design the lessons in the *Young Florida Naturalists* curriculum. This immediate, guided use of concept mapping in a real-world situation helped the teachers realize the potential of visually representing knowledge. The second preschool experience, the *Healthy Habits through Literacy* project built upon the first. The presence of returning teaching staff allowed us to provide evidence of concept mapping success through testimonials and videos of teachers successfully using concept mapping with preschool children.

At the organizational support and change level in the hierarchical framework, the effectiveness of the professional learning of the middle school and preschool teachers diverges. At the preschool center, the organizational staff was supportive of the project and the staff's involvement. The research team included the teaching staff in designing curricula lessons and the administrative staff was always welcome. Artifacts of the implementation of *Young Florida Naturalists* and *Healthy Habits through Literacy* were highly visible throughout the preschool center. We found this level of professional development effectiveness more difficult at the middle schools than at the preschool center. The administrative bureaucracy of the public school system is very large having layers of officials who need to support change, thus gaining support is more difficult than at preschool centers which are not part of the public school system. At each middle school, the administrative staff verbalized complete support of the concept mapping project; however, they did not attend any professional learning workshops. Another simple example of conflicted support came at one middle school where the IT staff allowed installation of IHMC CmapTools on the schools' computers for the Saturday professional training but uninstalled the program before school resumed on Monday.

At the level of participants' use of the knowledge acquired through profession learning, the effectiveness of the professional learning of the preschool and middle school teachers also diverged. Whether or not the middle school teachers implemented what they learned about concept mapping in their practice is unknown. They used concept mapping to design the summer camp curriculum during professional learning workshops and used the lessons in summer camp. Learning from our experience with the middle school teachers, the university researchers were far more involved with the implementations of *Young Florida Naturalists* and *Healthy Habits through Literacy* preschool projects. Unlike the middle school teachers, the preschool teachers' professional learning was not limited to workshops, but scaffolding which offered individualized support was provided and was ongoing throughout the projects' implementations.

The impact of the professional learning on student achievement at the middle schools is unknown. The preschool children's concept maps show increased complexity in their knowledge structures of concepts related to plants. A goal of both preschool curricula is to improve the children's background knowledge. This extent to which concept mapping in preschool achieves this goal is unknown at this time.

5 Conclusions

Improving learning outcomes for all children, particularly for low-SES children, continues to be a high priority at the local, state, and national levels. Reform efforts at all educational levels, prekindergarten through twelfth grade, have raised expectations for student performance, and as a result, increased expectations for teacher performance. There is little debate over the importance teacher quality and quality teaching plays in improving student performance (Corcoran, 2007).

To meet rising expectations and increase instructional capacity, teachers must strengthen their content and pedagogical knowledge as well as increase their proficiency in using them with their students. Cohen and Ball (1999) defined instructional capacity as:

> The capacity to produce worthwhile and substantial learning and is a function of the interaction among three elements – teachers and students around educational materials—not the sole province of any single one, such as teachers' knowledge and skill or curriculum. (p 2-3)

One important strategy for increasing instructional capacity is engaging in ongoing teacher learning and professional development. Standards and features of effective professional development have been identified (Corcoran, 2007; Elmore, 2002; Roy, 2006). The professional learning model emerging from our work embodies many of those elements including a clear focus on improving student learning, engaging in active, content-based learning, job-embedded support, team learning—all nested in researcher/practitioner partnerships.

Because we know that change is a dynamic process rather than a static event, we are excited about the results from 2 years of professional learning at the preschool center. Several key features of the preschool teachers' professional development supported the successful implementation of the projects. It is important to immediately use concept mapping in real-world, concrete ways and to provide feedback during the process. This was accomplished in our work with the preschool teachers by including within the professional learning the development of specific lessons/curricula the teachers would subsequently use as part of their daily practice. This is in contrast to providing concept mapping skills at professional learning workshops and then assuming teachers, on their own, will overlay concept mapping strategies in their practice. The content-based middle school teachers needed more support than we acknowledged as they transitioned from learning about concept mapping to using it in their practice. Thus, the on-site scaffolding and organizational support were critical to the successful implementation of the preschool projects.

We hope to build on the preschool success by implementing the curricula within one academic year—one in the fall and the other in the spring, thus increasing the children's exposure to concept mapping. However, because the *Young Florida Naturalists* and *Healthy Habits through Literacy* projects were implemented over 2 academic years, they provided an opportunity to longitudinally study the children who experienced concept mapping as 3-year-old preschoolers and then again as prekindergarteners. Preliminary results suggest the children benefited from 2 years of concept mapping experience. We would also like to extend the use of concept mapping to kindergarten teachers' practice thus providing children with three consecutive years of concept mapping experience. Expanding the children's concept mapping experience to kindergarten creates additional challenges. However, increasing the background knowledge of low-SES children is too important not to try to overcome the challenges.

6 Acknowledgements

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Tallinn, Estonia & Helsinki, Finland 2008

RAPID AND ACCURATE IDEA TRANSFER: EVALUATING CONCEPT MAPS AGAINST OTHER FORMATS FOR THE TRANSFER OF COMPLEX INFORMATION

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Abstract. Concept Maps (Cmaps) have proven useful for capturing and organizing knowledge, particularly of those who create the Cmaps. Their usefulness for transferring knowledge has not been as extensively researched. In business, government and military settings, slideshows (e.g., Microsoft PowerPoint) are a preferred format for presenting "complex" ideas, while the journal article remains the preferred format in academic circles. This empirical investigation compared Cmaps with other common formats of information presentation. Complex information expressed in a report about a humanitarian crisis was presented to military graduate students in four formats: journal article in traditional text, a hypertext version of the journal article, a Microsoft PowerPoint presentation, and a set of hyperlinked and resourced Cmaps. After reviewing the material, participants recreated the information and answered a set of questions to test comprehension of the material. Additionally, a preference survey was conducted with 34 professionals across military and industry domains to consider attitudes toward Cmaps for presentation. Cmaps were empirically demonstrated to be more effective than PowerPoint on key measures of knowledge transfer and rapidity in creation. They were also shown to be the preferred format for complex information presentation, when compared to PowerPoint.

1 Introduction

Concept Maps (Cmaps) have proven useful for capturing, organizing, and assessing knowledge (Cañas 2004b, Cañas 2006). Benefits have primarily been demonstrated for the creators of Cmaps. The benefits for *transferring* knowledge have not been as extensively examined, and empirical findings on the matter have mostly been limited to educational applications. Where Cmaps have been compared to other strategies for knowledge transfer, they have shown promise. Puntambekar, et al. (2007) demonstrated the advantages of Cmaps relative to hyperlinked text pieces, forming what he called a "Concept Mapped Project-based Activity Scaffolding System" for increasing the understanding of the interconnected nature of the concepts and principles in middle-school science. Kinchen and Cabot (2007), in looking at dental education, showed that Cmap presentations led to better performance than sequential PowerPoint presentations when the aim of knowledge transfer was a deep understanding of the subject – i.e., comprehension as opposed to a memorization of facts.

Outside of the classroom, the goals of knowledge transfer may not only be learning but also strategizing, argumentation, planning, decision making, policy making, and other practical applications. It has been claimed that Cmaps lead to improvement in the effectiveness and efficiency of knowledge transfer of complex ideas. Hoffman and Shattuck (2004), using a study design biased *against* Cmaps, found that military officers, both junior and senior, performed as well using a Concept Map-based version of their traditional "Operations Orders" as they did with the traditional structured paragraph format, on measures of comprehension and recall. Wagoner (2004) presented data from the same experiment showing a search efficiency improvement of up to 40% for experienced users of the Cmaps. Despite the potential gains, Wagoner also found a general reluctance to change from the traditional, linear, text-only format of Operations Orders. The finding was not unexpected, given that Cmaps are novel to many people, and that most people are more accustomed to and more comfortable with traditional text forms and formats.

This latter finding is of particular interest for the present investigation. One reason for the paucity of clear evidence regarding the usefulness of Cmaps for knowledge transfer is the general reluctance some people may have to depart from customary and ubiquitous formats of information presentation. Globally, in business, government and military settings, slideshows of the type created with Microsoft PowerPoint are a preferred format for presenting "complex" ideas,[1] while the journal article or proceedings paper remains the preferred format in academic circles.[2]

[1] We place the word 'complex' in scare quotes because the slide format often results in a simplification of the complex information.
[2] The irony of the latter situation is not lost on the authors as they draft this paper!

Tufte (2006) has been among the chief critics of the slavish and sometimes dangerous use of slideshows, pointing to *inter alia* their tendency to "reduce the analytic quality of serious presentations of evidence" (p. 3). The U.S. government's recognition of the pervasive use of PowerPoint presentations has led it to consider whether the conventions that such software supports – indeed encourages – may be serving as a contributing cause of systemic underperformance in organizations that depend heavily on the rapid and accurate communication of complex ideas. This consideration gave rise to the present empirical investigation.

2 An Empirical Investigation: Rapid and Accurate Idea Transfer

We conducted an empirical investigation to compare the impact of four different presentation formats on comprehension as a form of knowledge transfer, specifically tested by incidental recall of complex information. We hypothesized that the presentation of complex information in Concept Map-based formats would enable more rapid and accurate knowledge transfer than each of the other three formats: traditional text, hyperlinked text pieces (hyper-text), and PowerPoint slides. The study was conducted from February through June, 2008, with data collection occurring from April through June. In a related study, we conducted a survey of preferences for Cmap and PowerPoint formats in May 2008. This paper reports findings from both studies. References to the survey participants and methods are explicit – all other references are to the empirical study.

2.1 Method

2.1.1 Participants

The participants were 61 graduate students at Naval Postgraduate School, Monterey, California. The students were officers of varying ranks in the United States Military. Participants were recruited and selected for the study with no regard for age or gender, and they were not compensated or awarded for their participation.

2.1.2 Hypotheses

Three hypotheses were tested in the study.

H1: The presentation of information in Concept Map-based format will result in better comprehension of information, as compared to presentations of information in traditional text- (i.e., journal article), hypertext- (i.e., hyperlinked text pieces of the journal article), and PowerPoint-based formats (i.e., slideshows).

H2: The presentation of information in Concept Map-based format will result in greater efficiency of information transfer, as compared to presentations of information in traditional text-, hypertext- and PowerPoint-formats.

H3: The presentation of information in Concept Map-based format will not be preferred to the presentation of information in PowerPoint-based format. Following Wagoner (2004), we suspected that most people would prefer a customary format – PowerPoint – to Cmaps.

2.1.3 Design

The study employed a between groups design. Participants were randomly assigned to one of four groups each with N=15 (the hypertext group was assigned an additional participant after one participant was determined to be quite disengaged in the procedure, for a total N=61). All participants were presented with the same complex information. However, participants in each of the four groups were presented the information in one of four formats: traditional text, hypertext pieces, a PowerPoint presentation, and a set of Cmaps with hyperlinked resources (e.g., pictures, statistical graphs, text) taken from the source article. Thus, the main independent variable was format.

2.1.4 Materials

The learning materials and the test questions were developed independently so that those who worked through the source document to prepare the test questions would not be biased by having played a hand in preparing the learning materials (i.e., any inclination to have information that is salient in one or another of the formats be more likely to be queried in the recall test questions). Some members of our team developed the questionnaires, based on the traditional text journal article. Another member developed the Cmaps without seeing the questionnaire. And the PowerPoint version was prepared by a third-party (i.e., not the authors) graphics design company with no knowledge of the nature and purposes of the study. The company was chosen for its experience in creating professional PowerPoint presentations, and compensated via a ‘flat-fee’ arrangement that encouraged efficiency.

The complex information sets, in each of their formats, are illustrated in samples in Figures 1-4. These were derived from an article (Farzana, 2008), which described a complex set of historical economic, and political circumstances of the Bihari refugee community of Bangladesh.

The traditional text version was an abridged version of the journal article as it originally appeared, and was presented to participants as a 17-page Microsoft Word document, with a word-count of 4,523. The hyper-text version was created by the authors. It used the same text as the linear text version, carved into short text pieces that were hyperlinked together at appropriate relevant places within the document. The material was presented to participants as 25 hyperlinked PowerPoint slides, which followed the structure of the traditional text.

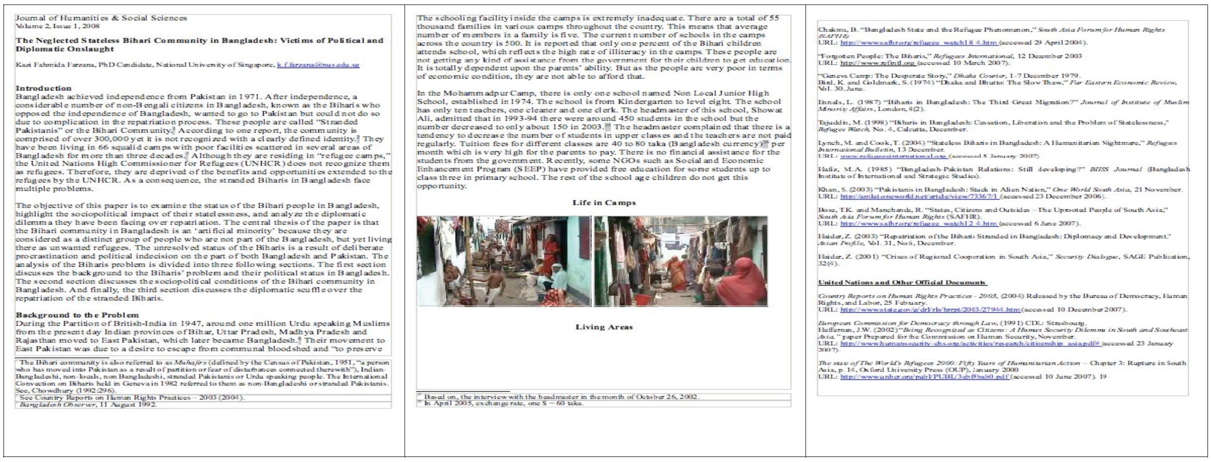

Figure 1. Traditional text samples.

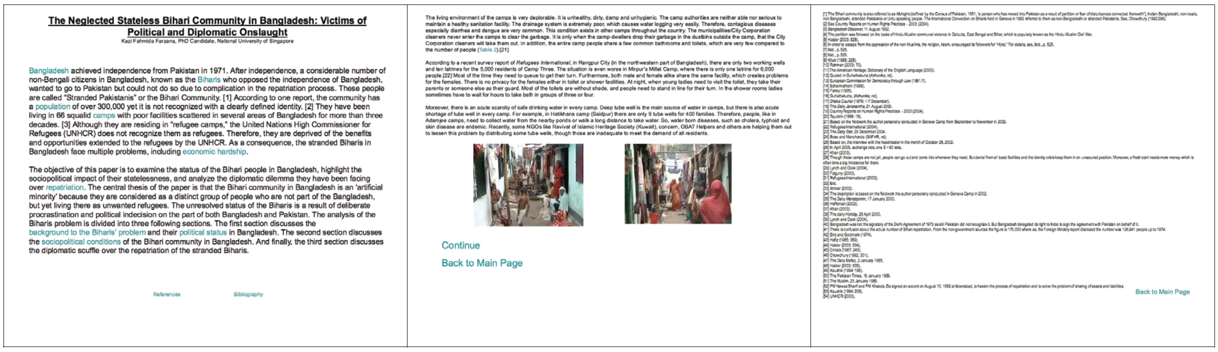

Figure 2. Hypertext samples.

The PowerPoint designer was provided with the traditional text version and was instructed to prepare a professional-looking presentation using his own design intuitions and discretion. Certain additional constraints were provided, and we based these explicitly on Tufte’s (2006) critique of PowerPoint, which was a driving factor in our sponsor's interest in studying alternative methodologies for briefing. The constraints were:

- Assume a presentation of approximately 20 minutes in duration,
- Allow the length of the presentation to principally be dictated by the content (not the time),
- Represent all of the source document material (some of the material became the “Notes” that appeared under some of the slides),
- Attempt to use no more than 40 words per slide, and
- Use multiple features of PowerPoint (which Tufte criticizes), as deemed appropriate, including bullet lists, templates, background graphics, photos, animations, sounds, summaries of statistical data, and AutoConent Wizard.

In total, the PowerPoint presentation was created in approximately 52 hours. The PowerPoint version was presented to Participants as a 56-slide presentation, with an approximate word-count of 1420, not including the text included in the Notes. Participants viewed the presentation in slideshow mode, but were not constrained to remain in that mode. Participants had access to the Notes in hardcopy.

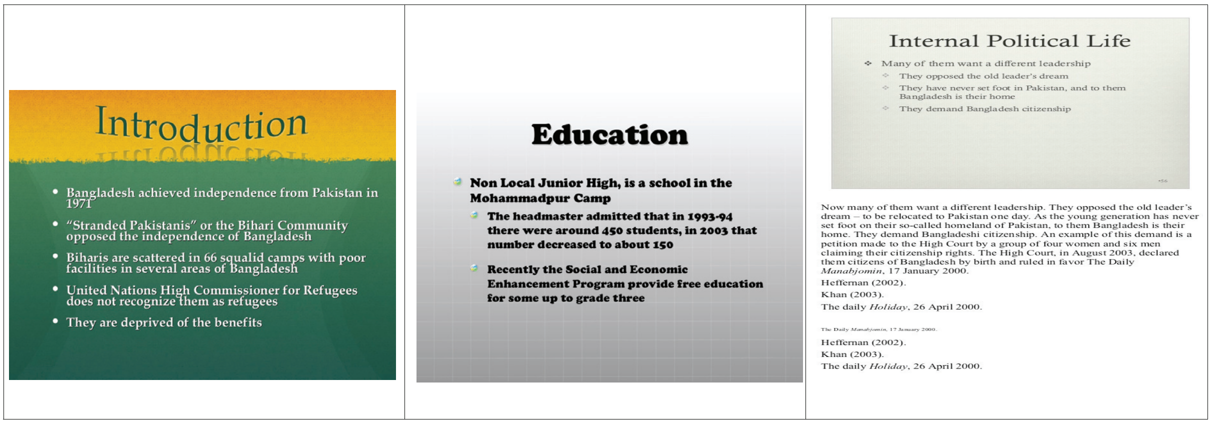

Figure 3. PowerPoint presentation samples.

The Concept Map version was prepared by the authors using CmapTools (Cañas, et al. 2004a). The traditional text version was transformed into 16 "propositionally coherent" and hyperlinked Cmaps. Hoffman (Crandal, Klein, Hoffman 2006) explains: "Using the link labels to express relations between two concepts, the node-link-node triples in Concept Maps form propositions, that is, they can be read as 'stand alone' simple and meaningful expressions" (p. 51). When all of the triples in a Concept Map are well-formed propositions, the Concept Map is said to be 'propositionally coherent.' In total, the Cmaps included 301 separate concepts, 344 propositions, and 3,345 words (not including the brief text pieces attached as resources). As each Cmap was made, propositions in the original text were marked off (understanding that a single sentence typically contains more than one proposition). An independent check assured that the Cmaps (with the text pieces included in the Notes) included all of the material in the original document. Notably, the bulk of the Cmap creation was undertaken by one author who was purposefully unaware of the content of the questionnaires. Hyperlinked to the Concepts were 22 Resources (e.g., text documents, photos) taken from the source article. In general, the material selected for inclusion in brief text pieces was material that conveyed a detailed example. Where Resources were added, the color of the concept nodes was changed to yellow in order to encourage participants (who would be generally unfamiliar with Cmaps) to follow the hyperlinks (shown in bold in Figures 5 and 6). In total, the Cmaps were created in approximately 18 hours. The Cmaps and resources were presented in an .html browser to enable all Cmaps and resources to be presented in the same application. Thus, Cmaps were presented in whole, not piecemeal, as each Cmap was selected. The icon and hyperlink for CmapTools that is standard for .html exported Cmaps was removed.

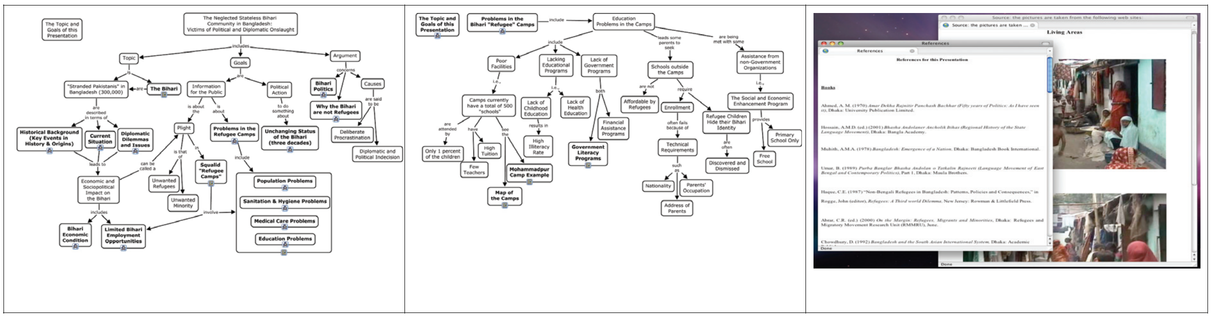

Figure 4. Concept Map samples.

Figures 5 and 6 present the Cmaps at viewable scale.

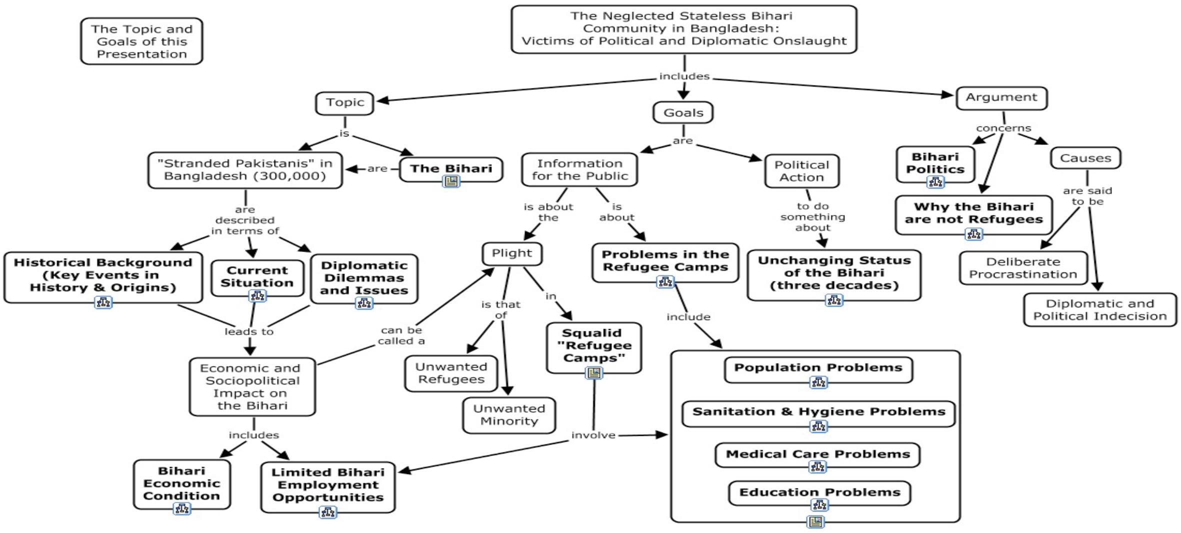

Figure 5. Concept Map sample #1 at viewable scale.

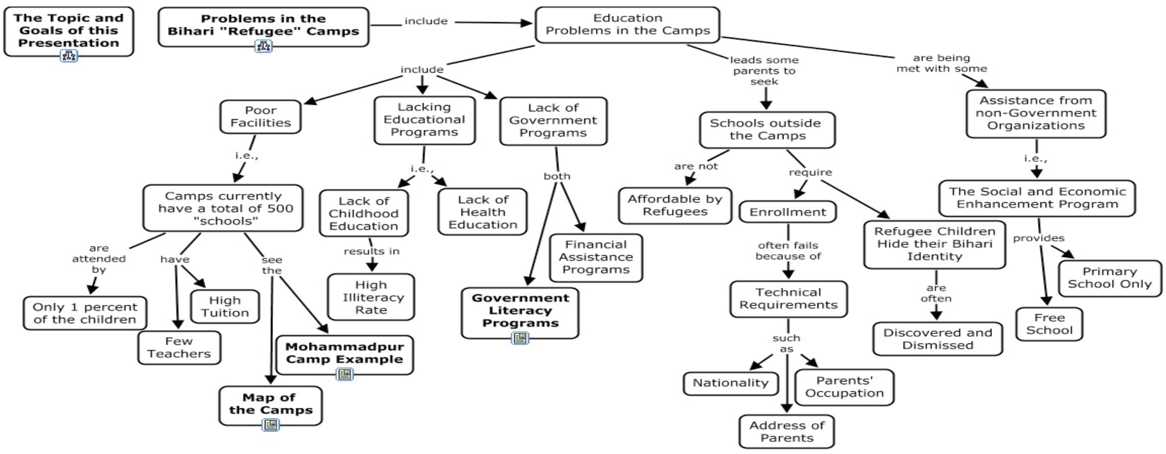

Figure 6. Concept Map sample #2 at viewable scale.

2.1.5 Procedure

We adopted the incidental learning paradigm since incidental recall can be a strong test of memory, and hence comprehension. The incidental learning paradigm is an experimental paradigm used to investigate learning without intent. "At the beginning of the experiment, participants think that their only task is to rate the acquisition stimuli...they do not know that they will later be asked to recall the acquisition [matter]. The purpose of this incidental procedure is not to trick the [participants], but to investigate how particular types of acquisition activities affect learning and subsequent recall" (Bransford, 1979). The incidental learning paradigm presumes that information processed at deeper – i.e., more conceptually connected – levels will result in superior recall – not recognition – of information.

Participants were presented a 10-question, short-answer Pre-test questionnaire (to measure content familiarity). Next, the participants were instructed to review the information sets (i.e., the acquisition task) in order to prepare to participate in a study in which they would be presented with a current challenge for the US military. They were led to believe that after reviewing the focus material they would engage in a group problem solving session about the humanitarian challenges now facing the US military. It was suggested the review should take about 20 minutes, but they were encouraged to not feel constrained by time. Following the acquisition task, the Participants were presented with a recreation task: they were asked to recreate the material in a format of their choosing. (We suspected that the hypertext and the Cmaps would result in recall of some form of net-like diagrams because we had seen this in Hoffman and Shattuck, 2004, and therefore it might be argued that Cmaps work because they are diagrams, as opposed to being Cmaps per se. If both the hypertext and Cmap groups recreated net-like diagrams, and the Cmap group outperformed on the incidental recall task, we would submit that gains in performance were due to the diagrams being Cmaps, not just diagrams.) Participants were then presented with a surprise 20-question short-answer Post-test questionnaire. All questions on both questionnaires were fill-in-the-blank, requiring numeric and text answers. Three of the questions were repeated on both tests.

We tested hypothesis H2 via analysis of the time each group took to review the same information in each of the four formats. Expanding on Wagoner's finding (2004), H2 postulated that Cmaps would also introduce efficiency gains into overall performance. We also examined the amount of time required to create the PowerPoint and Concept Map-based formats, since rapidity of idea transfer is relevant not only to the speed of transfer but also the speed of preparation for transfer.

All Participants were then briefed on the purpose and design of the study. Since the study's cover story was a form of deception, after the study was completed participants were given the opportunity to request that their data be discarded. None asked to have their data discarded.

In our related study, all participants were invited to review the PowerPoint and Cmap formats, and asked to complete an anonymous survey ("survey") regarding their preferences for and experience with either format, and their willingness to use Cmaps for presentation. Additionally, a sample of professionals drawn from one of the authors' social network (N=75) was invited to participate in the survey. All aspects of the survey were conducted online, to include the invitation, review of the formats, answering preference questions, and providing demographic data, which was optional. In total, 34 invited respondents completed the survey, with 25 providing demographic data. The sample included professionals, mostly age 26-45, with more than 16 years of education, drawn from government, military and industry occupations, including military officers, research scientists, and marketers.

2.2 Results

To test H1, we conducted an analysis of the Pre- and Post-test questionnaires, and the recreation created by each participant during the incidental recall phase of the experiment. Each Pre- and Post-test questionnaires were scored by two members of our team using a scoring key. Given the complexity of the information set, questions requiring descriptive answers or names of entities were marked conservatively, with allowances for spelling and semantic similarity. For example, a question requiring "Bay of Bengal" was credited for answers such as "Sea of Bengal" and "Bengali Sea." Numeric answers were strictly marked. The recreation artifact was scored by wordcount, and two of our team created proposition lists enabling a proposition count. The lists were deemed accurate representations of the recreations via two waves of inter-scorer reliability checks. The method of recreation was also noted (i.e., whether a participant recreated text, a bulleted-list, or some form of net-like-format.

Summary statistics are shown in Table 1 (STD = standard deviation).

Statistic	**Traditional text**		**Hypertext**		**Cmap**		**PowerPoint**	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD
Preparation time (in mins)	N/A	N/A	N/A	N/A	1080	N/A	3120	N/A
Review time (in mins)	22.13	5.51	21.38	5.89	27.25	8.32	26.36	12.16
Pre-test score (% correct, 10 questions)	16.67	13.84	15.63	14.71	13.46	16.51	25	16.29
Post-test score (% correct, 20 questions)	56.58	21.22	52.81	23.07	47.49	11.94	58.75	12.44
Pre- and Post-test score difference	**39.92**	N/A	**37.19**	N/A	**34.03**	N/A	**33.75**	N/A
Recreation wordcount	168.67	69.00	153.38	68.24	126.46	105.48	184.57	73.02
Recreation proposition count	38	14.66	35.69	9.56	33.77	19.46	43	19.21
Recreation format (net-like only)	0	N/A	1	N/A	3[3]	N/A	0	N/A

Table 1: Summary Statistics.

As a measure of each individual's overall effort on all the tasks, we simply summed the time they spent reviewing the material, their Post-test scores, and the word and proposition counts. The mean score for effort

[3] In addition to these three, two discounted Cmap participants created net-like formats.

was 263.78, with a standard deviation of 113.53. The fourth lowest score, 93.5, belonged to the hypertext group participant whose observed minimal effort warranted the exclusion. The three lowest participant scores, 38 (Cmap group), 46.42 (PowerPoint group), and 63 (Cmap group), were thus discounted from the analysis. The score for one of the Cmap group participants was adjusted by a method of proportions to account for accidental noncompletion of the final six questions on page two of the Post-test questionnaire. The mean score for all other participants on the final six questions (44.72%) was averaged with the participant's score (75%) for the first 14 questions (on page one of the questionnaire), for a conservatively adjusted score of 59.86%. (The Pre- and Post-test score difference for the Cmap group actually increases to 35.19 with the participant's page one score of 75%.)

Our survey data revealed that 55.88% of the respondents preferred the Cmap format, while 44.12% preferred the PowerPoint format. While 100% of the respondents had prior experience creating PowerPoint slides, on 52.94% had created Cmaps. And 70.59% of the respondents expressed a willingness to consider creating Cmaps for presentation.

2.3 Discussion

2.3.1 H1: The presentation of information in Concept Map-based format resulted in better comprehension of information as compared to presentations of information in PowerPoint-based format but not in traditional text- and hypertext-based formats.

On the primary score of interest – Pre-and Post-test score difference – the Cmap group outperformed the PowerPoint group, but underperformed relative to the traditional text and hypertext groups. We were not surprised by the underperformance, since the memory text questions were drawn directly from traditional text, and participants were very familiar with the text and hyperlinked text formats. We were, however, surprised by the comparison with PowerPoint. Possibly, the PowerPoint group was comprised of superior performers, despite randomized group assignment. The PowerPoint group as a whole scored considerably higher on the Pre-test score than all three of the other groups, strongly suggesting greater initial content familiarity, and scored higher on the Post-test. But the PowerPoint group's review time was higher than that for the traditional-text and hyper-text groups. This finding may help explain the performance differences among the groups. The wordcount and proposition count results for the PowerPoint group may be explainable by the abundance of information they had to review – i.e., the slideshow and comprehensive notes. In other words, the PowerPoint group effectively received the information twice by reviewing the slideshow and reading the notes. In hindsight, this study might have utilized a PowerPoint mode more closely resembling general use – i.e., the notes would be presented as an audio voice-over. Nevertheless, in terms of knowledge transfer, the PowerPoint group appears to have been advantaged by the performers and/or an abundance of information presented in the customary PowerPoint format.

The Cmap group, in comparison, scored the lowest on all three performance measures – i.e., Post-test score, recreation wordcount and recreation proposition count. However, the Cmap group included the most net-like-recreations, with only one participant in the hypertext group recreating a net-like diagram. And most importantly, the Cmap group's Pre- and Post-test score difference was higher than the PowerPoint group.

Echoing Kinchen and Cabot (2007), we view these findings, when taken in total, as persuasive evidence of the *comprehension* improvement strength of Cmaps, at least with regard to the PowerPoint-based format. The Cmap group did not necessarily recall more *facts* accurately, as tested by the Post-test. Nor did they recall more *information*, as tested by the counts. But compared to the PowerPoint group, they demonstrated greater overall improvement in their knowledge *between the Pre- and Post-tests* and were more likely to recreate their knowledge in map-based formats. Thus, we believe that the Cmap group outperformed the PowerPoint group because the information was presented *as* Cmaps. Future investigations could examine comprehension even more closely by considering the semantic accuracy of the recreated propositions.

2.3.2 H2: The presentation of information in Concept Map-based format partially resulted in greater efficiency of information transfer, as compared to presentations of information in PowerPoint-based formats but not with regard to traditional text-, hypertext-formats.

The Cmap group took longer than all other groups in material review time. We were not surprised by this finding, given both the low level of familiarity of most people with Cmaps (in particular, .html versions of CmapTools Concept Map files) and the navigation requirement put on the participants in order to review all of the material. We were intrigued by the performance of the hypertext group, as it may suggest that hyperlinking itself may indeed create efficiencies in the review of complex information. And we suspect that the navigation confound may all but disappear when Cmaps are presented by their creator, or if additional navigation aids were introduced. Future investigations could follow these lines. We were very surprised by the considerable difference in preparation time. Even when potential confounds such as the skill of the creators, the introduction of "Tufte constraints," and the incentives for efficiency, we believe that the dramatic difference provides the most compelling evidence to date of the efficiency of creating presentations of complex information sets in Cmaps, specifically in CmapTools. Future investigations could focus directly on this issue.

2.3.3 H3: The presentation of information in Concept Map-based format was preferred to the presentation of information in PowerPoint-based format.

Contrary to our expectations, the Survey yielded compelling evidence of a broader-based preference for Concept Map-based formats over Power-Point-based formats. Of particular interest to us were the familiarity of the respondents with Cmaps. Apparently, more people are becoming more familiar with them. When exposed to their potential value for presentation, we see a willingness to present information as Cmaps in the future. We consider this finding encouraging for the continued exploration of Concept Maps as tools for complex information transfer.

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REASONING ABOUT ELECTROCHEMICAL CELLS IN A CONCEPT MAPPING ACTIVITY AND IN THE SCHOOL LABORATORY

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Abstract. In this paper, we study students' actions in the classroom as a matter of learning to participate in situated practices. We investigate how learning is constituted in two classroom activities commonly regarded as directing students towards manipulating either concrete material or scientific ideas. We audio-recorded pairs of students as they engaged in a common reasoning task about electrochemical cells, either as part of constructing a concept map or working with a real electrochemical cell. In both settings students needed to learn the rules, norms and techniques of the practice as part of their reasoning. This included techniques for attaining an acceptable concept map, or for how to make correct and relevant measures of current and voltage in the electrochemical cell. Students also learned norms for including terms in the concept map, or for distinguishing and naming particulars of the electrochemical cell. Our results show that similarities and differences between two classroom settings can be specified in new ways by studying them as situated practices. How science is taught in the classroom may not primarily be framed as questions about the effectiveness of different methods, but of what students need to learn in order to act competently in different relevant practices.

1 Introduction

There is a large amount of work published showing students' conceptual difficulties in science (Duit, 2007; Kariotoglou, 2002). A general observation from that research is that instruction often fails to engage the ideas that students bring to the classroom, thereby leaving their everyday conceptions intact throughout the school experience (Driver et al., 1994). Accordingly, there is an extensive amount of research trying to find ways of making students go "minds on", as it were, in order to make teaching more effective in attaining the intended conceptual learning (Leach & Scott, 2002; Méheut, 2004; Vosniadou et al., 2001). Labwork and concept mapping are two teaching activities that have attracted much interest from science education researchers as to their effectiveness on students' learning in science (Lunetta et al., 2007; Nesbit & Adesope, 2006).

Concept mapping has emerged as a method with the potential to engage students' ideas head-on (Nicoll, 2001; Åhlberg, 2004). Concept mapping is typically considered to direct students attention towards abstract reasoning about relations between concepts of a science topic (Nesbit & Adesope, 2006; van Boxtel et al., 2000), as well as to help them represent their own cognitive structure (Nicoll, 2001; Slotte & Lonka, 1999). In a meta-analysis of the effects of learning with concept maps, Nesbit and Adesope (2006) found a small positive effect on knowledge retention and transfer, but they were not able to attribute this to concept mapping as such rather than to a lower effect of the comparison treatments. In a study on dyads working with an electricity task, van Boxtel et al. (2000) did not find any effect of concept mapping as opposed to producing a poster on the post-test scores. But they did find that students working with concept maps talked more about relations between electricity concepts whereas students working with the poster assignment talked more about relations between the concepts and concrete phenomena.

On the other hand, a central concern with laboratory work is that it tends to direct students' attention towards handling equipment and following prescribed procedures rather than towards working with ideas (Lunetta et al., 2007). Hodson (1993) viewed this focus on the practical details of labwork, this "noise", as unnecessary barriers to learning. Gunstone (1991) concluded that "students need to spend more time interacting with ideas and less time interacting with apparatus" (page 74). On these grounds, some researchers argue that laboratory work is ill-suited and overrated as a means to promote learning of science (Osborne, 1998). Others suggest that procedural and conceptual knowledge are intertwined (Psillos & Niedderer, 2002) or even that students do not understand the meaning of scientific concepts properly until they have learned to apply them in practical procedures (Jiménez-Aleixandre & Reigosa, 2006).

There is considerable variation in learning outcome in both these teaching practices (Lunetta et al., 2007; Nesbit & Adesope, 2006). In labwork, the variation is attributed to the complexity of most labwork tasks (Millar et al. 2002). Lunetta et al. (2007) concluded that the interaction between procedural knowledge, attitudes toward science, and understanding of science concepts and the nature of science needs to be examined carefully to better understand the potential and realities of laboratory experiences. There is less agreement on how to approach the variation in learning outcome in the case of concept mapping. However, some authors assert that concept mapping is something that has to be learned and mastered (Wandersee, 2000; Åhlberg & Ahoranta, 2004). There is also a discussion about what a good concept map looks like, how to improve the methods of concept mapping, and which criteria should be met for a product to count as a concept map in the first place

(Åhlberg, 2004). So even in this allegedly purely conceptual activity there are apparently better and worse ways to proceed. Nesbit and Adesope (2006) concluded that more carefully designed research is needed to better identify the mediating conditions for effective learning with concept maps, stressing that investigations should examine the processes by which students learn with concept maps.

The purpose of this study is to analyze students' reasoning in electrochemistry in two classroom settings commonly regarded as affording either the manipulation of ideas (concept mapping) or the manipulation of concrete material and equipment (laboratory work). The results presented here are part of a more elaborate manuscript that will be published elsewhere (Hamza & Wickman, unpublished). We approached the question of what constitutes difficulties for students in these two settings as a matter of learning to participate in two situated practices (Lave, 1993). Particularly, we are interested in the extent to which students encounter similar difficulties in these two seemingly different activities.

2 Analytical approach

We described and analyzed students' reasoning through the now well established discursive mechanism of a practical epistemology analysis developed by Wickman and Östman (2002). This approach to analyzing student action in the classroom acknowledges that the meaning of words, sentences, or actions is construed within socially shared practices (Lemke, 1990; Wickman, 2004). Both as teachers and researchers, we do not have direct access to students' thoughts but depend on what they do or say as part of an activity (Wickman, 2004). The approach avoids factoring a classroom activity into separate entities, such as students' conceptual frameworks or various contextual factors, supposed to affect students' actions (Greeno, 1997). Indeed, our analytical approach implies that people's actions are not divided into periods characterized by states (e.g., certain conceptions) interrupted by periods of change (e.g., learning). Instead, people live in a series of situation (Dewey, 1938/1996a, p. 25) in which continuity of experience is constantly established (Wickman, 2006). Because there is always something new in each situation, the process of making situations continuous also amounts to a transformation of experience, thus, to learning (Wickman, 2006). On this account learning the meaning of words and actions, for example in electrochemistry, is done through repeated encounters in the practices where these words or actions are used (Wickman, 2006; Wittgenstein, 1953/1997).

This process of establishing continuity of experience may be likened to a rhythm of construing *relations* between what occurs in an experience and what *stands fast* to the participants in the situation (Wickman, 2006; Wickman & Östman, 2002). In encounters occurring in a situation there will be a need to give meaning to them in relation to the whole experience (Wickman & Östman, 2002). Such a need is termed a *gap*. A gap may be filled immediately with discursive relations, or it may first be stated as a question and subsequently filled. If people fail to fill a noticed gap with relations the discourse stops or takes on a new direction. The gap is then said to linger. This approach amounts to a generous and inclusive operationalization of learning (Hamza & Wickman, 2008). Any gap noticed by the students demonstrates a need to fill the gap with relations to what stands fast. An account of the gaps noticed and the relations established to fill these gaps, according to this operationalization, is an account of what students need to learn to be able to proceed with these activities.

Our operationalized research question is: What gaps are important for students to fill in order to proceed with the two activities of reasoning in electrochemistry by (a) constructing a concept map and (b) constructing a real electrochemical cell?

Our analysis is based on two excerpts, one from the CM-activity and the other from the LW-activity. The two groups analyzed are both from the first session of each activity. When students are referring to the concepts written on the bits of paper this is indicated with quotation marks in the excerpts.

3 Study setting

We conducted the study in a municipal upper secondary school in Stockholm, Sweden. We presented the study to the chemistry teacher early on in the chemistry course so that he was able to include it in the regular curriculum for the course. The teacher chose to incorporate the activities of the study in the last quarter of the course. We also acquired written permission from the students to record their talk during the two activities.

The students were already separated into two "lab groups". For this study, one lab group first went to the chemistry lab to do the labwork activity (LW-activity), while the other group went to a regular classroom for the concept map activity (CM-activity). After 75 minutes, the groups changed activity. In both activities, the students worked in pairs as usual when working in the lab. In the CM-activity we audio recorded their talk and video recorded their production of the concept map. In the LW-activity we audio recorded their talk. The chemistry teacher stayed in the chemistry lab, whereas the first author alternated between the two activities.

The students were given identical instructions to discuss and try to explain (a) how a current can occur in *your* (labwork) or *an* (concept map) electrochemical cell, (b) which chemical reactions occur, and (c) what role the glass filter at the bottom of the U-tube has. In the CM-activity we provided 19 different electrochemistry terms (23 if synonymous verbs and nouns are included) on small bits of paper, an A3-sheet, and post-it notes (for additional terms) together with a schematic representation of an electrochemical cell (Figure 1). In the instructions, the students were told to "reason about how and why an electrochemical cell, as the one in the picture, can produce electric current and make a lamp give light". They were also instructed to use the concepts on the slips of paper (a) to support their reasoning and (b) for building a concept map according to a general example provided at the back of the instruction sheet.

In the LW-activity the students were asked to "construct a working electrochemical cell, that is a simple battery, and try to reason about how and why it can produce electric current". Moreover, the students were given detailed instructions of how to set up the cell in order to drive an electric fan or a light-emitting diode. They were also given instructions (a) to observe what happened in the cell, (b) to measure the voltage, (c) to look closely at the metal strips, and before quitting also (d) to connect the fan or the LED to a "real" battery. Figure 1 also functions to illustrate schematically how the real electrochemical cell was set up.

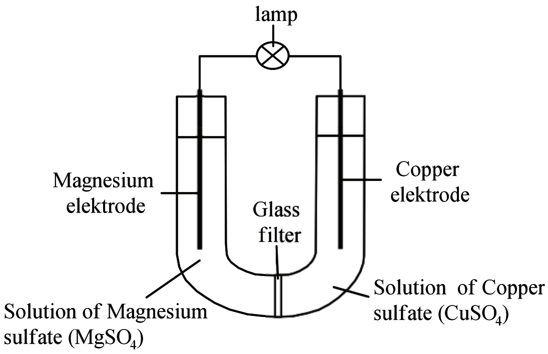

Figure 1. The picture of a schematic electrochemical cell presented to the students in the CM-activity. In the LW-activity, students set up a cell looking like this.

4 Findings

In both settings, reasoning about the electrochemical cell involved learning the rules, norms, and techniques relevant to each practice. At the same time, the specific content of these gaps differed. The students needed to learn rules, norms, and technologies that were specific to each practice. This was contrary to the content of gaps dealing with more conceptual issues where students in both settings identified gaps with similar content. As to the conceptual content, this will only be brought out here to the extent that it forms part of the excerpts showing gaps dealing with the rules, norms, and technologies. The two kinds of gaps, conceptual and, if you will, procedural, often occurred as part of the same line of reasoning. In order to be able to continue reasoning about electrochemical cells, the students needed to establishing relations to fill both kinds of gaps.

4.1 Learning what counts as proper ways to proceed with the activity

In the CM-activity, Andrew and Brian noticed a gap about how to begin their CM:

Andrew	Yeah. Well, so what do we begin with?
Brian	Oh shit [in english] this was hard.
Andrew	Uhm…
Brian	Well there is…
Andrew	Is there like… is there "Electrochemical cells" or something?
Brian	"Electrical energy". How about that? "Chemical energy", "Volt[age]…", "Chemical…"
Andrew	If, but yeah but, that could be something, like this, that something leads to that, they can…
Brian	Shall we make our own then, "Electrochemical cell"?
Andrew	Yeah that's good.

The students fill the gap "what do we begin with?" both by suggesting individual terms (lines 5 – 6) and by establishing relations (that something – leads to – that, lines 8 – 9; we – make our own [term], line 10) expressing rules or norms for how to begin. These students needed to decide on (i.e., learn) these rules in order to proceed with the activity. In the LW-activity, Chris and Daniel similarly needed to learn what counts as a proper start of the activity. Although having set up their electrochemical cell properly, their electrical fan does not move:

Chris	Weren't we supposed to make it [the electrical fan] rotate?
Daniel	Sorry?
Chris	Weren't we supposed to make it rotate?
Daniel	Yeah. Let's try to...
Chris	But we've got current here alright.
Daniel	Yeah.
Chris	I think it ought to begin.
Daniel	Yeah. You'd think so.

They notice a gap as to *whether* the fan *should* rotate (lines 12, 14, 18 – 19), rather than *why* it doesn't. So they are not entirely sure what to expect and how to act in response to the contingency of a non-working electrical motor in this activity. In the next excerpt Chris and Daniel negotiate what norms to apply to determine whether the fan is affected by being connected to the electrochemical cell:

Daniel	Well but we've only got to p… give it a small kick. Does it rotate this much without [the electrochemical cell]? Yes. No, not entirely.
Chris	Yes it does.
Daniel	Or? Yes. No. No but look, it's going a little here. Oh yeah look, I promise you, it is.
Chris	I still think it ought to move slowly by itself as well.
Daniel	Yeah maybe. Well, I don't know. Something's wrong with our fan.

Chris establishes the norm that the fan should move without their help (line 25). Daniel, on the other hand, suggests that the norm for having a working fan may be to compare the difference between how easily the fan moves when "giving it a small kick" with and without supply from the electrochemical cell (lines 20 – 24). You might say that it comes down to a discussion about the rules of the game. To close this section, we return to Andrew and Brian in the CM-activity. Here too, they need to agree on the rules of the game:

Andrew	We aren't allowed to draw on the paper so it's not that easy to show, but yeah, well.
Brian	But I think we should. We're supposed to write there in between.
Andrew	But I don't think we're supposed to do that.
Brian	Yes I think we are. Let's write there in between. Otherwise we can't really show, what we mean.
Andrew	No. Ok, let's do that.

4.2 Learning the techniques of the activity

In this excerpt, Andrew and Brian learn the technique of drawing a reasonable CM (lines 39 – 44, 46 – 52) at the same time as they are reasoning about the conceptual content of the task (lines 36 – 38, 45).:

Brian	But "Electrons", where is it [the piece of paper]?
Andrew	Here.
Brian	Okay. It enters like… It enters in both ["Oxidation" and "Reduction"].
Andrew	I mean, electrons are sent away and like…
Brian	Uhm, we do like this… Oops, well okay…
Andrew	Actually we should put one arrow up, so that you can see it's in that direction.
Brian	Yeah. Yes [in english]
Andrew	Put it like this, on the arrow, a line so that it…
Brian	Like this.
Andrew	Or like: "'Electrons', given off, 'oxidation'" [reads]. Strange.
Brian	Should we run one all around, "taken up" [draws an arrow from oxidation to reduction around the entire map]
Andrew	[Laughs]
Brian	It took up a great deal of space.
Andrew	[Laughs]. Perhaps a bit too big.
Brian	Like this [erases and draws a new arrow]
Andrew	Hell it was really hard to draw a map like this.

In the same way, Chris and Daniel need to learn the technique for measuring voltage and current in their electrochemical cell, as part of their effort to deal with the non-working electric fan:

53	Chris	We could check with this one [voltmeter/ammeter], if there's any…
54	Daniel	Right, if there's any…
[they ponder about the bubbles in the magnesium sulfate solution for 10 lines]		
55	Daniel	Okay, let's try uhm, where should we stick these in [leads]? Which one
56		should go into which [socket]? Ten, well. Well, it isn't more than ten
57		ampere, I think. Look at it, crazy, looks like…
58	Chris	Yeah but on this one it read, this one only read zero point one so…
59	Daniel	Yeah
60	Chris	[4 words missing]
61	Daniel	Nothing happens at all.
62	Chris	No. How should we actually measure this? Is it ampere?
63	Daniel	There it turned up.
64	Chris	One point eight, one point nine almost.
65	Daniel	Why does it read minus, what does that mean?
66	Chris	Not good. [turns the knob around]
67	Daniel	It reads like that [minus] on all sides.
68	Chris	Well I don't know.

In both cases, it is a matter of getting acquainted with the techniques of the practice. In each case they constitute ways of being able to proceed with the activity of reasoning about electrochemical cells. In the case of Chris and Daniel, they eventually get some help from the teacher, and manage to measure the difference in current between their electrochemical cell and the real battery provided:

69	Daniel	How many amperes do we have in our [electrochemical cell]? Zero. Zero,
70		zero, zero [turns the knob around]. How many amperes do we have in this
71		funny battery. Thirteen amperes, we've got no amperes, I mean, there's no
72		strength in our yucky current.
[…]		
73	Daniel	I see. That's why. Too little… to weak, or how do you say, to weak, to
74		little amperes.

Through this measurement they were able to make sense of the fact that the fan moves much easier with the battery than with their electrochemical cell.

4.3 Learning criteria for inclusion and exclusion

In both activities, the students had to establish relations to decide what aspects of the activity to include in their reasoning. In the next excerpt, Andrew succinctly states the generic problem of knowing what to include in the CM-activity (line 75):

75	Andrew	You don't really know what's important either. Or how to do it. I mean
76		perhaps we should include "Ions", since they've got a great part in this, but
77		it…
78	Brian	Yes. Well. Yes… ions.
79	Andrew	Third time a kick the stand [to the video camera]
80	Brian	Everything is "Chemical reaction". Or several chemical reactions perhaps.
81		Well, we can't include…
82	Andrew	No [laughs]
83	Brian	Uhm…
84	Andrew	"Electronegat…" No.
85	Brian	"Negative" and "Positive ions".
86	Andrew	"Plus-terminal"… is like… "Noble". We could've chosen that one. But
87		there's no room for it, kind of.

Andrew and Brian here construe several relations pertaining to norms for including or excluding certain terms in the CM. It seems, for example, as if they are implying both that terms applying too broadly to everything in the CM could be excluded (line 80) and that in any case, one cannot include all terms (lines 81 –

82). Furthermore, a term may be excluded because there is no space for it (lines 86 – 87). In the course of their reasoning, Andrew and Brian need to establish several such rules for inclusion and exclusion:

88	Brian	Do sulfate-"Ions" come in there?
89	Andrew	Yes.
90	Brian	Yeah. We can do like this. But then the "Glass filter" has to be included as
91		well.
92	Andrew	Like, through "Glass filter".
93	Brian	Heh [laugh], messy.
94	Andrew	Heh heh [laugh] No kidding.
95	Brian	There. Uhm, "Plus-terminal"… "From the 'Plus-terminal"…
96	Andrew	Yeah. Like… sulfate "Ions" move… through the "Glass filter" to the
97		"Minus-terminal".
98	Brian	Gee!
99	Andrew	But in fact I think, it's seems rather meaningless to add much more. Cause
100		it's only getting, like…
101	Brian	Yeah right. Heh [laugh] well, yeah.
102	Andrew	Yeah but I mean it's messy already, kind of.

They establish the norm that a good CM should not be too messy, and to the extent that adding more terms to it contributes to making it more messy, they might as well be excluded (lines 99 – 102). On the other hand, they also establish that including one term (sulfate ions, line 88) may require the inclusion of another term (Glass filter, lines 90 – 91). In the LW-activity too, Chris and Daniel learn norms for inclusion of the particulars and contingencies of the practice:

103	Daniel	Yes it… there's got to be a lot of copper on that one [copper electrode]. I
104		mean, more than before.
105	Chris	Yes. You can see that.
106	Daniel	Yeah, there.
117	Chris	Here there's much more copper color.
108	Daniel	Yes.
109	Chris	That we rubbed off.
110	Daniel	Cool.

In distinguishing copper on the copper electrode they establish a norm for accepting what they see as signs of a precipitation of copper, viz., in comparison with how the electrode looked like initially. Considering what they have been discussing before and how they express themselves in the excerpt (line 103), another norm for counting what they see as copper having precipitated is that theoretically, it *should* be there.

5 Discussion

Through the high-resolution mechanism for analyzing learning (Wickman & Östman, 2002) that we used in this study, we were able to point to some similarities between two settings normally considered to be very different. Our results support the notion that in laboratory work, students need to learn procedures and techniques as part of learning the science content (Psillos & Niedderer, 2002). But our results show that this was also an important part of their learning in the concept mapping activity. Åhlberg and Ahoranta (2004) claimed that students quickly learn how to construct good concept maps and Wandersee (2000) stated that it takes at least eight weeks for students to feel comfortable and improve their performance in a course. But it seems unlikely to assume that students will come to a state where they are only focusing on the conceptual issues of a new concept mapping task. It is more probable that the need seen in our results to fill different kinds of gaps in response to contingencies – even in the concept mapping activity – is something that students need to cope with in every new encounter (Hamza & Wickman, submitted).

From the point of view of concept mapping, our study indicates that "the processes with which students learn with concept maps" (Nesbit & Adesope, 2006) cannot only be studied from a purely cognitive, conceptual perspective. Kinchin (2001) observed that some studies on students' learning with concept maps have focused too heavily on the nature of their construction of valid links. He concluded that a focus on only the valid links may hide important aspects of the thought processes that lead a student along a certain path of understanding, because "'invalid' links may have a value to the student by supporting more valid links (sometimes temporarily)" (page 1260). Our results show that how students construe relations to fill gaps having to do also with the norms and techniques of the practice has consequences for how their reasoning develops.

From the point of view of laboratory work, the problem with students engaging in procedures and concrete material may be viewed, less as a problem particular to laboratory work, and more as a problem that arises whenever students engage in a task, even one alleged to be purely conceptual. So claims to the effect that laboratory work should be abandoned in favor of other activities, while still being possibly valid in content, cannot rest solely on the assumptions that laboratory work present students with its own, particular kind of problems. Our results indicate that there are similar problems facing students even in two activities being somewhat at the extremes of the theory – practice scale of teaching activities.

To conclude, some difficulties thought to be particular to practical work as it is normally conceived may constitute legitimate problems even in a task intended to turn students' focus toward conceptual issues. Studies of different teaching activities as methods or means for attaining certain learning outcomes construe the activities in terms of different effectiveness, either of different varieties of a method or between methods (Millar, 1991; Nicoll et al, 2001; Osborne, 1998). Although much has been learned through this approach, it may overlook important aspects of the learning processes going on in these activities. Åhlberg (2004) stressed that the use of concept mapping need not be restricted to the constructivist learning theories in which most studies of concept mapping are conducted. And Jiménez-Aleixandre & Reigosa (2006) successfully studied the contextualizing practices during student laboratory work. Viewing teaching activities also as situated practices in which students need to learn to participate may bring to the fore the process aspects of what constitute difficulties for students in these activities.

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SCIENCE TEACHERS' INTERPRETATIONS ABOUT INTERDISCIPLINARY TEACHING

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Abstract. In this paper, we target the problem, which has been much debated not only in the field of natural sciences, but across the whole comprehensive school curriculum – interdisciplinarity and interdisciplinary teaching. We first render an overview of some fundamental issues concerning the definition of interdisciplinarity and interdisciplinary teaching. We also consider its virtues and deficiencies as they have emerged in educational practice. Thereafter, we present a small-scale research conducted for examining how Estonian physics teachers (science teachers) understand the concept of interdisciplinary teaching and which aspects they regard most important. The method of *concept mapping* was used for data gathering and assessment. Estonian science teachers' understanding of interdisciplinary teaching is mostly limited to connections between different subjects and topics. Science teachers tend to use in concept maps static and very general linking words. The reason for that could be that they have very little expediencies using concept mapping.

1 Introduction

Traditionally, the comprehensive school curriculum has been divided into several subjects, each of which is intended to provide students with competencies in a certain area. Throughout the history of the Western comprehensive school tradition, boundaries between different subjects, or *disciplines*, have been rather well established. Sometimes this has even led educationalists to the claim that different disciplines, representing epistemologically distinct *forms of knowledge*, are mutually incommensurable and boundaries between them insurmountable (e.g. Hirst and Peters 1970, 65).

Natural sciences have commonly constituted an essential part of school curriculum. Via natural sciences, it is intended to provide students with a broad area of competencies necessary in their future educational and professional career and in daily practice.

Recently, the European educational system has experienced a drastic decline of students' interest in natural sciences (European commission 2005). At the same time the social significance of natural sciences and necessity for competent professionals in science and technology persistently grows.
Reasons for this situation are diverse and may vary from country to country. In this paper, we target the problem, which has been much debated not only in the field of natural sciences, but across the whole comprehensive school curriculum – interdisciplinarity and interdisciplinary teaching. Moreover, the topic has been hot throughout the Western higher education system and academic research community, amounting to the most fundamental epistemological, sociological and psychological questions.

Put briefly, interdisciplinary teaching is regarded necessary, since students often perceive learning subjects as isolated from each other and from everyday practice. As Strathern (2007, 125) puts it, interdisciplinarity here becomes a marker of *communicational* success – between students, teachers and scientific communities representing different disciplinary fields.

2 Defining interdisciplinarity and interdisciplinary teaching

Most generally, interdisciplinary teaching can be observed as an approach used to teach a unit across different curricular disciplines. Yet the concept is applied in educational literature in various meanings. Besides the term *interdisciplinarity* (and sometimes interchangeably with it), there have been used terms such as *multidisciplinarity*, *transdisciplinarity*, *cross-disciplinarity* and others.

In her seminal book, *Interdisciplinary Curriculum: Design and Implementation* (1989), Heidi H. Jacobs determines interdisciplinary teaching as constructing specific units or courses of study to bring together all the disciplines within the school's curriculum (Jacobs 1989, here: Kysilka 2003, 296). Jacobs explicitly distinguishes between interdisciplinary and *multidisciplinary* teaching, the latter meaning merely to bring together related disciplines in a formal way for analysis and study. Interdisciplinary teaching is thus a step forward from multidisciplinary teaching. However, while interdisciplinary teaching does not aim to supplant the existing disciplines, a more radical approach determined as *complete integration* is distinguished, where curriculum is determined out of the life experiences, needs and interests of students, regardless of the their initial disciplinary framework (*ibid*).

Other researchers agree that interdisciplinarity is more a matter of degree than that of clear contradistinction, whereby *inter*- and other prefixes largely determine this degree. Dillon (2008), basing on an historical account of Moran (2002), mentions that interdisciplinarity is the most widely but also the most indiscriminately used term for breaking out of disciplinary boundaries, while *inter*- refers to *between*, *among*, *mutuality* and reciprocity. Multidisciplinarity, on the other hand, is the juxtaposition of different disciplines, while multi- signifies combination (ibid). In both cases, however, the goals remain limited to the framework of disciplinary research. This leads to the more radical concept of transdisciplinarity, where the goal is the unity of knowledge and which cannot be accomplished within a framework of disciplinary research (Dillon 2008, 256-257). Strathern (2007) also observes the same sequence of multi-, inter- and transdisciplinarity in respect of their radicalism. She mentions that transdisciplinarity not only disrespects disciplinary boundaries, but disrespects institutional ones too (Strathern 2007, 124). Strathern nevertheless notes that many understandings of interdisciplinarity in fact substantially contain the characteristics of transdisciplinarity (ibid, 125).

Still, there are more terms applied in relevant context, such as post-disciplinarity and paradisciplinarity (Dillon 2008, 257), or complementary teaching (Widmer 2005). Without an attempt to dissolve this controversy in this paper, we stay to the term 'interdisciplinary' as the most generic one. As Moran (2002, quoted in Dillon 2008, 257) has pointed out, interdisciplinarity includes a valuable degree of flexibility, meaning any form of dialogue between two or more disciplines, but expecting it to be transformative, producing new forms of knowledge.

Although multi-, inter- and transdisciplinary teaching involve somewhat different interpretations, they are commonly perceived as being a clear step forward from the traditional, subject- centered teaching. Issues concerning interdisciplinary teaching and curriculum integration have gained enormous attention by educational and scientific institutions as well as in professional literature and conferences (e.g. Kysilka 2003, 292; Strathern 2007, 125).

Of many attempts to summarize the advantages of interdisciplinary teaching, the Marcella Kysilka's listing is indicative [Although she explicitly applies term *integrated curriculum* in this context, it can be seen throughout her text that she equates it with interdisciplinary teaching in a broad meaning of the term (e.g. *ibid.* 297)]. Kysilka (2003) argues that most advocates of integrated curriculum base their arguments on some fundamental beliefs, supported by positions of many eminent educationalists throughout the 20th century. Her recapitulation of these arguments comprehends the following:

1) Genuine learning takes place as students are engaged in meaningful, purposeful activity.
2) The most significant activities are those which are most directly related to the students' interests and needs.
3) Knowledge in the real world is not applied in bits and pieces but in an integrative fashion.
4) Individuals need to know how to learn and how to think and should not be receptacles of facts.
5) Subject matter is a means, not a goal.
6) Teachers and students need to work co-operatively in the educative process to ensure successful learning.
7) Knowledge is growing exponentially and changing rapidly, it is no longer static and conquerable.
8) Technology is changing access to information, defying lock- step, sequential, predetermined steps in the learning process. (Kysilka 2003, 292-293)

Kysilka warns that all these beliefs are obviously not new, nor are they necessarily confined to an integrated approach to curriculum, nor must they be packaged as a whole (*ibid*, 293). However, the Kysilka's listing embraces lucidly the generally espoused philosophical, psychological and sociological virtues of interdisciplinary teaching. It amounts to propositions about the essence of knowledge as well as about how knowledge should be organized and intermediated for students in constantly changing social circumstances.

This list has been reworded and supplemented by other authors, alternately highlighting whether the advantages of interdisciplinary teaching or deficiencies of the traditional subject-centered teaching. Labbudde (2003), for example, distinguishes between seven pro-arguments for interdisciplinary instruction:

1) Constructive learning approach
2) Comprehension of scientific processes
3) Key problems of mankind
4) School as a place for working through experience: learning from projects
5) Interdisciplinary competence
6) Finding and processing of information in the era of ICT

Conversely, Rogers (2003, 67) summarizes the common objections to the traditional subject-centered teaching, which include a fragmented nature as well as the fixed and one-dimensional quality of attained knowledge, the passivity fostered in students' learning, and the distance from the real-world concerns of many students.

Holbrook and Rannikmäe (1997) have brought out the fundamental criteria for interdisciplinary teaching:

- interdisciplinary teaching covers also the educational purposes, where students actively participate in the learning process;
- teaching a theme begins with relevant student's standpoint;
- students are involved in the learning process and active thinking;
- teaching and learning is student-centered;
- students are involved in acquiring communication skills;
- interdisciplinary teaching is closely connected to natural sciences, components of natural science are almost always entwined into the context of interdisciplinary teaching;

Based on literature we can define different dimensions of interdisciplinary teaching (Kremer & Stäudel, 1997; Labudde, 2003):

1) interdisciplinary form, where one subject uses the knowledge of other subjects
2) subject- binding form, where concepts characteristic to several subjects are systematically and mutually combined
3) theme-oriented form, where one *(or?)* more general theme is studied in different subjects
4) subject complementary form, where cross-curricular themes are studied separately in addition to subject lessons
5) integrated form, where concepts characteristic to different subjects are studied together with interdisciplinary themes, subjects are not taught separately

From the point of view of European teachers the most essential aspects of interdisciplinary instruction are: development of social competences, teamwork with colleagues, transmission of knowledge into other fields, connection of different contexts and considering different perspectives (Szlovak, 2002).

Researche shows that the teachers' understanding of interdisciplinary instruction in natural science is varying (Szlovak, 2002, Widmer 2005). The concept of interdisciplinary instruction is used in many different ways in the literature of science didactics (Kremer & Stäudel, 1997; Labbudde, 2003). There are lots of arguments for interdisciplinary instruction and the results of several empirical researches support it too (Yager, 1993).

3 Teachers' interpretations about interdisciplinary teaching

As a result of the above mentioned and many other factors, teachers' interpretations of interdisciplinary teaching may combine in numerous ways. In turn, interpretations of surrounding people, especially of those having a high status, is probably itself a factor influencing one's attitudes towards the interdisciplinary teaching. By the previous sub-chapters, it was intended to indicate that how one interprets interdisciplinary teaching may depend on substantially different factors. One may, for example, build his or her interpretation on some fundamental epistemological standpoint. In this case, one (most probably, a teacher or a dedicated researcher in the field) may hold his or her subject or its methodology as a model applicable for all other sciences and wish to call this *interdisciplinary* teaching. Alternately, one may hold that differences between disciplines are so radical that interdisciplinary cooperation is nearly impossible. In history of philosophy of science, these two theses – *disciplinary hierarchy* thesis and *irreducibility* thesis – have had strong support and have combined in different ways. Attitudes of this kind are relatively secure from sociological factors such as general acceptance or collegiate or institutional support. However, these attitudes may seriously inhibit successful interdisciplinary cooperation.

Another common option is that one's interpretation of interdisciplinary teaching is derived from a sociological factor such as the relative success of interdisciplinary issues in his or her institution or within a certain academic community or professional literature. In school context for example, students' interpretations may be determined by the attitudes of the most evaluated and enthusiastic teachers in the field. All this, in turn, can be shaped in a unique way in case of each student. In sum, number of mutually intertwined factors – epistemological, sociological and psychological – may ground one's interpretation of interdisciplinarity and interdisciplinary teaching.

4 Gap between knowledge and attitudes of students in Estonia

The unpopularity of sciences with students is not a new problem in Estonia (Mullis, Gonzalez, Chorstowski, 2004). The poor motivation caused by small interest is one of the reasons of estrangement (Teppo, Rannikmäe, 2005). Thus a conflict between the social needs and the traditional goals and content of teaching sciences and natural science has evolved, which doesn`t guarantee the sufficient number of career choices in the specialties of sciences and technology. The results of the international comparative study (TIMSS) show clearly that the problem of the Estonian students is not the knowledge level in these subjects but the attitudes to science (Martin, Mullis, Chrostowski, 2004).

The isolated instruction of different subjects and its low connection with practical life dominates at our schools. There is also lack of ability to do practical work. In secondary school students should pick up the literacy in natural science, the ability of finding information from literature and media and also the basic knowledge in the writing, forming and presentation of a research work (Henno, 2005). The current curriculums and classes are often too subject dominant. The real work in several subjects is orientated to the state exams and won`t allow the students to see the problems and phenomena as integrated with other subject fields. At the same time the main purpose of teaching should be the formation of relevant knowledge in the subject (Rannikmäe, Reiska, Holbrook, 2005).

In the planned scientific, development and innovation strategies of Estonia - Knowledge based Estonia 2002-2013 - it is considered important to involve students in science research (Haridusministeerium, 2001). Research as a method is being applied in schoolwork in order to eliminate the gap between theory and practice in science education and also to improve the students` technological awareness. It is essential to make the learning of natural sciences important and at the same time to raise the awareness of students in choosing jobs in the field of science and technology (Haridusministeerium, Majandusministeerium, 2001).

A comparative survey carried out in Estonia and Germany 1996-1999 showed that Estonian students have got very good declarative academic results whereas German students were more successful in applying their knowledge to computer simulated activities (Dahncke, Behrendt, Reiska, 2001; Reiska, 1999). The research was carried out among grade 9 students. The concept mapping method designed by the research group was used to test the knowledge (Reiska, 2005, Fischler etc., 2001).

5 Methodology and data collection

The aim of this research was to discover how Estonian science teachers understand the concept of interdisciplinary teaching and which aspects do they value as the most important ones. The method of concept mapping was used to gather and assess their knowledge about interdisciplinary teaching. That method was chosen due to an essential similarity- interdisciplinary teaching and concept mapping both requires the ability to create connections and combine various themes and subject fields.

35 teachers from different schools all over Estonia were participants in this research. During several trainings for science teachers they were asked to electronically create a concept map of interdisciplinary teaching using a CmapTools program (Novak & Cañas, 2008). The task was accomplished individually. No specific concepts or thematic areas were given, so while composing the concept map teachers could only rely on and base their map on their own knowledge and personal experience. During the research all created concept maps were analyzed in comparison with the Labudde model.

Labudde, Heitzmann, Heiniger and Widmer (2005) base their model of interdisciplinary teaching on six main dimensions: forms, themes, interdisciplinary competencies, the roles of teachers, methods and assessing, all of which can be further split into a number of sub-dimensions. For example the forms of interdisciplinary teaching divide into the level of subjects and the level of schedule (curriculum). The level of subjects is made of disciplinary-, interdisciplinary- and theme oriented teaching, the level of schedule consists of complementary and integrated teaching etc.

The analysis was mostly based on concept level, it was compared how the concepts used by Estonian science teachers fit into the Labudde model. To express and compare the results a table was created where each row stood for one teacher and columns stated: all concepts, all propositions, propositions with medium quality, propositions with high quality, subjects, collaboration and additionally six dimensions from Labudde`s model (forms, themes, interdisciplinary competence, roles of teachers, methods, assessments and evaluation) (Table 1).

6 Results

In figure 1. a typical concept map from an Estonian science teacher is represented.

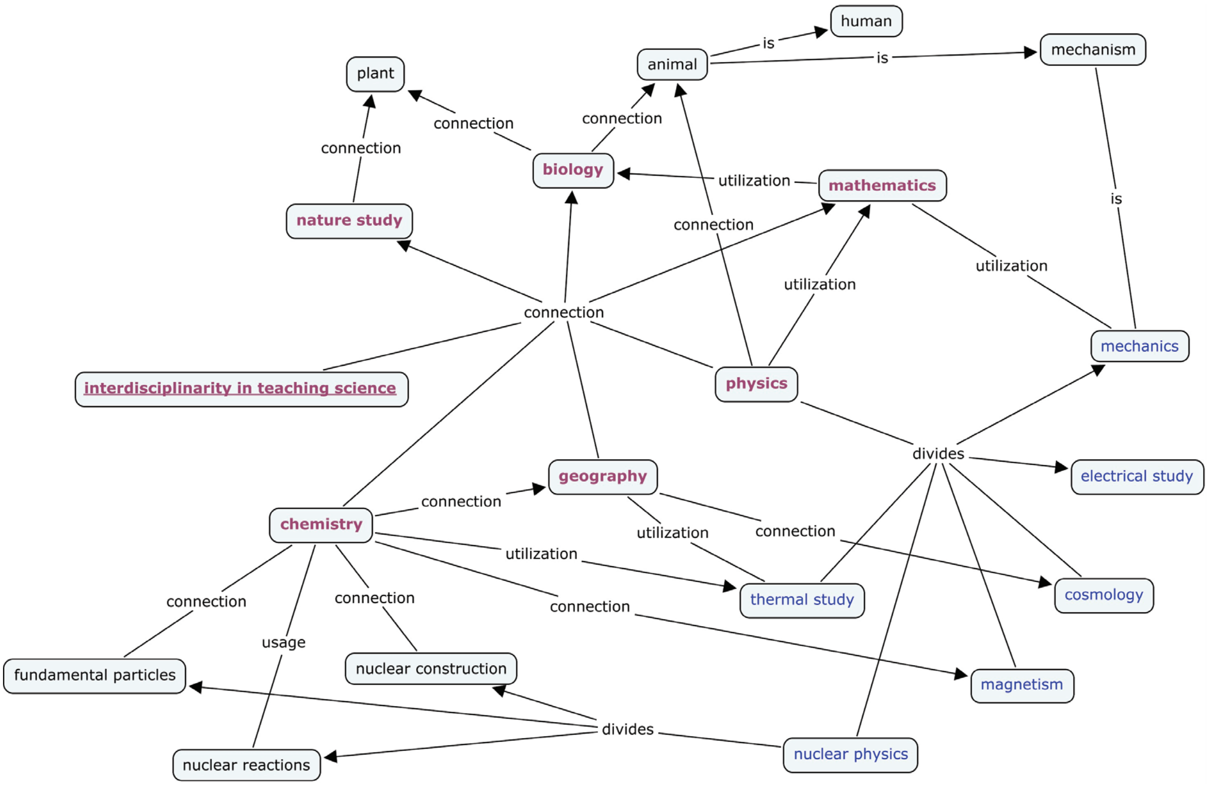

Figure 1. A typical concept map from an Estonian science teacher about interdisciplinary teaching

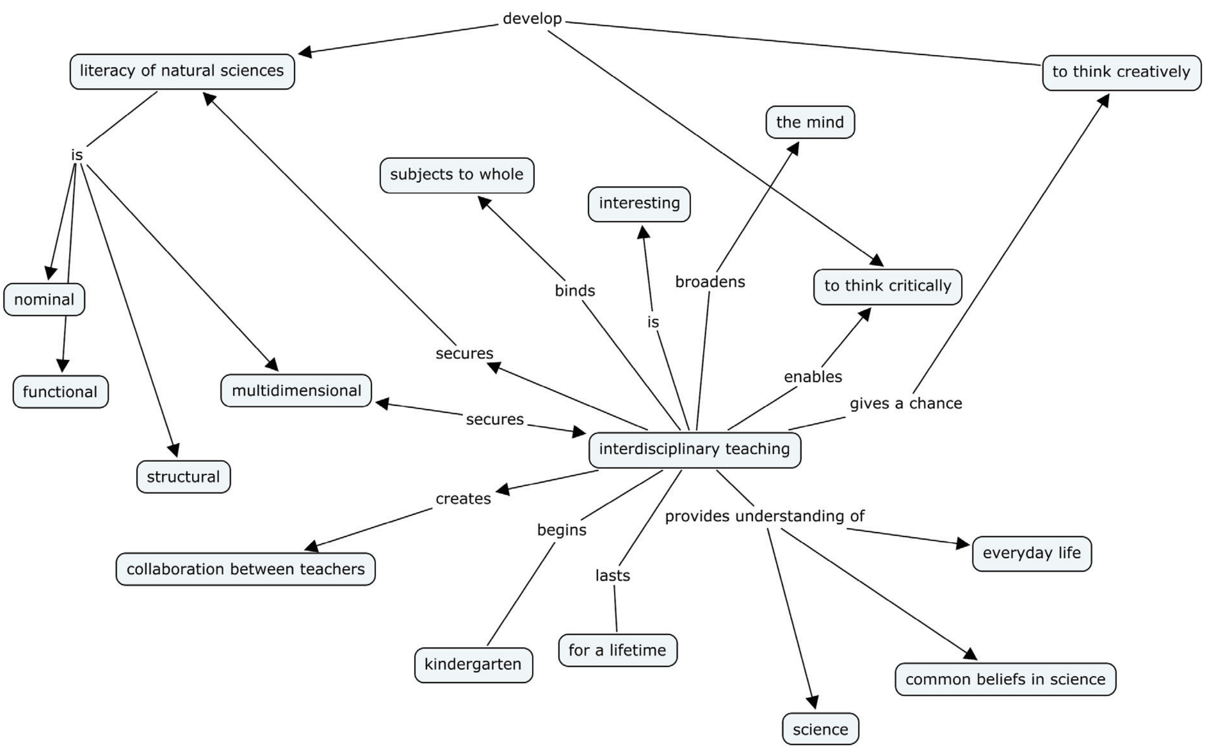

Figure 2. A concept map which represents different dimensions of interdisciplinary teaching

Estonian science teachers interpreting usually the interdisciplinary teaching just on curriculum level. This means that they tend to find connections between different subjects and topics. It's also common that they describe the connections in the most general way (see Fig. 1.). On the map in the figure 2 are also other dimensions of interdisciplinary teaching represented (e.g. collaboration). In table 1 all the data from science teachers' concept map are presented.

Table 1. Data from science teachers' concept maps.

	Variables						Concepts from Different Dimensions					
Teacher	All Concepts	All Propositions	Prop. with Medium Quality	Prop. with High Quality	Subjects	Collaboration	Forms	Themes	Interdisciplinary competences	Teacher Roles	Methods	Assessment and Evaluation
1	13	14	0	0	5	0	5	0	3	1	1	3
2	14	21	4	0	5	0	6	7	0	0	1	0
3	11	10	4	6	8	0	8	3	0	0	0	0
4	14	18	0	0	4	0	6	2	1	1	2	2
5	14	19	19	0	5	0	5	9	0	0	0	0
6	13	24	0	0	5	0	6	4	1	0	2	0
7	13	14	8	0	4	0	5	4	1	2	1	0
8	13	16	11	0	5	0	6	0	3	2	1	1
9	7	21	0	0	6	0	7	0	0	0	0	0
10	13	16	0	0	5	0	6	7	0	0	0	0
11	10	9	0	0	0	0	0	9	1	0	0	0
12	15	11	0	0	5	0	5	9	0	0	1	0
13	20	33	0	0	5	0	6	13	1	0	0	0
14	12	14	0	0	4	0	5	7	0	0	0	0
15	9	12	0	0	4	0	5	2	1	0	1	0
16	22	38	0	0	5	2	7	0	3	1	9	2
17	5	7	7	0	0	0	3	0	3	1	1	0
18	13	15	0	0	4	0	4	9	0	0	0	0
19	7	6	0	0	0	0	2	0	2	1	1	1
20	12	15	5	10	0	0	1	3	4	1	3	0
21	9	15	10	0	5	0	7	0	2	0	0	0
22	8	15	0	0	5	0	6	0	1	1	0	0
23	12	12	10	0	0	0	1	5	4	0	2	0
24	18	14	0	0	7	0	9	6	3	0	0	0
25	15	15	0	0	5	0	6	8	0	0	1	0
26	5	7	0	0	5	0	5	0	0	0	0	0
27	9	16	0	0	8	0	8	1	0	0	0	0
28	8	10	0	0	6	0	7	1	0	0	0	0
29	16	19	8	0	1	1	4	0	7	1	4	0
30	11	16	7	0	9	0	8	0	1	0	1	0
31	11	10	0	0	6	0	6	5	0	0	0	0
32	9	8	0	0	0	1	5	0	1	1	2	0
33	12	12	0	0	8	0	8	2	2	0	0	0
34	7	7	0	0	3	0	4	3	0	0	0	0
35	12	18	8	0	5	0	8	4	0	0	0	0
Avg.	**11,77**	**15,06**	**2,89**	**0,46**	**4,34**	**0,09**	**5,43**	**3,51**	**1,29**	**0,37**	**0,97**	**0,26**

In table 1 we can see that the quality of propositions is weak. The main reason for that is, that the teachers don't describe the links exactly enough and they use very general linking words. They use mostly concepts from "subject" category. Comparing the maps with the Labudde's model we can see that the teacher are using concepts mostly just from two dimensions: "Forms" and "Themes".

7 Summary

Estonian science teachers' understanding of interdisciplinary teaching is mostly limited to connections between different subjects and topics. Other dimensions of interdisciplinary teaching are in maps very rarely presented. Science teachers tend to use in concept maps static and very general linking words. The reason for that could be that they have very little expediencies using concept mapping.

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SUPPORTING COMPREHENSION IN CHEMISTRY EDUCATION – THE EFFECT OF COMPUTER GENERATED AND PROGRESSIVE CONCEPT MAPPING

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Abstract. Teaching and learning chemistry in a context based curriculum requires the process of decontextualization to make chemistry concepts transferable to other contexts. The method of progressive concept mapping is promising to support this process. Research results report difficulties in teaching chemical concepts like the solution concept because students often have resistant alternative conceptions of the processes, formed in everyday life experiences. It is assumed that the process of externalizing concept with the method of concept mapping and also communicating the maps in a group can support the awareness of misconceptions and also to overcome them. In a study 13 to 15 year old students learning chemistry through the German curriculum Chemistry in Context (ChiK) use the computer based concept mapping program CmapTools as a progressive reflecting tool. The experimental design compared this method to the conventional ChiK portfolio method "Lernbegleitbogen" (LBB). Additional the condition reflecting in pairs or alone is altered. The presentation will report theory, design and instruments of the study as well as the results of the pre-study in two classes with 60 students.

1 Introduction

Computer based concept mapping is a promising method for reflecting activities in classroom learning. It allows the learner to (re-)arrange complex knowledge structures easily and in a flexible manner. Therefore it is of interest to use it as a supporting tool in science education. Concepts in biology, chemistry or physics like the energy concept are often complex and will be developed over a longer period up to several school years. The students need methods or instruments to build up a coherent knowledge structure. In recent years, it has been emphasized that teaching science need to account for pupils' daily experiences. Considering and connecting application areas of science and elements of students' everyday life in school seems to be an appropriate method to enhance motivation and interest in scientific concepts on the one hand and to foster students' understanding of these concepts on the other hand (Bennett, Gräsel et al. 2005; Parchmann, Gräsel et al. 2006).

Context Based Curricula like "The Salters Advanced Chemistry Project" (Bennett, Gräsel et al. 2005) and the German approach "**Ch**emie **i**m **K**ontext" (ChiK, Chemistry in Context) (Parchmann, Gräsel et al. 2006) comply with these requirements. According to these approaches chemistry education is characterised by context-oriented aspects in connection with a cumulative development of fundamental concepts (so called basic concepts, e. g. the particle concept, the concept of chemical reaction or the concept of the chemical equilibrium). Following the theory of ChiK, the term "context" refers to a complex, multidisciplinary, and ongoing problem, which addresses pupils' everyday experiences and which is supposed to clarify the essential structures of the discipline (Parchmann, Gräsel et al. 2006). Tuition deals with chemical phenomena and problems, which are embedded in different contexts and which can normally be referred to one fundamental chemistry concept. This curriculum also takes into account the formation of a coherent knowledge structure referring to the fundamental concepts of chemistry. In order to build up an understanding gradually, students get repeatedly the opportunity of transferring the particular concept to further examples: the concept is taken out of its familiar context, it will be "decontextualized" (Parchmann, Demuth et al. 2001).

Until now there is a surprising lack of appropriate instruments for this procedure. ChiK uses a portfolio method called "Lernbegleitbogen (LBB)"; a proper translation might be the term "monitoring worksheet". Students answer questions to explain phenomena using a part of concept. The students then get the opportunity to modify their answers after completing a new learning period. We assume the computer based concept mapping method as an alternative method with benefits in correcting alternative conceptions. This paper reports an experimental study comparing both reflection methods (concept mapping and LBB). The study is based upon the theory of conceptual change that also reports benefits when learning takes place in a collaborative setting. So as a second variable we compare reflecting alone or in pairs. In the following we first provide an insight into the important theoretical aspects of conceptual change, collaborative learning and using concept mapping as a reflective tool. We then describe our research questions and the design of the study. Currently the study is carried out with two classes as a pre-study testing the design and the instruments. This part will be finished at the end of June 08. The presentation will consider the results of the pre-study also to illustrate the aims and possible results of the study itself[1].

[1] The reader of this paper will also get this further information on www.chemiedidaktik.uni-hannover.de/projekte_procmap.html

2 Theoretical Framework

2.1 Conceptual Change

Since the procedure of "decontextualization" is an instrument for discovering students' misconceptions, this study is primarily based upon conceptual change theory. In general there are two cases conceptual change theories are considered in: first, if students' preconceptions do not go along with functional concepts and second, if a new concept causes (typical) misconceptions in many cases. There are a lot of theoretical approaches, which describe conceptual change using different terminologies (e. g. Chi, Slotta et al. 1994; Vosniadou 1994; Tyson et al. 1997) whereby Tyson et al. (1997) developed a multidimensional framework most theories can be located in. In our project, we will adopt this common framework. Tyson et al. describe conceptual change from three perspectives the ontological, the epistemological, and the social and affective perspective. From the epistemological perspective conceptual change requires an adequate understanding of knowledge. Knowledge is not absolute and certain and ever has to be viewed in relation to a specific context or situation. Otherwise it might be difficult for a student to give up or modify a concept of a phenomenon even if he or she recognizes that it is inapplicable to a new situation. From the ontological perspective conceptual change can be described as a shift of the concept from one ontological category into another. The social and affective perspective considers non-cognitive aspects like motivation and design aspects of the learning environment. All perspectives can hardly be regarded independently. A conscious conceptual change in terms of a shift from one ontological category into another will be most likely when the learner is motivated to deal with the subject and also when he or she has a relativistic position of knowledge. How concept mapping can support conceptual change will be discussed below.

2.2 The method of Lernbegleitbogen - LBB (proper translation: monitoring worksheet)

The method of LBB is a ChiK internal development and can be described as a kind of open-ended questionnaire: students have to give answers to questions about a part of a basic chemical concept, which was not considered during the lessons before, in form of short texts. Furthermore the pupils are invited to prepare a drawing in order to illustrate their understanding and application of the respective concept. The students' LBB will not be commented or corrected by the teacher and is disseminated progressively to the students in certain intervals. After the students have answered the questions for the first time, they consistently get their answers back in order to refine or revise them (progressive reflection). This method can be regarded as a kind of portfolio. In ideal cases the students could see their progress every time they get back their LBB for revision.

2.3 Concept Mapping as a Reflective Tool

Concept mapping bases upon Ausubel's cognitive learning theory (Ausubel 1968). Ausubel assumes, that in human's mind knowledge is presented in form of a network. Concept mapping is a process of organizing this knowledge in an external visual form. Following Ausubel, Novak and Gowin (1984) suggested that creating a concept map is a means for identifying scopes of a concept which are understood and which are not. The more a domain is understood the more complex the accordant concept map will be. In comparison to a (normally linearly) written text, constructing a concept map does not impose limitations with regard to the structure. Because of its absent linear structure a concept map can easily be augmented or refined; creating new or deleting incorrect propositions does not entail as many problems as correcting a text. The method of concept mapping is said to be supportive for the process of conceptual change (e. g. Martin et al. 2000; Pearsall 1997). A first map of a concept can be seen as a pre-conception. Being engaged with the learning object might cause new knowledge that can be integrated into the map. Additions and extensions are smaller changes of the existing knowledge structures. The reconstruction of larger parts of the map can indicate the process of conceptual change. Studies that use the concept mapping method in this context could not provide evidence sufficiently. Van Zele et al. (2004) noted that a problem might occur in the uncertainty of analyzing the maps when the method will be used as an assessment tool: "there should be a fair chance that the instructor intuitively adds and assumes links that are not mentioned or inadequately described in the student's response and that may not exist in the student's mind" (van Zele et al. 2004, 1045). We will use the concept mapping method progressively as a learning tool and not as an assessment tool. The term "progressively" goes back to a definition of Liu: "students create progressive concept maps through ongoing revision" (Liu 2002, 377) meaning that revision takes place in an isochronous way.

Computer Generated Concept Mapping: In this research project the concept maps will be computer generated using CmapTools, although the application of a computer is not essential for concept mapping. However, computer generated concept maps can more easily be revised than paper and pencil concept maps. As

Royer and Royer showed (2004), students who used a computer to create a concept map (a) made more complex maps and (b) preferred using this tool instead of using paper and pencil. Following the theory of Novak and Gowin (1984), computer generated concept mapping supports more meaningful learning by facilitating the construction of complex concept maps.

2.4 Collaborative Learning

A Concept map can be regarded as an externalization of parts of the individual's knowledge structure and gives the opportunity to communicate this structure. Discussing and comparing these externalizations can be seen as a collaborative learning phase (Hathorn & Ingram 2002). Students work together in searching for understanding and a shared knowledge. If students get the opportunity to discuss about their ideas of a concept there will be a right chance to detect existing alternative conceptions. By verbalizing their thoughts the students themselves might perceive deficits sooner. The students begin to "reflect on their limitations, contradictions, presuppositions and the implications of their conceptions" (Havu-Nuutinen 2005, 262) so that conceptual change may be stimulated.

3 The study proCMap – progressive computer based concept mapping in chemistry education

3.1 Research Questions

With our study, we refer to research conducted by Schmidt et al. (2003). In their project pupils of a 7th grade ChiK course in Varel (Lower Saxony) had the opportunity of reflecting progressively on the solution concept by using a LBB dealing with the dissolution concept (brewing and sweetening tea). In their report, Schmidt et al. predominantly gave an overview about the misconceptions pupils mostly have with regard to the dissolution concept. Without having analysed the reflection method systematically, experiences showed that students, who used the LBB, had a deeper understanding of the respective concept. In our empirical investigation we will address the possible connection between kind and process of reflection on a basic concept on the one hand and its impact on students' understanding on the other hand. Beyond this (possible) interconnection, the study seeks to gain information about students' attitude towards the reflection method they used.
In summary, the following research questions will be considered:

- Does students' understanding of a basic concept depend on the reflection method they used? If yes, to what extend?
- What do students think about reflection itself and especially about the method they used?
- What kind of misconceptions about the respective concept can be determined? Are there any differences between German and English speaking students?

3.2 Design of the Study

3.2.1 Participants:

The target group of this study is pupils of 7th grade chemistry courses (13 to 15 years old students) from different schools in Lower Saxony (Germany). The selection is dependent on teachers who are experienced in teaching ChiK and volunteering to teach one default teaching unit. The unit is a consensus of all participating teachers, reached in a workshop before the project will start (in-service training).

3.2.2 Procedure

In this study two reflection methods will be compared: Constructing a concept map and answering the LBB. The concept maps will be computer generated using the software CmapTools. These methods will be combined with a second variable: pair working students and single working students. Pupils discuss their results or they have to check it on their own. Figure 1 gives an overview:

		reflection method	
		concept mapping	Lernbegleitbogen
social arrangement	single working	I	II
	pair working	III	IV

Figure 1: 2x2 design; combinations of reflection method and social arrangement

Since two methods for the procedure of decontextualization are supposed to be compared, instruction of these courses has to be context-oriented, according to the German approach ChiK (Chemistry in Context). Following the theory of ChiK, the term ‘context’ refers to a complex, multidisciplinary, and ongoing problem, which addresses pupils’ everyday experiences and which is supposed to clarify the essential structures of the discipline. Tuition deals with chemical phenomena and problems that are embedded in different contexts and can normally be referred to one fundamental chemistry concept. According to the theory of ChiK, tuition can be divided into four characteristic phases (Parchmann, Demuth et al. 2001):

- 1st phase: The phase of contact with a new context: At this point, students are encountered with the context getting the opportunity to orientate themselves within this context.
- 2nd phase: The phase of curiosity and planning: At this stage, students are invited to ask questions with simultaneous regard to the context on the one hand and their personal interests on the other hand. Important questions are identified and a schedule (e. g. planning different experiments) for the next lessons is formulated.
- 3rd phase: The phase of elaboration: Now, the formulated questions will be considered in depth. Different social arrangements and methods are used (working in groups, aggregation and presentation of results, carrying out experiments in order to answer the formulated questions).
- 4th phase: The phase of deepening and connecting: At this stage, the considered and compiled concept is decontextualized meaning, that it is transferred to further examples and other contexts.

In this study, a defined and standardised unit dealing with the dissolution concept will be taught. In order to achieve this standardization of the respective unit, two aspects will be considered: Firstly, only ChiK experienced teacher will take part in the study. Secondly, an in-service training for the participating teachers will take place in the forefront of the study. Furthermore, the teachers are supposed to keep a standardised tuition-diary meaning that they have to describe several aspects of each lesson, which are considered as important with regard to the development of the comprehension of the dissolution concept (e. g. description of the blackboard drawing, materials used in the lesson, etc.). We are aware of that a complete standardization of instruction is nearly impossible, but we assume that little variance in the work plan of the course has no relevant influence on the results of the study.

In the run-up to the start of the teaching unit the students are introduced to the method of concept mapping by members of the research team. During this introductive session, the students get the opportunity of constructing a concept map using the software CmapTools for a topic of their choice. Furthermore, two questionnaires are administered to the students in the forefront of the unit: the first questionnaire is a cognitive ability test (Heller 2000), whose results are used for assigning the students to the four experimental groups. By doing so, homogeneity of the groups will be controlled. Secondly, the students answer a questionnaire, which is based on the solution concept test developed by Uzuntiryaki and Geban (2005). The test used in the current study consists of 15 multiple-choice questions, which refer to the dissolution concept. Since the test will be used for two more times (as a regular post-test and as follow-up-test, eight weeks after the unit is finished), data about students’ learning progress respectively conceptual change and comprehension of the dissolution concept will be collected.

During the course, reflection takes place for three times: after finishing the ChiK phases 2, 3, and 4. Thus the students have the opportunity to revise or refine their “reflection results” for two times. Since intensity and length of reflecting maybe differ between pair and single working students, the latter will get some additional questions following Duschl and Gitomer (1997) (e. g. Which concepts belong together? Does your statement tell what you want it to tell? Is your statement clear to someone else?). Thereby the single working students are supposed to reflect as intense as the pair working students. All students will get comparable instructions.

After the unit is finished, some students will be interviewed. According to a study of Ebenezer and Gaskell (1995) an informal conversational interview will be conducted with approximately 24 students (six from each experimental group). The data collected by interview are supposed to validate the questionnaire. In addition these data allow a deeper insight into students’ understanding of the respective concept. Figure 2 gives an overview about the schedule of the study:

IT	RU	Q1 Q2	RI-1	T1	RI-2	T2	RI-3	T3	P	I	RI	F
			teaching unit									

IT: in-service training
RU: run-up
Q1: cognitive ability test
Q2: solution concept test

RI-1 phase of curiosity and planning
T1: 1st reflection activity
RI-2 phase of elaboration
T2: 2nd reflection activity
RI-3 phase of deepening and connecting
T3: 3rd reflection activity

P: post-test
I: interview
RI: regular instruction
F: follow-up-test

Figure 2: Schedule

3.3 Analysis

The solution concept test will be analysed by the number of correct answers. Since the items also contain common alternative conceptions concerning the dissolution concept, students' response patterns can be used for assessing the development and the stability of the comprehension of the dissolution concept. With regard to conceptual change theory, the expected developmental character of students' responses will be classified according to the ontological categories following Tyson et al. (1997) and Chi et al. (1994).

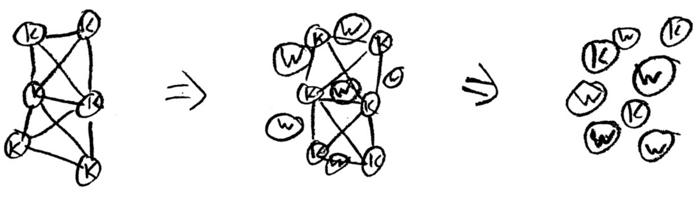
According to the description and classification given in Uzuntiryaki and Geban (2005), the data collected by interview will also be assigned to the respective ontological categories on the one hand and to the common students' conceptions of the dissolution concept on the other hand. By doing so, the validity of the solution concept test can be controlled as well.

Teachers' notes and description given in the tuition-diary will be compared and checked with regard to the default teaching unit. In case of discrepancies its impact on the reflection activities and on the results of the solution concept test will be investigated in more detail.

4 Piloting and Preliminary Results

In February 2008 we started the study with two classes (60 students) using the complete design and methods described above. Because we are testing all instruments and are willing to refine the design in case we will detect some difficulties or inaccuracies, this phase could be regarded as a pilot of the study. Until now (June 08) three reflection activities took place. The whole teaching unit will be finished at the end of June 08 and the data sampled and analyzed to be reported at the conference. Up to now, following rudimental findings could be detected:

In the case of answering the LBB students often revised their initial texts by crossing out single words or little parts of the old one and only a few students formulated complete new answers. Generally, correctness and complexity of the texts increased during the three reflection activities. After ChiK phases 2 and 3 a lot of answers contained alternative conceptions concerning the particle concept (e. g. sugar confers its sweetness upon water particles) or only phenomenological descriptions of the process of brewing tea ignoring the chemical aspects (application of the particle model). However, after ChiK phase 4 a lot of students used the particle model at least for describing the structure of sugar. Figure 3 shows a drawing which was added during the third reflection activity whereas this student did not use the particle concept in his / her former answers.



Caption: K = Kandis (rock sugar) W = Wasser (water)

Figure 3: Drawing describing the process of sweetening tea after ChiK phase 4

In the case of constructing a concept map, hints are found that the method (a) supports the addition of concepts and relation in a further reflection phase (see figure 4, 5 and 6) and (b) allows students to externalize alternative concepts as well. Within one concept map a student argues “hot water abstracts substances from tea” because “substances will dissolute automatically” while “changing their state of aggregation from solid to liquid”. Latter proposition is a misconception that can often be found in the description of the solution process. It can be traced back to the observation that a rock sugar will disappear forming flowmarks. Another student describes the solution of sugar in tea in two ways as “a mixture of sugar and tea” and that “sugar will partly dissolute in tea”.

So the revision of the answers given in the LBB and the revision of the concept maps both can be characterized as enhancement of the previous one rather than as restatement. We want to emphasize that the concept maps and the answers given in the LBB both will not be part of the analyzing procedure for answering the question of the use of the learning methods as tools to foster conceptual change. But a first look at the concept maps as well as at the LBBs provides an indication that the methods are used as intended and that they both functions as learning tools (independent of the social arrangement). That is why currently no statement can be made with regard to the question whether one reflection method outclasses the other.

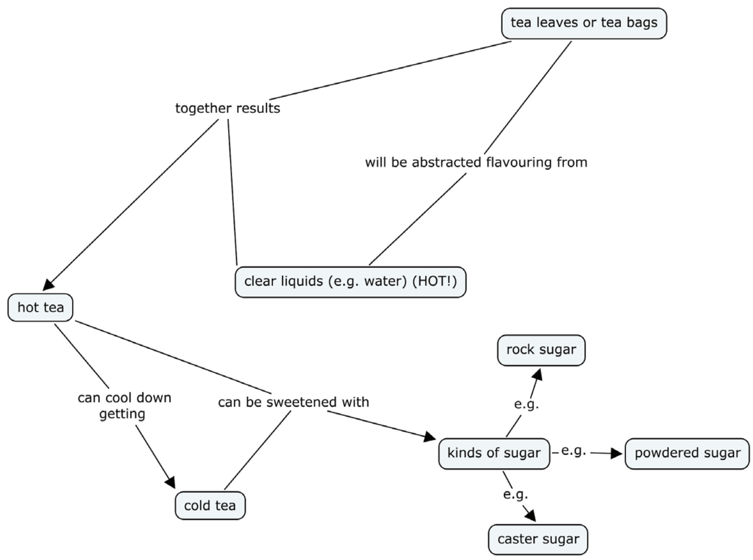


Figure 4: Concept map describing the process of making and sweetening tea after ChiK phase 2

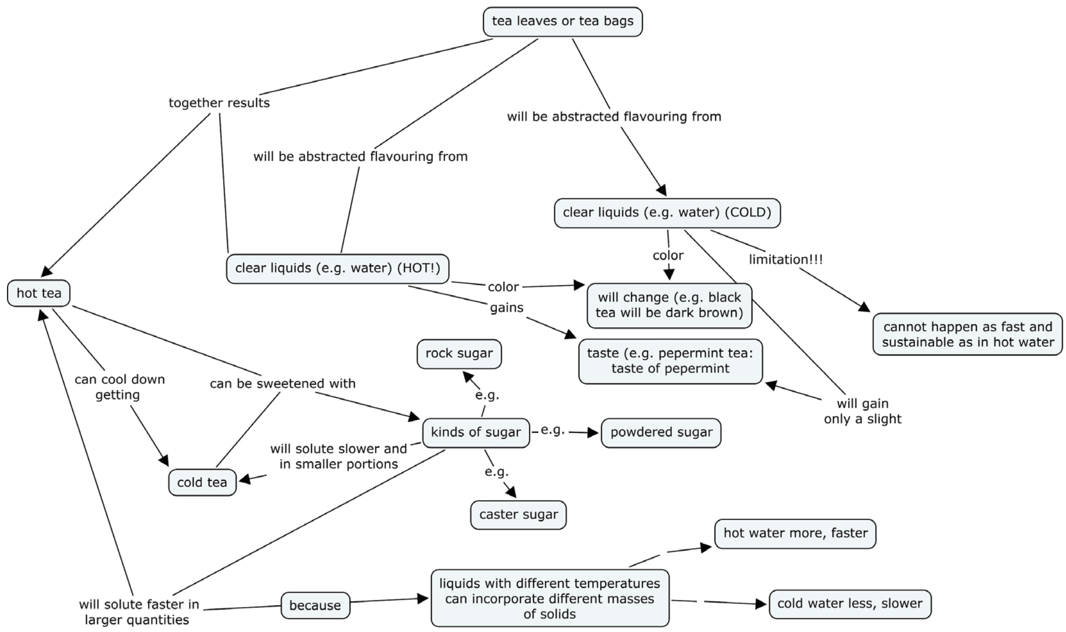


Figure 5: Revised concept map from figure 4 after ChiK phase 3

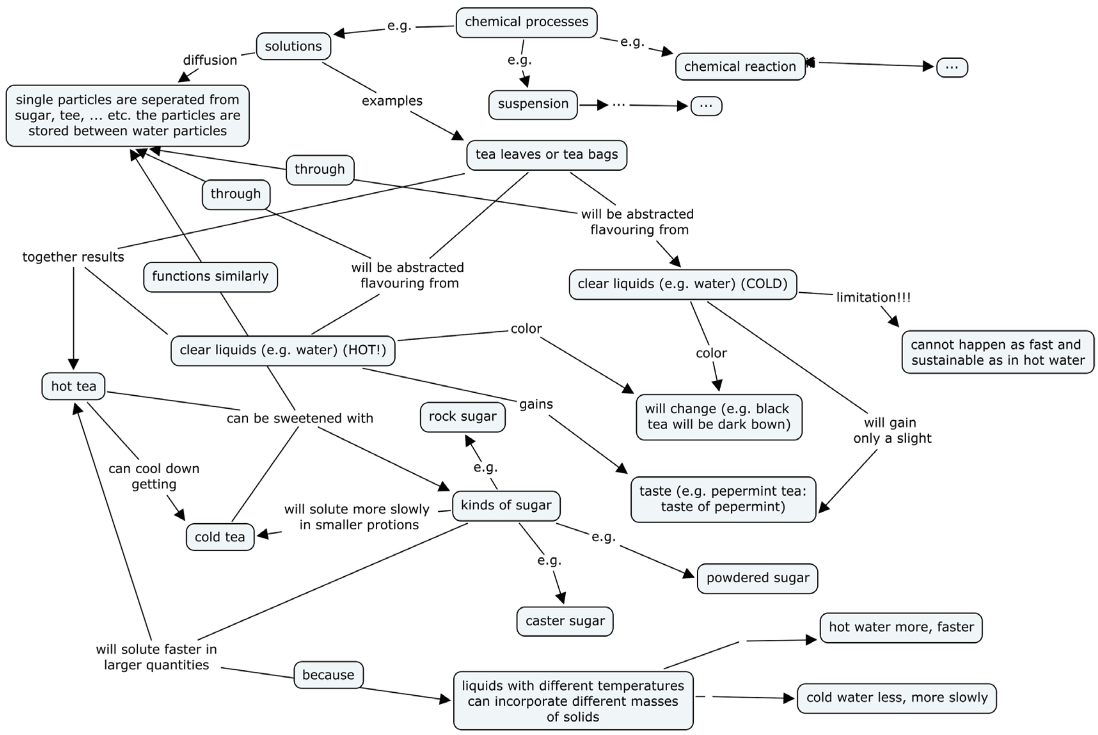


Figure 6: Revised concept map from figure 5 after ChiK phase 4

5 Acknowledgements

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TESTING ACHIEVEMENT WITH CONCEPT MAPPING IN SCHOOL PHYSICS

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Abstract. This article describes the use of concept mapping for achievement testing in school physics. It is based on two empirical studies with 9 and 10 grade students. In the first study the students' knowledge was tested with concept mapping before and after learning sequence about the topic "Energy supply in a dynamic system of different power stations". Two different teaching methods ("traditional" and STS) were compared with a control group design. The results confirm that concept mapping is a suitable method for testing students' declarative knowledge and that the STS method is appropriate method for physics concepts. In the second study we researched relations between students' knowledge and competences to act. The topic in this study was "Energy consumption at home". We couldn't find any proof that knowledge influences acting directly, but these students who had more knowledge, acted in some aspects more relevant.

1 Introduction

This article describes the use of concept mapping for achievement testing in school physics. It is based on two empirical studies with 9 and 10 grade students in Germany and Estonia. Both studies are part of a research project, which deals with the connection between science teaching and action.

In the first study the students' knowledge was tested with concept mapping before and after learning sequence about the topic "Energy supply in a dynamic system of different power stations". Two different teaching methods ("traditional" and STS) were compared with a control group design. In the second study we researched relations between students' knowledge and competences to act. The topic in this study was "Energy consumption at home."

2 Method used in both studies: concept mapping

The constructs activated in long-term memory are called concepts in cognitive psychology. These concepts represent the information depending on our experience and our relations to this information. The concepts are connected with each other. The concepts activated in our memory construct a data bank that helps a person make decisions and act. In such kind of formulations the word "concept" takes the first place (Hoffmann, 1994). Still the meaning of a concept in cognitive psychology is not identical with the meaning of a concept in education.

According to Arbinger (1991) there are three kinds of knowledge presentation: declarative knowledge, procedural knowledge and analogical knowledge. Declarative knowledge is recorded as a proposition. A sentence consists of two related concepts. Every sentence is meaningful; it can be evaluated and presented by its structure. Declarative knowledge can be divided into episodic and semantic knowledge. Episodic knowledge involves personal experience; semantic knowledge is more general and is a sum of single occasions of experience.

According to Tergan (1986) knowledge is organized and structured. Like Arbinger, Tergan differentiates between three kinds of knowledge presentation, one of them being semantic spatial model. Semantic spatial models represent declarative knowledge. Knowledge is sorted by similarity of the concepts (psychometric model), is presented by sentences as a network structure (network model) or is visualized conceptually (conceptual model).

Concept mapping is a graphic technique for representing ideas, helping to think, solving a problem, planning a strategy or developing a process. Concept mapping means connecting different concepts of the subject and constructing relations by compiling the map. The concept mapping method is based on the theory of meaningful learning (Ausubel, 1963) and on the assumption that knowledge is saved in the human brain propositionally and the generated concept maps just represent this propositional knowledge saved in the brain (Atkinson, Shiffrin 1968, Norman, Rumelhart 1978). The method was introduced in didactics by the American scientist Novak (1990) in the 1960s. Later on analogous methods have been developed by several research groups (see Scheele & Groeben 1984 or White, Gunstone 1992). Much success has been achieved by the application of concept mapping in the teaching process to integrate new concepts into the existing system of knowledge (Novak 1990).

“Concept mapping is a process of meaning-making. It implies taking a list of concepts – a concept being a perceived regularity in events or objects, or records of events or objects, designated by a label, – and organizing it in a graphical representation where pairs of concepts and linking phrases form propositions. Hence, key to the construction of a concept map is the set of concepts on which it is based.” (Cañas et. al. 2003).

Today concept mapping is widely and successfully applied in many different fields of education, e.g. concept mapping is widely used in science education (Behrendt et. al. 2000; Fischer et.al. 2001; Reiska 1999, 2005).

Reiska (2005) describes some advantages of using concept mapping in education:

- Possibility to use concept mapping in every phase of teaching process (e.g. at the beginning of lesson for introducing a new concept or at the end of lesson to assure the learned concepts);
- Independence of age (concept mapping can be used by children in kindergarten but also by adult students in the university)
- The constructing of maps helps students to reflect on they own knowledge;
- Concept mapping helps students to concentrate themselves in the process of group work;
- Concept maps give teachers information about students` knowledge;
- Concept mapping can be used for planning the lessons.

3 Using concept mapping as an assessment tool

When the method of concept mapping is used in lessons or in research, a significant component of the application is the evaluation of concept maps. Reiska (2001) describes four different types of evaluation. They range from intuitive impressions only to computer-aided quantitative evaluation. In addition, the possible stages are listed according to the type of evaluation and computer application:

1. Intuitive evaluation

Intuitive evaluation is suitable for giving advice on learning with the aid of concept maps. The advisor or researcher is able to view the maps of the subjects and, on the basis of intuitive impressions (size, structure and correctness of individual propositions), evaluate the range of the subject’s knowledge. An intuitive evaluation can only be performed with small, clear concept maps. This kind of evaluation is not very suitable for comparative studies because the results are only intuitive and depend to a large extent on the respective interviewer (advisor).

2. Semi-quantitative evaluation

Semi-quantitative evaluation can be used for assessing small concept maps and for small numbers of maps. With this type of evaluation, several simple variables are calculated (number of all the propositions, number of correct propositions). Since everything has to be evaluated manually, this type of evaluation is very time-consuming and therefore not suitable for evaluating large numbers of concept maps.

3. Computer-aided quantitative evaluation

Computer-aided quantitative evaluation can also be used for large maps and large numbers of maps. Before evaluation can be carried out on a computer, the information from the concept maps must be entered into the computer. Special computer programs can be used for this in order to reduce the time involved and input errors, yet it is still too time-consuming for using in everyday school life. Computer-aided quantitative evaluation is very suitable for using in research.

4. Quantitative evaluation by computer only

Quantitative evaluation by computer is the most efficient type of evaluation. This type of evaluation can, however, only be carried out if the concept maps are created on the computer itself. This type of evaluation rules out human input errors. It is suitable for using with a large number of maps and comprehensive maps as well. It is the only type of evaluation which, apart from using in research, is also suitable for using in schools as far as the time factor is concerned.

Although Ruiz-Primo and Shavelson (1996) show also the problems in using concept mapping as assessment tool, there are many studies showing that concept mapping is an appropriate tool for testing students achievement (McGaghie, et al, 2000; West at al, 2000; Fischler et al, 2001; Reiska 2005). Some of the studies also show that there is a high correlation between the concept mapping and other knowledge tests (Mikelskis, 1999) but some studies did not prove the correlation between concept map scores and e.g. multiple choice exam performance (McGaghie, et al, 2000).

Different levels of evaluation were used in education; however we could not find the fourth level of evaluation. The possible reason for this can be that there is no suitable evaluation tool for concept maps developed yet.

4 Study one: knowledge before and after instruction and relation between knowledge and taking action

This study aims at two interrelated main objectives. On the one hand we examine the - didactically constantly postulated, but rarely substantiated - relation of learning and acting on the basis of a determined instruction. On the other hand we are looking at this aim parallel on the basis of several learning matters which differ relevant to learning and acting. In this study verbalized knowledge (tests including concept mapping) and actions of the subjects (intervention in computer simulations together with the thinking aloud method) are established and recorded at two stages in a teaching phase which is significant both for society and for physics (energy consumption and energy supply). This is linked with teaching approaches (traditional German science teaching and teaching according to the Anglo-Saxon STS model: Science - Technology - Society).

5 Concept mapping in study one

The information processing approach in psychology and the constructivism which is very common in research of science teaching start out from a network of knowledge concepts. Therefore knowledge can be described e. g. in the form of directed graphs, the nodal points of which are concepts and the edges are relations between these concepts. The connection of two concepts each with a directed relation therefore represents a part of the subject's knowledge in form of a proposition. Such graphs can be ascertained relatively easily for different fields and can also be analyzed by using evaluation programs (entailing, however, great expenditure). In this context we refer to the papers of White and Gunstone, 1992, of Bonato, 1990, and of Weber, 1994, as well as to our own preliminary work.

In this study we used concept mapping to record students' knowledge before and after a teaching unit. 51 concepts and 10 relations were given and they were printed on self-adhesive labels (see Fig 1).

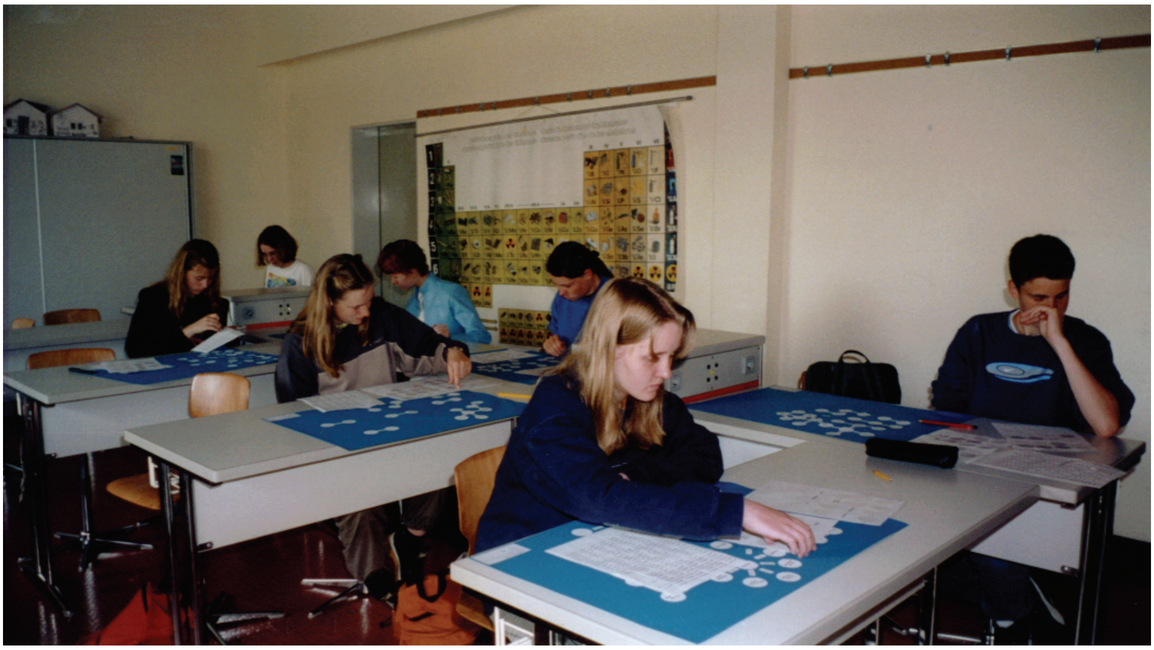

Figure 1. Data collection with concept mapping in study one

To be in a position to evaluate 130 extensive concept maps with maximally 51 concepts and 10 relations we raised, we elaborated our own evaluation procedure (see Fig. 2). As a connection we have a reference matrix of all 51 concepts where the relations are entered which a physicist would use. This matrix was created by expert rating in several stages. The concept maps of the subjects are initially transcribed into adjacency matrixes. Afterwards these matrixes are computer-aided analyzed. It was our initial idea to evaluate the nets with the help of the graph analysis program GRADAP. We found corresponding suggestions in Bonato (1990) and Weber

(1994). As GRADAP is not very user-friendly and neutral concerning the content, in our evaluation procedure this program became a preliminary stage of the program CMVARI which we developed (Reiska 1997).

With this method we were able to reduce the time required to evaluate the maps, but it still has some weak points. The most important one is that the evaluation of the maps is still very time-consuming. This is one of the main reasons why concept mapping is still not very often used in schools for assessment.

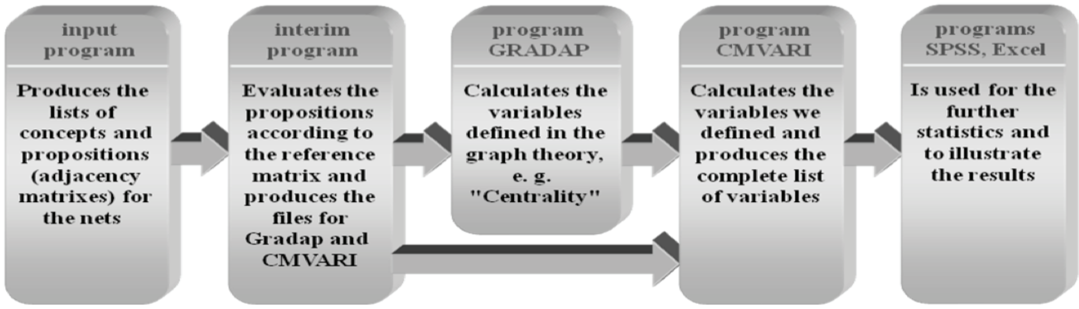

Figure 2. The evaluation procedure for concept maps.

6 Results of the first study

It was possible to prove by means of concept mapping that there had been a learning effect in the student groups with the instruction programs.

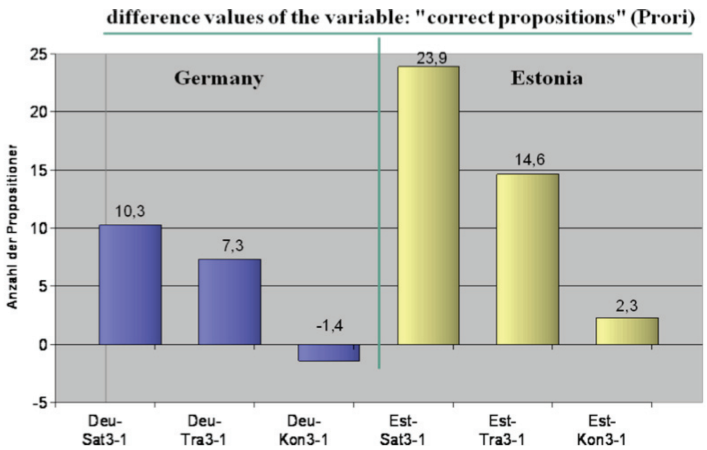

Figure 3. The increase of number of concepts in Germany and Estonia

We summarize our results in note form:

1. The increase of knowledge of the subjects we observed is indeed to be explained by the instruction.
2. The increase of knowledge depends on the teaching approach. It is larger in STS-teaching than in traditional teaching of physics, namely in the use of concepts of the terminology as well.
3. The school mark of the subject physics has only a minor prognostic worth concerning the increase of knowledge and the progress in acting.

According to the design of our study (Dahncke, 1996) before and after instruction the data is collected with the same procedure. Thus, we have a design of repeated measuring (see e.g. Bortz, 1985). Therefore, an evaluation procedure of several stages suggests itself. We combine this procedure with our own developments we outlined before which lead up to our programs CMVARI for concept mapping and SIMVARI for computer simulation. We are showing one example for concept in the different profundities of evaluation (MANOVA-procedure, LEAST SIGNIFICANT DIFFERENCE (LSD)-test and PARALLELING). Data collecting, processing and evaluation for the concept mapping is carried out in steps up to CMVARI, then we set up the averages for each variable in the groups and phases (see bar graph in fig. 4). In the further analysis we are looking with the MANOVA-procedure for the values which show significant differences between groups respectively phases (see * in the matrix of fig. 4. As an example we choose the variable „number of concepts from terminology“ because just in this field STS-teaching is often reproached with a deficit.

ZaFa	Average	0,31	0,40	0,38	0,65	0,67	0,39
Average		Sat1	Tra1	Kon1	Sat3	Tra3	Kon3
0,31	Sat1						
0,40	Tra1						
0,38	Kon1						
0,65	Sat3	*	*	*			
0,67	Tra3	*	*	*			
0,39	Kon3				*	*	

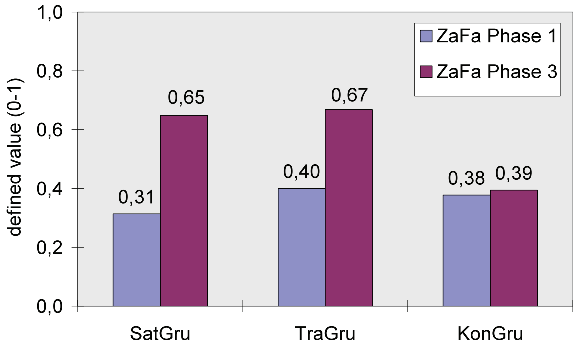

Figure 4. Variable: Number of concepts from terminology (ZaFa)

It turns out that the control groups achieve nearly no increase, both instructed groups achieve nearly equal increase. Therefore, with the LSD(p)-test on the level p=0,05 we are examining whether the differences of the single groups vary significantly.

The expected effect of instruction can be seen. The increases in the use of terminology are nearly the same for the SATIS-group and the traditional group (no significant difference), but they are significantly higher than of the control group (significant on the 5-%-level).
In summary may be stated: the more knowledge is shown during concept mapping, the more anticipating thinking, less mistakes and more reasonably economizing could be observed concerning the acting during the computer simulation.

7 Study two – learning physics and taking action

Although the competence to take action is postulated in most statements as an important objective of science teaching we don't have enough evidence of that. This is at least in part due to the fact that taking action of school students is difficult to observe and to record. In this field computer simulations can be helpful.

The subject matter of our project is the relation of learning and taking action. We examine this relation on the basis of examples from physics lessons, which belong to the concept of energy. Our methods of data acquisition comprise concept mapping, taking action as carrying out experiments and as intervention in computer simulation and the method of thinking aloud.

Progress in learning is established through differences in concept maps and in thinking aloud before and after lessons. We developed a computer program for concept mapping, CCMap, which enables the subjects to design the maps on screen. The results of our study in which we used about 200 maps designed by students confirm the advantages of using CCMap.

Taking action means in the understanding used in our studies that the subject makes a plan and follows it. Actions have to be elective, arbitrary and controlled. Following this criteria (Edelmann, 1996) we regard intervention in computer simulation and carrying out physics experiments as actions.

8 Concept mapping in study 2 - CCMap

For this study we developed a computer program for concept mapping, CCMap, which enables the subjects to design the maps on screen (Figure 5). In particular, the new method excludes the former weak points of concept mapping, thereby increasing its fields of application. In order to increase the screen area to maximum size, the bar of concepts was programmed in such a way that it is automatically scaled down if the number of concepts not yet used allows this. The bar of relations is only displayed if the user moves the mouse onto the bar of concepts. The user interface does not have complex structural menus. CCMap was developed in close cooperation with students at schools and universities in order to make it as user-friendly as possible.

An important feature of the researcher version of CCMap is the evaluation tool. It is possible to evaluate the maximum of 40 concept maps at the same time with CCMap. The maps are evaluated according to size, content and structure. In addition, MapChar, a variable made up of other variables, is calculated and visualized as a diagram. This variable is very suitable for grading students' performance at school. Evaluation of the maps with CCMap is based on a comparison of the maps with a reference map, i.e. the propositions from the students' maps are compared with those of a reference matrix or list. If the corresponding reference matrix does not yet exist or is still not complete, it can be created or completed during evaluation.

Eight different variables for the maps will be calculated:

AlPro - Total number of propositions;
RiPro - Total number of correct propositions;
FQ - Error rate;
Fach - Correctness in physics (value from "0" to "3");
VNet - Integration;
Zent - Centrality of the map;
Insel - Number of sub maps (islands);
MapChar - Combined variable (combined from size, correctness and structure of the map).

The advantage of this method of evaluation is that a proposition only has to be evaluated once. The next time, the program automatically searches for the proposition in the reference matrix and subsequently applies it.

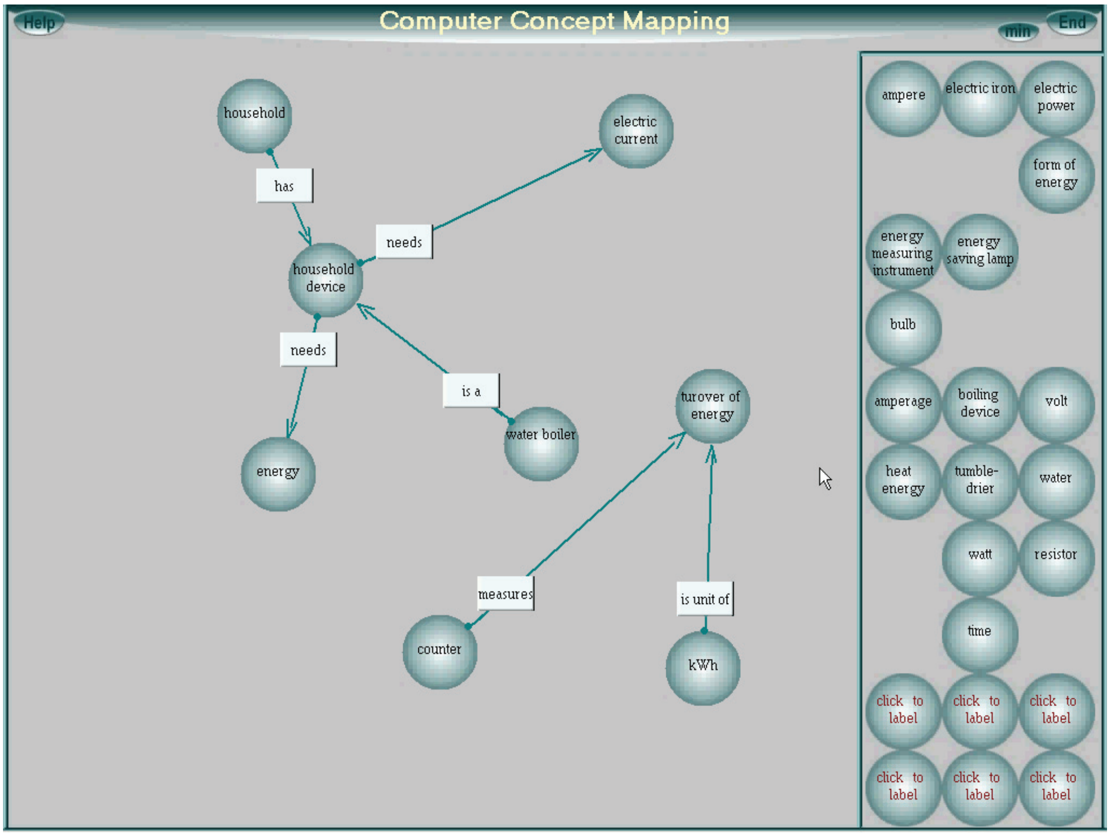

Figure 5. CCMap program

This means it is possible to generate a reference matrix file for each topic which can then be used repeatedly. When all the propositions have been evaluated, the variables are calculated on the basis of this evaluation.

With CCMap it is possible to calculate the compound variable MapChar. Since this variable is made up of several significant variables, it forms a sound basis for assessing students' performance grades and also for illustrating the results.

9 Results of second study

Our results drawn from a sample of 100 9th graders show a strong impact of teaching on both types of taking action and that the actions themselves are learning situations which are at least as effective as learning in the classroom.

The concept maps show the effect of lessons (Fig. 5). Our findings also confirm that actions in the real situation and in computer simulation are learning situations. We compared the concept maps before and after taking action both in the STS group and in the control group (Fig. 6). Our combination of teaching and taking action leads to better knowledge than in control classes.

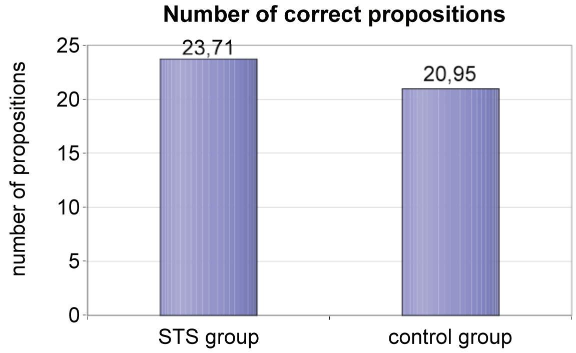

Figure. 5. Number of correct propositions

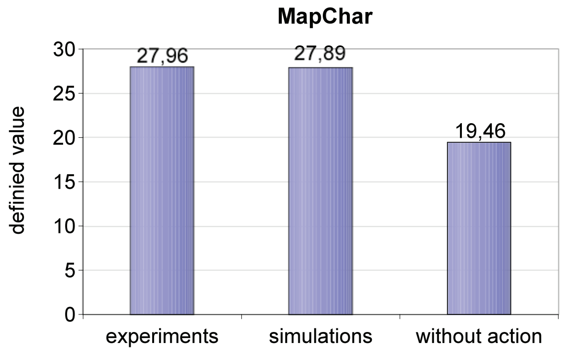

Figure 6. Increase in variable MapChar: Concept maps before and after experiment and computer simulation

10 Summary

Although in the literature we can find much criticism about validity and reliability by using concept mapping as an assessment tool (see e.g. Ruiz-Primo, Shavelson, 1996). Our studies showed that:

1. physics instructions have influence on knowledge measured with concept mapping;
2. different teaching methods have different influence on knowledge measured with concept mapping;
3. instructions about non-relevant topic don't have influence on knowledge measured with concept mapping;
4. there is a correlation between taking action and knowledge measured with concept mapping.

Based on these evidences we continue our research on concept mapping as an assessment tool in science education.

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THE CONCEPT MAP AS A TOOL FOR DESINGING A COMPETITIVENESS AND INNOVATION SYSTEM FOR CAUCA - COLOMBIA

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Abstract. The projects called "Strategy of Innovation for the Competitiveness of strategic sectors for the Cauca Department in Colombia" and "Knowledge Management System for the Pacific Zone in Colombia", financed by Colciencias and SENA, explore the applicability of the concept maps in this territory as a mechanism to facilitate the knowledge capture regarding strategic topics for this region with the purpose of determining its supply and demand. During the development of these projects a method has been designed for allowing mapping or organizing the knowledge on small-scale agroalimentary chains, analyzing them as social networks made up by heterogeneous actors. This allows emphasizing the roles played by the different actors of a competitiveness system supported by Science, Technology and Innovation (SRCyT&Inn), in a predominantly rural, pluriethnic, biodiverse and multicultural region.

1 Introduction

The emergence of the global economy has had profound implications for the sustainability of small-scale rural producers in Colombia. The redefinition of Colombia's competitive position in order to face the globalization processes has focused on different sectors of the economy and left aside the great majority of small-scale rural producers, generating a combination of factors that affect the competitiveness of these producers, among which are the following: i) the reduction of Government support in technical assistance and research, ii) the direct competition with foreign products, many of which are subsidized, iii) the municipalization and regionalization of the responsibility necessary to support the rural sector. The latter implies having to face great responsibilities whilst having very small budgets. The combination of these factors has resulted in a deep crisis of the agrarian economy and has affected in particular those areas with a rural majority such as the Cauca Department.

This paper presents the results obtained during these research processes, focused on the design of an Innovation Regional System that promotes the Competitiveness.

2 Objective and Scope of the research

2.1 Main Objective

To create in a participative way the component innovation within the Competitiveness Strategy of Cauca department.

2.2 Specific Objectives

- To provide technical support to the Competitiveness Regional Commission for the designing and implementation of management processes of the innovation in the productive sectors.
- To contribute to the innovation capacity of the actors who participate in the Regional Competitiveness System, specially the Mipymes and new local authorities.
- To generate a project portfolio in order to promote regional Innovation.

2.3 Analysis Unit: Small Scale Productive chains as Social Networks of the SRCyT&Inn

A Regional Innovation System can be defined as a "set of networks of public, private and educational agents who interact in a specific territory taking advantage of a particular infrastructure, for the purposes of adapting, generating and/or spreading technological innovations" (Carlson, B. & Stankiewicz: 1991).

The Regional System of Science, Technology and Innovation (SRCyT&Inn) is, for the Department of Cauca, the mechanism of joined construction in which to articulate, dynamize and integrate the active forces of the department, allowing the system actors to understand the complexity of this society for generating the capacity of giving them their own solutions and promoting the creation of their own model of development.

The social networks that integrate the SRCyT&Inn join different actors together with the purpose of developing potential innovation, both in the communities of small scale producers to facilitate their insertion in the knowledge and information society, and the entrepreneurs' networks of companies with technological base. Both types of organizations have different conditions, but the same model can describe them for the sake of this research project.

3 Methodology

3.1 Description

The methodology designed considers one phase for research followed by one of social interaction, as it is inherent to the research action projects. This implies that the direction that should be taken after the interaction is determined by the actors rather than by the research project team.

The research team has to face three responsibilities: i) the population of the Department of Cauca should be encouraged to develop a sense of belonging and the need to use the Knowledge map, ii) the development of a method for the construction of Knowledge maps, and iii) the construction of a technological platform that can help to get an automated map.

3.2 Research Techniques

This encourages the users of different kinds of methodologies with common contact places through the execution of the research. Some of the techniques to be used are: workshops, interviews, surveys and narrative records among others.

The project works with the help of a mixed model, recapturing a hermeneutic and historical approach sustained in the understanding and interpretation through the consent rather than outrage, which required getting deeply involved with the analyzed communities. Data has been collected through interviews, narrative records and workshops.

4 Results

4.1 Competitiveness and Innovation System of Cauca

The members of the SRCyT&Inn research team have to accept that the government and the institutional agents cannot fulfill the demands of the social actors in the productive chains, and as a consequence ~~so~~ the social actors have produced non-formal second level organizations. The formal and non-formal organizations do not recognize each other, leading to a work disarticulation. Therefore, it is essential for the two types of organizations to dialogue and try to work together. Most of the actors participating in the SRCyT&Inn project (Policy makers, Centers for Technological Development and researchers, Interface Institutions) privilege the codified knowledge and find it particularly hard to understand, and hence value, the ancestral knowledge that the rural producers, entrepreneurs and others possess; so we think it is important to develop the institutional ability to acquire that non-codified knowledge.

In order to facilitate the conception of a SRCyT&Inn model, it is very useful to classify the actors in arbitrary categories. For this model, such categories are:

Policy Makers (State - Donors): Organizations with national, regional and local scope who are in charge of designing and implementing policy mechanisms and financing the support of enterprise development initiatives. "The government, through its organizations in the national, regional and local environment, is responsible of designing and implementing policy mechanisms to support the initiatives of rural managerial development" (Lundy and Gottret: 2004).

Interface Institutions (Agencies of Development): The governmental and non governmental organisms that are in charge of facilitating processes of enterprise development and to provide support services for diverse actors, so that these can adhere effectively to the chains, networks, etc, with opportunities to generate income and employment for the population.

Centers of Technological Development and Researchers (Research Institutions): These are institutions with the ability to lead and to facilitate research processes and contribute with co-innovation that generate and apply both on the processes innovations (or management), and in the technological innovations (or basic). Centers of R+D. "The research institutions with capacity to lead and facilitate research processes and co-innovation that generate and apply process innovations (or management) as much as technological innovations (or basic)".

Producers, Companies, Chains, Clusters: Actors of the community, organizations who develop production processes that include transformation of resources into goods (i.e. goods of transferable property) or services (activities, nontransferable). Actors of the community, organizations of the productive chain (Producers, Transformers and Traders).

The challenge for SRCyT&Inn is to introduce the use of the knowledge map mechanism in the dynamics of the social networks as a support for the management processes of knowledge. The creation of "Cauca Región de Conocimiento" (Cauca a Region of knowledge) is an initiative led by the SRCyT&Inn that will become the scenario to be used for the generated advances.

Considering that the actors involved in the SRCyT&Inn have valuable tacit and explicit knowledge, they have to face complex approaches because of the following factors:

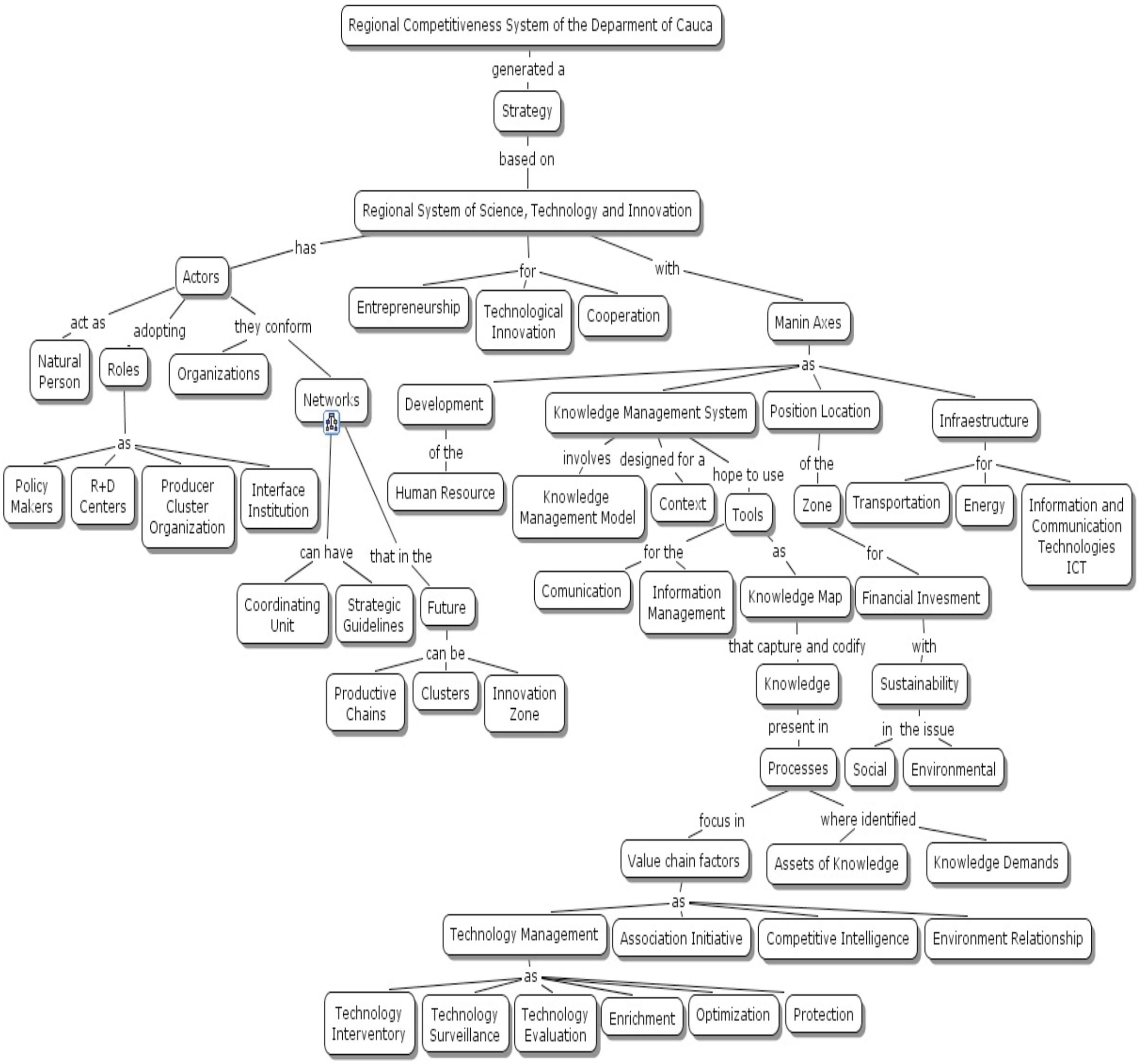
- The difficulty to relate them to the knowledge of other actors, given their diversity.
- The impossibility to codify them in a complete and valid form.
- The coverage of a characterization of actors for a purpose of meso-competitive impact is too demanding and requires long term resources.
- The spreading and appropriation of knowledge are based on the confidence of the actors to share their knowledge freely.

In the Department of Cauca the project implies to work with the knowledge maps as a tool to facilitate their codification for minimizing their complexity and maximizing the access to them. The figure 1 shows the analyzed aspects of this project: on the one hand, it shows the components of the SRCyT&Inn, on the other hand, it emphasizes on the importance of the knowledge management system as a way to support the learning processes found within the social networks, a basis that fosters the innovation at microcompetitive level, which is the real environment in which the SRCyT&Inn is intended to work properly. The knowledge Management System: i) analyzes the Department of Cauca context as a region whose people know the need they have for searching alternative ways to neo-liberalism as a development strategy and an aid for their insertion in a globalized economy. The regional actors explore particularly the opportunities that the theories of Endogenous Development and the guidelines given by the Systemic Competitiveness offer, highlighting the importance of the networks, and the social actors as creators of a growth process that should work with equity and social inclusion; ii) it also suggests an adequate knowledge management model that supports the construction of an own development model linked to a knowledge management strategy that contribute to the knowledge dialogue among peasants that count on valuable ancestral knowledge and legacies, most of which are tacit, before actors of support local institutionality that work with codified knowledge, specially about markets and technologies. This knowledge flow is characterized by important obstacles and some potentialities that this type of projects helps to recognize; iii) it also requires a planned, cyclic, and feedbacked communication process, which shall be nonexclusive and responsible to facilitate the SRCyT&Inn actors to be backed by a cultural factor that may reinforce formal communication and minimize informal communication. It will similarly allow them to get more integration in order to share and acquire information and new knowledge that will help them to fulfill the objectives and processes of the networks and the consolidation of the system itself, and iv) describes communication, management of information, and knowledge management tools. One of these tools, subject of this study, is the knowledge maps that allow codifying the processes that take place within the networks. These codes get associated to factors such as associability, relation with the environment, competitive intelligence and technological management. This paper will focus on the latter.

During the execution of this project, the concept maps have become tools for knowledge capture; it may be possible that the depth of this approach is not very meaningful, but it offers important judgment elements. Having this purpose in mind, the project has taken the definition of concept map as a process that represents the structures of knowledge used during learning, in a bidirectional graphic that includes labeled concepts and concept links to associate, hierarchize or present them in a proposition form. (Novak 1984).

The advantages of a concept map are the following:

- The possibility of presenting knowledge in a precise way relating it with other knowledges and establishing concepts that can group up knowledge in case there is no possibility to show it with all its components.
- The easiness that the captured knowledge offers to communicate because of its graphic structure so that it can be included in Web or printed tools for those actors that do not have computer means to provide feedback on the process.
- It is useful to understand and integrate different aspects of knowledge found in a social network.
- It fosters collective spaces for discussion because it makes the participants to debate the hierarchy of knowledge they have acquired and its connection to others.



Source: Deycy Sánchez – Adolfo Plazas - Luz Stella Pemberthy

Figure 1. Concept map: Synthesis of the Research Project

4.2 Method for a Knowledge Map building

The purpose and the scope of these projects created the necessity of thinking about knowledge maps oriented toward the processes, since these "provide a representation of the strategic processes and the knowledge sources that the program of knowledge management should maintain to adequately support the business processes" (Sanchez 2004). It is also important to think about the production, knowledge management, associability, technological administration and competitive intelligence processes and about those related to the environment. By virtue of this requirement, a knowledge map construction method was proposed, which includes the following phases:

4.2.1 Work Context

This context is built up in the frame in which a knowledge map is being generated. In the case of a territorial field, the development model adopted must be mentioned, plus the particularities of the actors and their responsibility in the construction of the development model that has been chosen. In other fields, this is carried out by the governor, institutional, academic, and other actors, who in some occasions do not have the adequate information about the communities' problems. The generalization they make is not the best interpretation, as the communities' expectations may be different and even opposed to other communities located in the same area. This makes the process more expensive, although enriching.

4.2.2 Selecting the study object

With the view offered by the analysis mentioned previously, some important regional aspects that are considered relevant should be privileged. The best way to do this is to take into account the initiatives, projects and institutions that have already made the analysis regarding this issue; otherwise, the prioritization may be based on biased viewpoints that may distort both, the process and the final results. The regional vocation should be clear and the help needed should be located on those projects which may have a promising future.

Later, a social network or productive prioritized chain will be chosen; the documents that contain parts of the history, evolution, composition, and interesting thematic areas need to be studied. The information obtained will help to relate the real context with the chain or network chosen. When the "where" is selected, it is necessary to determine the "what," which are the important aspects or topics to be known through the map. This part of the work requires extended discussions for avoiding misinterpretations and the aforementioned work not to be distorted and future actions can be oriented properly.

4.2.3 Instrument Design

When all the elements to be studied are ready, specialists who know the selected unit for analysis are consulted. These actors are members of institutions who generally have confidence with the other members of the chain or network; for this reason they feel secure when suggesting strategies, instruments of working sketches, oriented towards the information needed. Furthermore, they are the ones who present the initiatives to the communities and back them so that the environment for working is adequate for an efficient teamwork. This is the way the instruments for working are developed, which in the case of the knowledge map is focused on the interviews and narrative records because they provide the characterized information since it is produced in the daily language of the actor that provides it.

4.2.4 Field work

The first visit is made with the design instruments. This visit determines if the instrument responds to the generated expectations or if it is necessary to adapt it. The research team takes the information that is possible to obtain and decides if it is necessary to program new visits with the purpose of obtaining the information missing. This information is generated by means of an interview or a narrative recording, so that it becomes a simple transcription of the actor words without any style adjustment. Each one, from his/her point of view, can give different interpretations, but at the end the actor will be the one to reaffirm the validity of the suggestions.

4.2.5 Analysis and Synthesis of the Information

A formal scheme to organize the obtained information is needed; the tables are particularly useful to this purpose. However the tables can not allow seeing a wide panorama, which makes the use of a concept map as a tool to get this aim. Initially only bits of a map are carried out with the obtained information, but later they become integrated as in a puzzle. It is necessary to discuss if this way of presenting the map really involves the concepts in a coherent way. Additionally, it also describes the knowledge and the meaning the concepts adopt in the context of the work for the target communities.

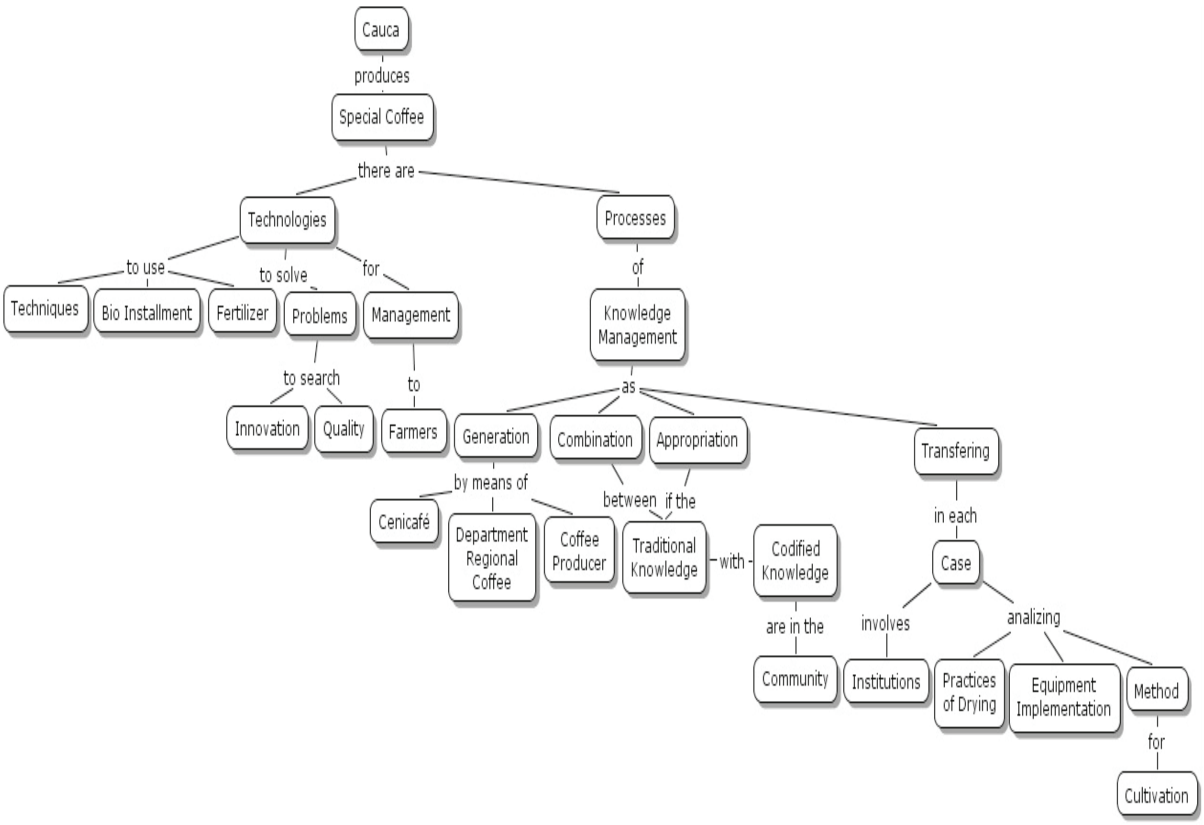
4.2.6 Knowledge Codification

The first abstraction level reached with the concept maps allows deepening little by little in each aspect. Moreover, it is possible to think about structural ways to organize the information with the purpose of including an application based on ontologies; this requires the construction of concept collections (described in classes) with their characteristics (attributes) to help to generalize the information and to extend the model to other similar organizations. The topic must be known deeply before proposing a model that makes knowledge codification easier. Nevertheless it is not possible to think that the whole knowledge can be included in it; however, it must be analyzed as if it were possible for avoiding the loss of rigorousness of the process.

4.2.7 Feedback

Once a proposal is ready, it must be presented to the community again. The possible way to socialize it is by using the concept maps. This tool helps to refine the model and to communicate the ideas in a specific and clear way promoting discussions among the actors. The appropriate size for these maps is that of a poster so that it becomes legible and easy to observe. It is really advisable to think about a way of avoiding to overload it with too much information; it is preferable to use several images and not to include all the information that has been found in just one single map.

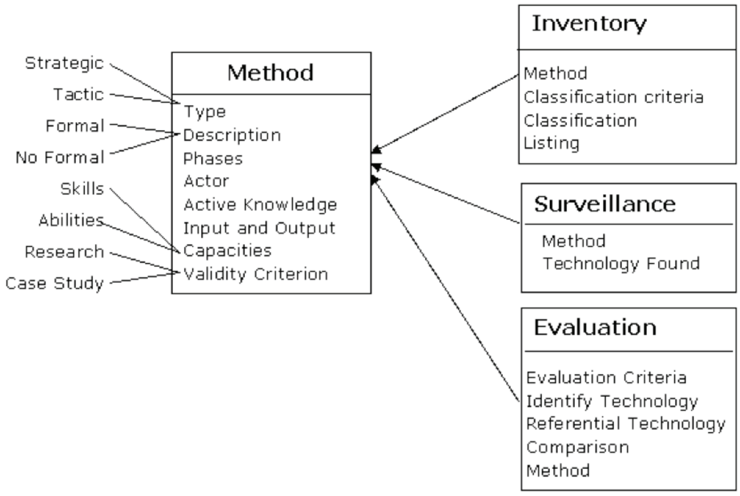
The following conceptual map (Figure 2) explains those technologies inherent to the production of special coffee varieties and how the culture through the processes of knowledge management establishes particular practices for this productive process in Cauca.



Source: Deycy Sánchez

Figure 2. Concept Map of Technologies for the production of special coffee varieties in Cauca

The previous map sets the starting point to establish a way for codifying and organizing the knowledge, one of the topics of interest to use is the technological management. Figure 3 shows the characteristics considered to codify knowledge associated to the technological inventory, technological monitoring, and technological evaluation, which are three of the six processes that allow analyzing this topic. In this regard, the projects determine that a technology in a productive chain or network must describe its name, its associated topic, an evolution step (embryonic, growth, maturity, saturation), a condition (inside or outside the network), a superior technology (that includes others), and an associate technology (depends on others). With this general description of a technology, the technological inventory and evaluation can be made. The process of technological evaluation permits to compare the technologies used in the productive chain or in a social network with respect to the ones found in the social environment (outside the network). To fulfill this, arbitrary criteria are adopted and the technologies are compared to each other. Nowadays the work is concentrated on the refinement of this representation model and on its knowledge codification.



Source: Deycy Sánchez – Luz Stella Pemberthy

Figure 3. Aspects of the technological management approached in the knowledge codification

5 Conclusions

The conceptual maps have helped the project executor equipment in the process of internalization and reflection on different topics arising during the development of the initiative. It has also allowed the coherent integration of different knowledges and concepts with a pre-established intention. In addition, they have ensured and facilitated the communication of different approaches given the multidisciplinarity of the team.

The appropriation of the knowledge map as a tool for knowledge management requires management strategies within social networks that constitute the SRCyT&Inn. This appropriation is only possibly perceived in the long term; in the short and mid term it must be frequently nurtured and improved with the purpose of giving answers to the actors and to the local users' demands.

The conceptual maps, as tools for capturing and codifying knowledge are limited regarding their updating; this is because they must obey to static glances in a specific moment. If this reality changes it is necessary to start over all the process and adapt the whole concept map to a new situation, which makes its use expensive and complex.

For rural producers the concept maps are difficult to understand. Perhaps it is due to the educational level of some of them, so it does not allow them using this tool now. In the future we need a deep educational process to promote the learning of this concept maps.

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THE CONCEPTUAL CARD DECK

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Abstract. The conceptual card deck is a game for the collaborative construction of concept maps. It was developed at the *Conéctate al Conocimiento* Project of Panama as an easy way to introduce novice mappers to concept maps and propositional structure, with very little prior explanation of these notions. Though it has been used by some of the Project's facilitators in teacher training workshops, as well as in follow-up visits to schools, this is the first attempt to methodically explore the benefits of its application. The present study's results show that apprentice mappers were able, using the card game, to produce a complex concept map topologically, and of good semantic quality. Aside from providing a practical way to introduce concept mapping, results suggest it may have other benefits as well such as: 1) breaking away from the typical tree structures and one-root concept maps thus leading to a greater variety of map topologies; 2) stimulating the formation of cross-links in a natural manner; and 3) simultaneously promoting competitiveness and collaboration.

1 Introduction

The *Conéctate al Conocimiento* Project was born as part of a national strategy called Panama Inteligente (Intelligent Panama), whose main concern was to foster a new way of learning among Panamanian children, characterized by flexibility, non linearity, and interconnectedness of ideas, so that they may be able to live up to the challenges of our present day world (Tarté, 2006). It is guided by the Secretaría de la Presidencia para la Innovación Gubernamental (The Presidency's Office for Government Innovation), and supported by other institutions, national and international, public and private (see http://www.conectate.gob.pa).

The Project was given a constructivist approach, based on learning tools such as concept maps. Concept maps originated from the work that Novak and his Cornell University colleagues carried out since the early 70's (Novak, 1998, p. 27), based on Ausubel's Theory of Assimilation and its key notion of *meaningful learning* (Ausubel, 1968). In this theory, an individual's previous relevant knowledge is the fundamental element for a meaningful learning process to occur. Concept maps, by enabling the organization and representation of knowledge, constitute a concrete tool to support meaningful learning, as they allow us in some sense "to observe" an individual's knowledge structure, both concepts and relationships among them, for any given domain under consideration (Novak & Gowin, 1984, p. 40).

Much of the effort at the Conéctate Project involves teacher training. Teachers first attend a 2-week workshop imparted by Project, during which they are *re*introduced to concept mapping.[1] At the workshops, most concept maps are constructed using the computer program CmapTools (Cañas et al., 2004), a program that makes concept map construction easier, and allows collaboration between individuals and schools; thus, during the workshops teachers are able to experience the benefits of working with learning tools supported by technology.

Facilitators subsequently conduct follow-up visits to participating schools in order to support teachers in their efforts to implement the meaningful learning methodologies advocated by the Project. During these visits, facilitators have become aware, on the one hand, that teachers confront difficulties in introducing concept mapping to their students, and sometimes give up on maps. On the other hand, they have noticed that students tend to construct rather poor, maps, both topologically and semantically. In terms of structure, their maps generally display a tree configuration, with little ramification, little depth, and practically no cross-links. In terms of content, there are often incorrectly constructed propositions, in the sense that concepts may not be clearly identified and/or linking words may not actually establish any relationship between them (as when *pre*positions are used); in addition, content is mostly classificatory or descriptive, with rather simple linking phrases, and few, if any, dynamic propositions. Nonetheless, upon questioning students about their maps, one realizes that they possess more knowledge than is actually being expressed in their concept maps.

We suspect that the above situation arises from two related facts: 1) after a short workshop of 2 weeks, most teachers are not sufficiently comfortable with the notions like *concepts*, *linking phrases*, and *propositions*, and often introduce concept mapping by conveying these ideas in traditional behaviorist fashion, as "bits" of disconnected information (not always correct) for students to memorize; 2) teachers themselves, upon

[1] Most teachers in Panama knew about concept maps before attending the workshop. However, their knowledge included many erroneous ideas (Miller, Cañas, & Novak, 2008).

completing the workshop, generally construct maps rather similar to the student maps just described (Miller, 2008).

For these reasons, some of the research conducted at the Conéctate al Conocimiento Project has focused on designing strategies to help teachers introduce concept mapping to students in a way that will lead to a better understanding of concept mapping and, in consequence, to more accurate representations of learners' knowledge structures. One area of research and action is the use of ludic methodologies, that is, methodologies based on play.

According to Piaget & Inhelder (1969, p. 65), "play" has an essential role in the life and development of a child, and is "indispensable to [the child's] emotional and intellectual equilibrium."[2] Piaget & Inhelder (1969, p. 66) identify various forms of play, one of which includes "rule games." This type of play begins to appear at around 5-6 years of age, is socially transmitted, and becomes increasingly more prevalent as the child grows older and his/her social life takes on greater significance.

One of the first developments at the Conéctate Project in the area of play methodologies was the *conceptual dice* game, designed by facilitator Adrián Chang (Hughes et al., 2006). In this game, concepts are placed on each of the faces of the dice, and upon throwing them, the player attempts to establish a relationship between the two concept that appear on the upward faces.

More recently, and inspired by the conceptual dice, facilitator Rita Marissa Giovani developed the *conceptual card deck*. The card deck may contain as many cards as desired, on any desired subject. Concepts, either in the form of text, image or both, are placed on one side of the cards. In order to make the cards more attractive to students, they can be made out of Bristol board, of a relatively large in size (for example, 4x5 in), and the side without the concept may be decorated in various ways. Because of their size, cards are placed on the floor, concept-side down (see figure 1). The rules for playing the conceptual card game are detailed in section 2.1.

Figure 1. Conceptual card deck on subject of the "Fairy OddParents." Cards are placed on the floor with the concepts facing down. The up-face is decorated to make cards more appealing to students.

In principle the game could be played with replacement or without replacement of cards. We have chosen to play it *without* replacement, mainly to guarantee that more concepts are used, and also to avoid the practical problem of having to shuffle the cards around on the floor. This specification places a restriction of the number of cards in the deck, which now must be an even number.

Like the conceptual dice, the cards game is also a game of chance in which the learner is required to establish relations between randomly selected concepts. However, unlike the dice, the card game is not limited only to the 36 outcomes appearing as distinct combinations of concepts on die 1 and die 2. Since the card deck can contain as many concepts as desired (provided the number is even), and since any two cards can be chosen, the participants have many more choices of concept pairs that can be mutually related.[3] Moreover, the nature of the game is designed to simultaneously promote collaboration and competition, since team members help each other, and teams compete against each other.

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[2] Translated by authors.

[3] For a deck of n cards, the number of possible combinations is $\binom{n}{2} = \frac{n!}{(n-2)!2!}$. If $n > 9$, there will be more than 36 combinations.

2 Methodology

The present study took place in a school with one of the largest student bodies in the country. It is located in a marginal urban area of Panama City, with many socio-economic limitations. Despite the fact that the school has been incorporated to the Conéctate al Conocimiento Project since 2006, and is equipped with a fully functional innovation classroom,[4] with CmapTools installed on all of its computers, not all of the school's teachers use concept maps.

Given the nature of the study, namely, to use the conceptual card deck to introduce concept maps to a group of students, we sought a group which had had very little or no exposure to concept mapping in the past. The particular group selected corresponded to a 5th grade class,[5] whose teacher did not work with concept maps. Students apparently had had a brief exposure to concept mapping in 4th grade and thus had some idea of what they looked like; however, upon quizzing students it was clear that not much correct knowledge was retained about them.

The group, comprised of 28 students, was divided for the study into two subgroups of 14 children each. Children were assigned randomly to the subgroups. One of these subgroups, designated the experimental group, was to build a concept map by playing the conceptual card game. The concept map was to be constructed using CmapTools and the Cmap projected onto a large screen in order to make it visible to all of the children participating in the game. The focus question was provided by the researchers, as well as the deck of card containing the concepts to be included in the map.

Meanwhile, the second subgroup was further divided into two teams of 7 members each, called control group 1 and control group 2. Each control group was to collectively construct a Cmap with CmapTools as well, using the exact same concepts and focus question as the experimental group. The concepts were presented to them in the form of a "parking lot" (Novak & Cañas, 2008) on the screen of the computers being used.

Novak & Cañas (2008) recommend introducing concept mapping to novice mappers through subjects familiar to them. The use of familiar, non-curricular subject matter is advantageous because it makes it easier for children to integrate personal their experience and creativity. Following their advice, the research team decided to use a T.V. cartoon as the topic for the concept maps.

In order to choose the particular cartoon to be used, in the weeks prior to the activity the teacher conducted a poll amongst her students to determine the group's favorite cartoon. The results of this poll yielded "The Fairy OddParents." A total of 26 concepts based upon this cartoon were then chosen by the researchers and a conceptual card deck was created. This number of concepts was deemed appropriate considering the time available for the activity, 3 and half hours, and the number of children participating. The list of concepts consisted of the following: *Timmy Turner, oranges, clowns, Trixie Tan, babysitter, brain mass, Cosmo, Wanda, fifth grade, California, parents, rules, pool ball, millionaire, professor, Denzel Crocker, comic books, mischief, imagination, family, unhappy, magical creatures, television, school, magic wand, and videogames.* The focus question "What would you do if you were Timmy Turner?" was used only as a loose guide for the Cmap.

Prior to beginning map construction, the experimental group was explained the rules of the conceptual card game. As far as concept mapping was concerned, they were only told that the objective of the game was to relate pairs of concepts selected from the deck in such a way as to create a true, meaningful statement, and an example was given. The control groups were given similar instructions (excluding the rules of the game, evidently); the main difference was that in their case concepts would be selected from the parking lot. Both the experimental and control groups were shown how to construct propositions on CmapTools.

It must be pointed out that this study was not intended as a comparative study: we know full well that students with very little knowledge of what a proposition or a concept map is, and with practically no guidance from "more knowledgeable others," to use Vygotsky's (1978) term, can not be expected to produce "good maps," that is, maps that provide an accurate representation of their knowledge structure in any given domain. In fact, the "no game" condition need not have been included at all; it was included simply as a reference, to provide a feel for the kind of concept map that results from when no knowledge - no guidance is give. Thus, in

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[4] Schools integrated into the Conéctate Project are provided with this special classroom, equipped with computers and various other technologies whose specifications have been established by the Project.

[5] The reason for choosing fifth grade was in order to be able to follow these students next year, as most of them will still be attending the same school during 6th grade.

this study the terms "experimental" and "control" are used merely as a way to distinguish between the two conditions.

2.1 Conceptual card deck: the game

TO BEGIN:
The set of players is divided into two teams (of 1 or more members). The cards of the conceptual card deck are mixed and placed on the floor, with the concepts facing down. The teams are given a focus question to guide the construction of the collective Cmap.

OBJECT OF THE GAME:
The object of the game is to create propositions with between pairs of concepts 1) selected randomly from the deck, and 2) already present in the Cmap being constructed.

TURNS:
The game begins with a player from either of the teams uncovering two cards from the deck. The player then has 1 minute to think up a proposition relating the two concepts and place it in the Cmap. If the player comes up with a "correct" relationship, as judged by the entire group of players (both teams), the player is granted two additional chances[6] to establish relationships between any two concepts already present in the Cmap.[7] If the player is unable to establish a correct relationship in any one of his/her chances, the player's team member may help out. If fellow team members are unable to establish a correct relationship within a minute's time, the team's turn is over.

POINTS:
Relationships established by the player whose turn it is earn the team 1 point; relationships established by other team members earn the team only ½ a point.

BONUS
If the player whose turn it is successfully establishes all three relationships between concepts, he/she is given the option of creating a new concept and placing it directly in the Cmap, provided it is used to establish one last relationship (and scoring an additional point).[8]

END OF GAME:
The game ends when the last two conceptual cards from the deck have been uncovered.

WINNER:
The team that scores the most points wins.

2.2 Measurement tools

In assessing the concept maps we used two tools developed at the Conéctate Project: the topological taxonomy (Cañas et al. 2006) and the semantic scoring rubric (Miller, 2008). The former is used to measure the structural complexity of concept maps, and considers criteria such as: presence of linking phrases, hierarchical depth, ramification (breadth), and presence of cross-links. The latter assesses quality of content, and considers among other things: correct propositional structure (propositions as units of meaning), presence of dynamic propositions, misconceptions, and quantity and quality of cross-links.

3 Results

Figures 2, 3, and 4 show the concept maps elaborated by the experimental group, and control groups 1 and 2, respectively (the parking lot of concept, or part of it, can be observed in the Cmaps of both control groups).

[6] The first participant does not enjoy this benefit since there are no previous concepts to relate.
[7] This is where the possibility of cross-links arises.
[8] Control groups did not have the option of adding concepts to the parking lot of concepts given to them.

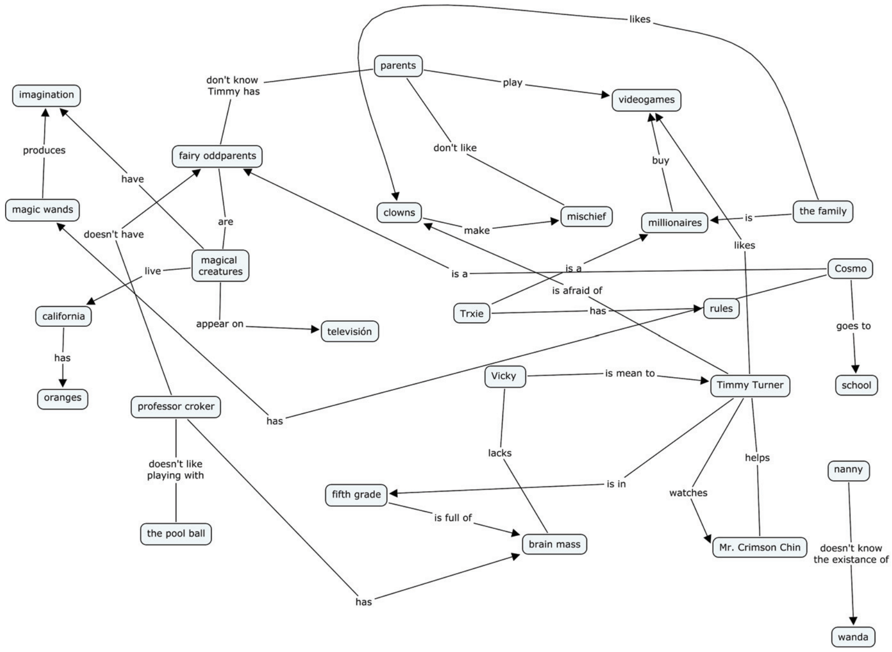

Figure 2. Cmap constructed collectively by the experimental group playing the conceptual card game.

This image of the map does not distinguish between those propositions players created when it was their turn to select two cards from the deck, and those created as a bonus by joining concepts and/or linking phrases already in the map.[9] However, by the way the game was played it is obvious that concepts and/or linking phrases were reused, or else a completely disjoint Cmap would have resulted.

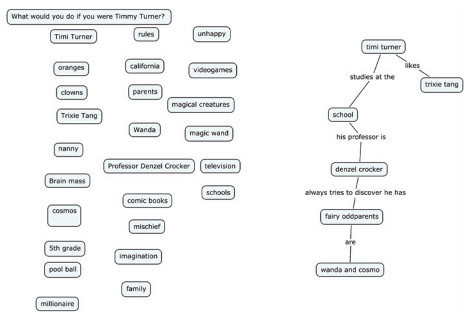

Figure 3. Cmap constructed by control group 1

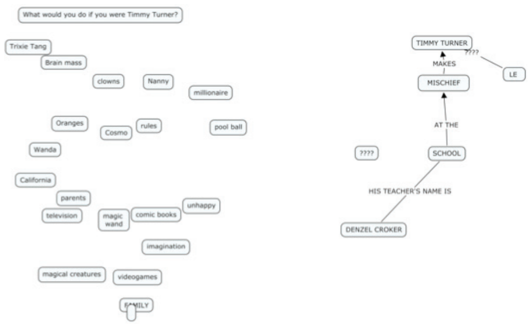

Figure 4. Cmap Constructed by control group 2.

The main features of these Cmaps are summarized in table 1, below. As can be observed, the Cmap generated by the experimental group is quite complex and rich from the structural standpoint: it contains an important number of concepts and propositions, and multiple cross-links. The Cmaps produced by the two control groups are much simpler: they include few propositions, have only one branching point, and no cross links.

[9] Unfortunately we do not have this data available as we did take note of this.

GROUP	Number of concepts in Cmap	Number of propositions in Cmap	Number of cross-links in Cmap	Topological level	Semantic level
Experimental	26	30	10	6	high
Control 1	6	5	0	1	Low
Control 2	4	3	0	1	Very low

Table 1. Summary of basic features of Cmaps constructed by the experimental and control groups.

As table 1 shows the experimental group added the following 4 concepts:

- *Timmy Turner*
- *Vicky*
- *Mr. Red Chin*

One of these concepts (Timmy Turner) was already included among the deck of card; however, at the time it was added, this card had not yet been uncovered. The experimental group also came up with a number of cross-links:

- *Trixie is a millionaire*
- *Vicky lacks cerebral mass*
- *Vicky is mean to Timmy Turner*
- *Professor Broker has cerebral mass*
- *Professor Broker has no Fairy OddParents*
- *Clowns make mischief*
- *Parents play videogames*
- *Timmy Turner watches television*
- *Fairy OddParents are magical beings*
- *Timmy Turner is in fifth grade*

We must point out that although both conditions were supposed to have the same amount of time for their activities, in reality, due to logistic difficulties, the control groups only had 2 hours to build their maps. Nonetheless, one would expect that this would be sufficient time for them to construct more complex maps.

3.1 Topological analysis

A glance at figure 2 reveals that the map produced by playing the conceptual card game has a highly complex structure. Applying the topological taxonomy to it yields a level-6 map, the highest level possible in this classification. This results from the fact that the map not missing any linking phrases, has very high ramification (over seven branching points), is deep (over 2 hierarchical levels), and has multiple cross-links (more than 3). In addition to this, one notes that this map does not have a unique root concept (concepts from which arrows leave, but to which no arrows arrive); in this sense the Cmap is quite different from the typical maps produced by teachers and students alike.

In contrast, the maps of the two control groups are rather simple. By our topological taxonomy they qualify as a level 1 maps due basically to their extremely linear structures (both exhibit only one branching point).

3.2 Semantic analysis

As far as content is concerned, the application of the semantic scoring rubric to the experimental group's concept map indicates a "high" quality map. This follows from the fact that practically all given concepts were used in the map, including 4 new ones added by the participants. This high score is also a reflection of the map's correct propositional structure, the absence of misconceptions, the presence of dynamic propositions, and the many correct and relevant cross-links it contains. An interesting feature of this map is that it is not hierarchical, in the sense meant by Novak & Gowin (1984, p. 15), where narrower, less inclusive concepts are subsumed under broader, more inclusive ones.

On the other hand, the quality of the maps of control groups 1 and 2 resulted in "low" and "very low," respectively, due to the small number of concepts used, the lack of understanding of propositional structure, and the absence of cross-links and dynamic propositions.

4 Discussion of results

As predicted, the two control groups produced very simple maps, both structure-wise and content-wise. This outcome was expected since it is known that, even with knowledge of concept mapping and adequate guidance, it takes time and practice for learners to be able to construct good concept maps (Novak, Gowin, & Johansen, 1983).

The unexpected result, the result we wish to emphasize, is the fact that the experimental group was able to produce a map with a complex, highly non linear, structure, and good quality content, in spite of having practically no knowledge about concept mapping, simply by playing the conceptual card game. It is important to emphasize that this map contains a large number of relevant cross-links, which were placed in the map in a very "natural" manner. In our experience with teachers and students at the Conéctate Project, generally cross-links are added *after* the map is completed, almost as an afterthought.

In addition to the topological and semantic results, the collective construction of the Cmap by playing the card game appears to have other benefits which include:

1. Keen interest and active participation of all the players, since rule games such as this one appeal greatly to young students.
2. Significant interaction among participants, as the group had to discuss and accept relationships before they could be placed in the Cmap.
3. Competition and teamwork, but ultimately a sense of satisfaction among all players, since a joint map was constructed as a result of their "competitive collaboration."
4. Integration of knowledge, as players included propositions that reflected previous knowledge not directly related to the content of the cartoon.

We wish to note that the conceptual card game has been used by the authors in the Conéctate workshops to introduce concept maps to teachers. In every instance, results have been similar to those reported in this article.

5 Conclusions

This paper presented a ludic methodology developed at the Conéctate Project to introduce concept mapping to novice mappers, and reported results of its application with a group of 5th graders from a Panamanian public school. The methodology requires no formal explanation of ideas such as *concept*, *proposition* or *concept map*, and thus may be used without difficulty by teachers who do not yet feel at ease explaining these theoretical notions.

This experience suggests that the conceptual card game is indeed a good methodology to introduce concept maps: using the card game, apprentice mappers constructed collectively a concept map that was complex both structurally and semantically. Particularly noteworthy was the way in which cross-links were naturally included into the map as it was being constructed, rather than at the end, as is usually the case.

These results are important for the Conéctate Project, as they suggest that the conceptual card deck could be used as a way to overcome teacher reluctance to introduce concept maps into their classrooms, often due to their not feeling comfortable with the theoretical foundations underlying concept mapping.

However, an important question that arises is whether the card game produces any long term benefits? That is, if students were asked to construct a map individually, or even in teams, after having been introduced to concept mapping via the card game, what kind of maps would they build? Would these be any better than the maps they would have built if they had not played the game? We hope to look into these and other questions in future studies.

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THE ROAD TO TRANSFER: CONCEPT AND CONTEXT APPROACH TO THE SUBJECT OF ECONOMICS IN SECONDARY SCHOOL

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Abstract. In this study we investigated the effects of two treatments supplementing students' regular courses in Economics in pre-university education. Although students may have acquired a reasonable amount of conceptual knowledge as a result of courses in Economics, two deficits may prevent students from achieving transfer. One possible deficit is the lack of rich and coherent conceptual network, whereas deeply understood and well organised domain knowledge is viewed as a prerequisite for achieving transfer. Second possible deficit is that students are hardly able to make connections between the acquired conceptual network and realistic social problems that can be looked at from an economic perspective. Both deficits result in low transfer-value of conceptual knowledge. In an experimental study we compared the effects of two instructional interventions, based on concept mapping as a learning activity, each directed to one of the assumed deficits. 139 high school students of Economics participated, randomly assigned to one of the conditions: Concept and Context. All students took a pre-test and two transfer tests. Students performed significantly better on the concept post test than on the concept pre-test. We consider this result is due to the concept mapping learning activity in both conditions. Maps seemed to be very useful both in concept tasks and in context tasks.

1 Introduction

The aim of education in Economics in secondary schools is shifting from a predominantly academic approach towards making more effort to teach Economics for the needs of students in society, in their current and future lives. From this perspective, education in Economics should enable students to use economic knowledge in daily life, even in the contexts that are different from those in which they acquired this knowledge. When students can apply acquired knowledge in a more or less novel situation, they have achieved the transfer (Marini & Genereux, 1995). In her Model of Domain Learning, Alexander (2003) considers transfer as an ability of experts. She describes the long road to expertise in three stages: *acclimation*, *competence* (*early, middle* and *late*) and *proficiency*. Each of these stages is characterised by a certain amount of domain knowledge, interest and types of strategies used. Although in the upper levels of secondary education, students may have acquired a reasonable amount of conceptual knowledge as a result of economic courses, two deficits may prevent students from achieving the transfer. One possible deficit is the lack of rich and coherent conceptual network, even though deeply understood and well organised domain knowledge is viewed as a prerequisite for achieving transfer (Mayer, 2004; Sternberg, 2003). The conceptual network attained by students after instruction often shows gaps. Concepts are missing or relations between the concepts are not well defined. This kind of deficit is normally the effect in case of students learn for a knowledge-oriented achievement test. They learn for reproduction, not for deep understanding. It may be sufficient for near transfer if the context is similar to the studied problem, but it will be not sufficient for far transfer where the context is different from the studied problem. Along near transfer and far transfer as it is concluded by Stark, Mandel, Gruber and Renkl (1999), can be useful to distinguish middle transfer as well. We consider the same stages in this study but we use the terms of near transfer, semi-far transfer and far transfer. We are talking about near transfer when concepts and context are the same as in the instruction; semi-far transfer when concepts are the same but the context is different; far transfer when both concepts and context differ from the instruction.

Second possible deficit is that students are hardly able to make connections between the acquired conceptual network and realistic social problems that can be looked at from an economic perspective. Students do not have the ability to connect the abstract network of concepts to practical phenomena in daily life that can be looked from an economic perspective. And on the other side they are not able to connect the real life situations with the appropriate conceptual network they have in mind that match with the practical phenomena.

2 Learning for transfer in school

We have noticed the two different deficits for achieving transfer, the lack of a rich and coherent network of knowledge and the lack of making connections between the network and the realistic social problems. The ability to transfer however is a necessity for students to look as an economist at real life problems. Perkins (1992 p. 3) wrote:

> Consequently, the ends of education are not achieved unless transfer occurs. Transfer is all the more important in that it can not be taken for granted. Abundant evidence shows that very often the hoped-for transfer from learning experiences does not occur'. Perkins added: Thus the prospects and conditions of transfer are crucial educational issues.

Mayer (2002), Kratwohl (2002) and Anderson (2002) were members of a committee that revised Blooms' taxonomy(1968). This original taxonomy contained a cumulative hierarchy between the three processes: memorizing the concepts, understanding them, and applying the concepts in a context, necessary to achieve deep understanding and transfer. The committee decided to delete the hierarchy. Students can come to an understanding of a concept *while* applying in a context. The question arises as to what contributes most to the ability of transfer strengthening the conceptual knowledge or strengthening making connections between contexts and concepts. In other words; are we following the concept road or the context road to transfer?

2.1 The concept road to transfer

In literature about transfer (Alexander, 1997; Gelman & Greeno, 1989; Salomon & Perkins, 1989) there is an agreement that a basis of deeply understood or processed knowledge or, one can say a well organized body of knowledge, is a condition for transfer. Such a body of knowledge requires meaningful learning. Novak (2002) stated that meaningful learning is defined by a conscious choice to integrate new knowledge into existed knowledge. This prior knowledge (Alexander, 2006 p. 72): 'encompasses all that a person knows or believes, whether positive or negative, accurate or inaccurate, real or imagined, verifiable or nonveriable.' Prior knowledge influences the perception of new knowledge and modifies the mental models or network of concepts. This can hinder the forming of the conceptual models required for the domain knowledge. In the case of misconceptions conceptual change has to take place. Conceptual change is described as a process of accretion, refining, constructing and reconstructing of mental models (Chinn & Brewer, 1993; Vosniadou, 1994). Students must have sufficient time to construct and reconstruct their mental models to develop a well organized body of knowledge to achieve transfer.

2.2 The context road to transfer

The context road has originated from a recent theory of learning, situated cognition or situated action (Brown, Collins, & Duguid, 1989; Engeström, Miettinen, & Punamäki, 1999). This theory emphasises that all knowledge is situated, in a particular time and in a particular place. It is a part of a culture, in which the knowledge has been developed and used. This has many consequences for learning in school. The context in school is very different from the context in real life. It is not very surprising that students do not connect the economic concepts to practical contexts. They possess mainly inert knowledge that will sink in no longer than necessary for their exams. They hardly ever get the opportunity to see the world as a historian (Whitehead, 1957) or in our case, as an economist. That is why the out-of-school situation in which students function must be understood very well (Brown et al., 1989 p. 36) :

> This is not to suggest that all students of math or history must be expected to become professional mathematicians or historians, but to claim that in order to learn these subjects (and not just learn about them) students need much more than abstract concepts and self-contained examples. They need to be exposed to the use of a domain's conceptual tools in authentic activity to teachers acting as practitioners and using these tools in wrestling with problems of the world. Such activity can tease out the way a mathematician or historian looks at the world and solves emergent problems.

Other differences between school and real life are (Resnick, 1987):

1. While problem solving in real life situations is often a collaborative activity, students in school learn mostly individual.
2. In real life problems there are a lot of tools available, such as visual/material tools; in school it is more a matter of mental acting.
3. In school, abstract thinking is common while in real life more context reasoning is used.

Theories of situated cognition emphasize that students need to be exposed to the use of domain specific concepts and methods in authentic activity and 'problems of the world' (Brown et al., 1989). And where it is not possible to join a community out of school for situated learning, 'the world' has to be brought into school. School has to become a community of learners, where students are struggling with each other on the problems of the world. In an experimental study we compared the effects of a concept road to transfer and a context road to transfer. Each of these approaches focuses on one of the deficits described above.

2.3 Concept mapping as a learning activity

Concept mapping is a learning activity that can be used in both the concept road and the context road. Novak (1990) describes a concept map as a compilation of concepts connected by relations. O'Donell, Dansereau and Hall (2002) use the word "knowledge map" rather than "concept map". Besides concepts, they say that a knowledge map can include dynamic relations, static relations and elaborative relations that contain information. We think that conditional knowledge, that can be defined as the understanding of the 'when or why' of strategy use (Alexander, 2006), and situational knowledge, that can be defined as knowledge specific to a particular situation (Ferguson-Hessler, 1989) can also be included in a map. Taconis (1995) made this kind of maps for problem solving in physics. He describes such maps as 'a unit in human memory representing a functional package of knowledge.'

3 Research question

In the previous section we mentioned that meaningful learning occurs when students actively construct and build out the mental models they possess. The formation of a well organized body of knowledge which is the result of that activity is expected to have a positive influence on the ability for transfer. The concept road to transfer is characterized by the acquisition of this well organized knowledge *before* applying it in a context. The context road to transfer is characterized by the acquisition of this well organized knowledge *while* applying it in a context.

The research question of our study is: Which instruction, added to the usual lessons of Economics in the fifth grade of pre–university education, is more effective in obtaining transfer: an instruction aimed at strengthening knowledge of concepts and relations between concepts or an instruction based on constructing relations between knowledge of economic concepts and the real world.

4 Method

This research is an experiment with two experimental conditions with a pre-test and a post-test. The pre-test was administered to check whether groups did not differ in prior economic knowledge. There is one independent variable: the type of instruction. The dependent variables are near transfer, semi-far transfer and far transfer.

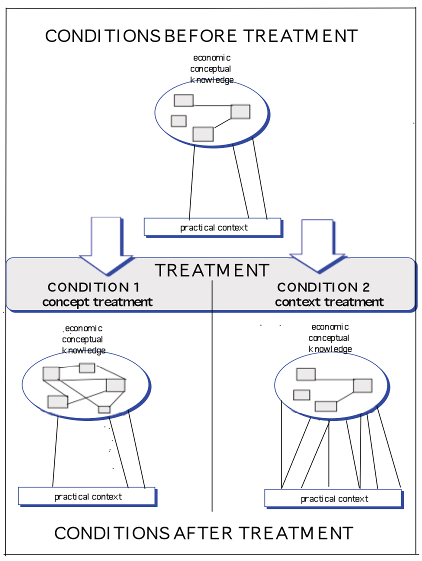

Figure 1. The desired changes in knowledge in concept- and context conditions.

139 students, aged 16 – 18 years old, from eight classes of the 5^{th} grade of pre-university education, from six different schools participated in our study. Within each class students were randomly assigned to one of the two conditions. The first instructional intervention - called *concept-condition* – consists of tasks which challenge students to reconstruct and consolidate their conceptual networks. This intervention is in fact an extension of the instruction that students normally receive in courses on Economics. It is expected to repair the first deficit. The second intervention – called *context-condition* – consists of tasks that challenge students to strengthen the connections between the conceptual framework and contexts, i.e. economical phenomena in the real world. Figure 1 gives a schematic view of the change we are expecting in the concept- and context condition. The point of departure is the same for the two conditions: the students have concept knowledge at their disposal (acquired in school instruction), but the concept network is not complete and not all concepts are related to each other.

The connections from the conceptual knowledge to the practical context are shown by the lines in between. In the upper part of figure 1 there are not many lines to been seen.

In the lower part of the figure, the effect of our expectations after the instruction can be seen. The concept condition improves the conceptual network and the context condition increases the amount of connections between concept and practical context.

Before the experiment the students followed their traditional school program, a course on money circulation and the economic climate. In the pre-test students' knowledge about these concepts was measured. In both conditions we used a concept mapping task (using the computer program 'Inspiration') as a meaningful learning activity. We thought that it should be possible to add conceptual as well as contextual labels to a map. So we were able to see what connections students made between them.

In both conditions the instruction session took two lessons. The instructions and the test were part of the school schedule: two 50-minute lessons a week. The total experiment covered 2.5 weeks, five lessons all together: two for instructions and three for pre- and post-tests.

5 The learning materials

5.1 Tasks

Both approaches (concept and context) were implemented through a concept-mapping task, in which students worked in pairs. The domain knowledge consisted of the money circulation and the economic climate. Students worked first individually on a concept map using paper, post-its and a pencil. Then they worked in pairs, constructing one concept-map on the computer (using the program called Inspiration) in which they had to reach an agreement. In the second instruction lesson students got information about the subject. With this information they had to reconstruct their first jointly made concept-map. In the task for the concept-condition students were asked to make a scheme of labels and relations to show what the money circulation has to do with the state of the economy in a year when the state of the economy is in balance. Students were given three concepts (labels) they had to use and they were stimulated to use concepts they knew from earlier instruction.

The task for the context-condition was oriented towards a complex social problem. In the Netherlands a supplementary duty (25 cents) was set by the government on the price of petrol to discourage motorized traffic. Some members of Parliament wanted to discard this supplement with a retroactive effect. Students were to discuss the possible economic effects of this proposal for the society. Students got some examples of practical outcomes and the same three concepts. They were explicitly stimulated to think from the practical context to economical concepts v.v. Both conditions spend the same amount of time on the tasks.

5.2 Information material

The information used in this experiment differed from the textbooks students used in class. The information was fit on both tasks. Besides the economical concepts there was a lot of practical information, so students had an example of how to use economical concepts in practical contexts.

5.3 Tests

All students took four tests:
(a) a pre-test to measure prior domain specific conceptual knowledge. This test consisted of 25 questions. The test was made in a computer test program (wintoets). The item homogeneity was just sufficient: Cronbachs' alpha was .60.
(b) a far transfer test testing the ability of the students to connect *new* knowledge to existing knowledge in a *new* context. The test was labelled '*Five circumstances that mean difficult economic times'*. It entailed writing five texts associated with five economic cartoons allegedly made for the newspaper. The students were informed that the editor accidentally threw away the original stories associated with the cartoons. The students' task was to write appropriate economic texts for the five cartoons. Each student received two scores for this test, one score for the amount of connections between context T and concept C (context-scoring) and one score for the economic correctness of C (concept-scoring) (see Appendix A for details about the scoring). The minimum score was 0 and there was no maximum. The texts were scored by two researchers. Researcher 1 divided the texts in scoring units. Both researchers scored the C units on economic correctness. The definitive scoring was

determined by dividing the correct C units by the total C units. The inter-judge reliability for the context score was good (Cohens' kappa .85), for the concept score sufficient (Cohens' kappa .64).
(c) a near-transfer/semi-far-transfer test. This test consists of two parts, a concept part and a context part:

- a concept post-test to measure conceptual knowledge (a near transfer test for the concept condition and a semi-far transfer test for the context condition). This test is equal to the pre-test. The item homogeneity of this post-test (Cronbachs' alpha .72) was higher than that of the pre-test.
- a context post-test to measure the ability to make connections between concept and context instruction (a near transfer test for the context condition and a semi-far transfer test for the concept condition). This test consists of two open questions related to practical problems. The problem of 'abolition of the mortgage deduction' starting from the practical context and 'the economic climate in 2003', starting from the concepts. Students were initiated to make connections between context and concept v.v. Two independent researchers scored the amount of connections made between C and T. The minimum score was 0 and there was no maximum. The inter-judge-reliability was good (Cohens' kappa .85).

6 Experimental procedure

The experimental procedure lasted five sessions, each of 50 minutes: one session pre-test, two sessions treatment, one session far transfer test, one session near- and semi-far transfer test.

7 Hypotheses

We expected that students in the concept condition would perform better on the concept post-test than students in the context condition. We expected that students in the context condition would perform better with regard to making relations between concept and context (context post-test) than students in the concept condition. Furthermore, we expected that the concept-condition would be a better starting point for solving far transfer tasks than the context condition. This expectation is based upon the strong case, made in the literature for the importance of a solid, coherently organized conceptual framework, especially when students have to adapt to new, unfamiliar tasks. Connections to contexts may be desirable, but supplementary. Our hypotheses were the following:

1. The concept condition results in more concept knowledge in the near–transfer/ semi–far–transfer test, compared with the context condition.
2. The context condition results in making more links between concept and context in the near–transfer/semi–far–transfer test, compared with the concept condition.
3. The concept condition results in more concept knowledge and in making more links between concept and context in the far–transfer test, compared with the context condition.

8 Results

There appeared to be no significant difference in prior knowledge between the conditions. No significant difference appeared in the school marks for economy (t = -1.09; df = 1.34.5; p = .28) and in de results of the pre-test (t = -.22; df = 138.1; p = .83).

We expected that students in the concept-condition should perform better on the near transfer-test than students in the context-condition (hypothesis 1). But they did not, as was proved by the results of the covariance analyse ($F(3,132)$ = .059; p = .94). Hypothesis 1 had to be rejected.

This was also the case for hypothesis 2. We expected that the context-condition should result in making more connections between context and concept v.v., than the concept-condition. But this was also not the case ($F(3,129)$ = .356; p = .70). From the results we can conclude that in this research near transfer is not better reached than semi-far-transfer.

The third hypothesis was that the concept-condition should result in more conceptual knowledge *and* in making more connections between context and concept v.v. than the context-condition. The covariance test showed that there were no significant differences between the conditions for the far-transfer-test (concept): ($F(3,136)$ = .213; p = .80) and for the far-transfer-test (context): ($F(3,135)$ = .168; p = 85). We, therefore, had to reject the third hypothesis as well.

The scores on the far-transfer-test (context) are extremely low in both conditions: the mean was nine connections between concept and context or v.v. Because the pre-test concept was equal to the near-/semi-far-transfer-test, it was possible to determine whether students had made progress on conceptual knowledge. From a t-test for paired-sampled test we learned that the total group improved significantly in conceptual knowledge (t = -2.663; df = 132; p = .009).

9 Discussion

In this research, we compared the effects of two roads of instructions to reach near transfer, semi-far-transfer and far transfer: the concept road and the context road. The ability to transfer is an important goal to reach in economic education. To be able to transfer, students must have a deep understanding of the economical concepts *and* they must be able to make connections between contexts and economical concepts. One of the two abilities is not enough for transfer. We designed two instructions: the concept road emphasizing the learning of economic concepts and the context road emphasizing connections between concepts and contexts. Tests were performed on near transfer, semi-far-transfer and far transfer. Our hypotheses that the concept condition would perform better on the near concept test and that the context condition would perform better on the near context test, could not have been confirmed. Also it could not be confirmed that the concept condition, due to the better organized knowledge base, performed better on the far transfer test. But the whole group of students significantly improved in conceptual knowledge. After two lessons all students had more knowledge of economic concepts. We expected that students in the concept condition should acquire more conceptual knowledge than students in the context condition. For that reason, they should be able to perform better on the far transfer test. This was not the case. Probably the ability to make connections between concepts and contexts is a necessary skill. The students in the context condition however learned as many concepts as the students in the concept condition. We would expect that the students in the context condition performed better on the context part of the far transfer test because they have been instructed for that. But that is not the case either. It seems that both conditions have trouble with connecting the context with the concepts. Both conditions performed low on that. Students in the context condition have not learned more on making connections between concept and context than students in the concept condition. The conceptual learning was equal in both conditions. It's possible that this result can be described by the concept mapping learning activity in both conditions. Students working in the context oriented concept map learned as many concepts as students working in the concept oriented concept map.

One of the reasons for the low ability to make connections can be that two added lessons are not sufficient for the students to develop a new ability. In their traditional lessons students are thinking in concepts. Both conditions were working on a concept mapping task. In the concept condition the concept map was aimed to be concept oriented, in the context condition the map was aimed to be context oriented. But in both cases the students were thinking in concepts as they used to do. It is possible that concept mapping is not the best learning activity to perform a context task, but we do not think so. From the examples, we observed that concept mapping is working quite well for it. Conditional knowledge can easily be part of the concept map. But we assume that it takes more time and training to develop this ability.

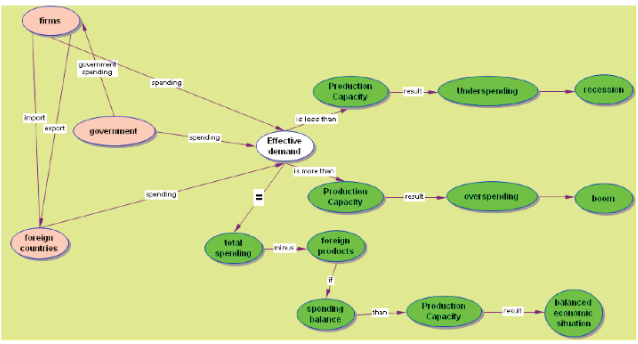

Figure 2. Part of a map made by two students in the concept condition.

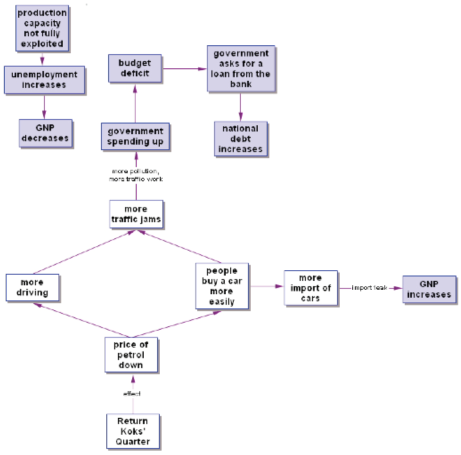

Figure 3. Part of a map made by two students in the context condition

The figures 2 and 3 are showing examples of a concept map, made by students of both, the concept condition and the context condition. The concept condition had to connect the concept of ‘money cycle’ with the concept of ‘state of the economy’. In figure 2 students made that connection by using ‘effective demand’. In figure 3 students had to connect contexts with concepts v.v. In the figure you can see two context-concept connections: One is connecting ‘more import of cars’ with ‘GNP increases’ and another is connecting ‘more traffic jams’ with ‘government spending up’. Another reason for the inability for far transfer in both conditions can be that, despite the extra training, the conceptual knowledge for both conditions is still not sufficient to reach far transfer. Perhaps, we have overestimated the (deeply understood) knowledge students had acquired in their traditional lessons. Or, it could be explained by the fact that the students followed the instructions only in part. By performing the task students were asked to formulate questions, but they didn’t know what to ask and they didn’t use the information they had got. Perhaps they needed more feedback than it was given them in this experiment. Bransford and Schwarz (1999) underline the importance of new information and feedback. Working with context tasks can stimulate students to ask for feedback and information. In traditional economic lessons students first learn the concepts, and then they learn to apply them. We followed that tradition in our experiment. But we can assume that this tradition needs to be changed. Context oriented learning can be seen as the framework where concepts are learned *by* researching a context. The Model of Domain Learning (Alexander, 2003; Alexander, Buehl, Sperl, Fives, & Chiu, 2004) describes the development from novice to expert. This model is relating transfer to expert behaviour. The students in this research will be in the stage of acclimation. In this stage, the students are more interested in topic knowledge and not that much in domain knowledge. Partly because of the small amount of domain knowledge students have to turn to surface level strategies to solve problems and they are not capable of processing deep strategies. But by researching the topics, students learn economic concepts related to the topics and that can make them more and more motivated for domain knowledge. That is another reason to change the tradition. It was surprising to see the students to be so motivated in their work. They were working with a lot of pleasure on their task. We think that the concept mapping task on the computer by using the program ‘Inspiration’ (www.inspiration.com) was the reason for it, both in the concept condition and in the context condition. The last point to consider is that we can wonder if the goal of reaching transfer in pre-university education is possible. Particularly, far transfer proved to be difficult for the students. Bransford and Schwarz (1999) attribute this to the fact that in school expert behave often is being asked. In their model of *Preparation for Future Learning* they emphasize not to go for *Direct Application* but to set the goals on the phases before that, how to question the problem, how to tackle the problem, etc. It is not clear if there is enough attention paid to this in economic education in schools.

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THE TEACHING VALUE OF CONCEPT MAPS

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Abstract. This paper aims to defend the use of concept maps in science lessons. We begin by presenting a theoretical ground for the use of metacognitive instruments in lessons where it is meant to create a constructivist environment favorable to a meaningful learning, as well as to some features of the cooperative work and negotiation of ideas, which is the ground for the above mentioned environment. Afterwards we are going to present some empirical evidence which points to the value of the concept maps for a better learning of sciences.

1 Introduction

In the theory of learning of Ausubel, as in Novak's as well, the key-concept in the educational process is the one of the meaningful learning. This, as Ausubel says (2003), is "the human mechanism par excellence for the acquisition and storage of the huge quantity of ideas and information represented in any area of knowledge " (p. 81). The meaningful learning is a process where the new items of information are related to a relevant aspect that exists in the structure of knowledge of an individual" (Novak, 2000, p. 51). The pupil will only learn in a meaningful way if there is a substantive incorporation, neither literal nor arbitrary, of new ideas with the ones that already belongs to the cognitive structure. It is essentially in this character - non-literal and non- arbitrary - of the relationship of the learning task with the cognitive structure that lies the efficiency of the meaningful learning as a mechanism to transform and store information (Ausubel, idem).

Meaningful learning requires relevant learning structures, well organized, and an emotional commitment to integrate the new knowledge into the already existing one. Different studies have demonstrated that the information acquired in a context of meaningful learning is not only kept for a much longer time, but it can also be used much more successfully in the resolution of new problems (Novak and Cañas, 2004).

2 Theoretical ground of the teaching value of concept mapping

2.1 Concept Mapping

A concept map is a theory-driven graphic organizer (Trowbridge & Wandersee, 1998, pp. 115-126), where there are represented in a diagram hierarchically organized a body of concepts concerning a given topic, connected by means of linking words so as to build meaningful propositions. Even though at first sight the concept map seems to be merely another form of graphic presentation of information, its real use by an individual will let him see that it is a really deep and powerful tool (Novak & Cañas, 2004).

When a pupil makes a concept map on a subject or discusses a concept map made by one of his mates or a group, he shows ideas he already has about this subject and which often seem to be misconceptions. This way the teacher gets to know his pupils' ideas about objects and/or events, and the pupils are made to reflect on their own ideas, to argue based on them, thus realizing when they have or not any normative validity and, even, when they have or not any axiological validity, if the teacher can and is able to establish the conditions so that his pupils can check if their own ideas agree or not with the observations and the collected data of these objects and/or events. This activity of *metacognition* has proved to be extremely enriching, helping the pupils to progress conceptually towards the great scientific ideas that have got a great explanatory power. The metacognitive tools and, in particular, the concept maps (Novak's) also help the pupils to know the nature of knowledge production/construction better and better (Novak & Gowin, 1999; Moreira & Buchweitz, 1993).

The reflecting on and the negotiating of ideas among the pupils, based on the maps and the Vees, mainly when the teacher adequately leads them, help them to penetrate the structure and deepen the meaning of the knowledge items upon which those instruments were made.

These tools stimulate the reflective thought (Novak & Gowin, 1999), being able to become an excellent contribution to the building of a social cooperative and constructivist atmosphere. They are excellent to detect the pupils' early conceptions and to know their cognitive structures, which allows to teach constructively in agreement with them and become good tools for a formative evaluation (more retroactive), or even more forming (more pro-active), making the pupils recognize new relationships and new meanings among concepts and often stimulating their creativity (Novak, 2000; Valadares & Graça, 1998).

The map made by a pupil about a certain subject never has a final character. It gets better and better as the understanding of the *conceptual structure of the subject* by the individual who is making it improves, and the concepts about this subject improve. It is therefore "a diagram which is changing as the meaningful learning is taking place" (Moreira, 2000, p. 56). To make them, negotiate them, present them, remake them are processes which very much facilitate a meaningful learning.

2.2 Cooperative work

Learning is a personal construction where the cultural agents are essential for it. The constructivist concept considers teaching as "a combined process, shared, in which the pupil, thanks to his teacher's help, can show that he is getting more and more skilled and autonomous in problem solving, concept using, having certain attitudes, and in many other questions" (Solé & Coll, 2001, p. 22).

Thanks to the interaction and help from his teacher and mates, each pupil can work or carry on a task at such a high level of achievement he would not have if he were working individually (Vygotsky, 1991). Having *cooperative activities*, when it takes place in an adequate environment, enriches since it often leads to meaningful learning by the pupils. Different authors such as Bessa & Fontaine (2002), Johnson & Johnson (1994), Johnson, Johnson & Holubec (1994, 1999), Johnson, Johnson & Stanne (2000), Slavin (1995, 1999) refer to researches made in this area that point to advantages of using it in the classroom environment.

However, "stimulating the cooperative work is more than having the pupils work in group" (Bessa & Fontaine, 2000, p. 57), and it is not only to assign them a task, to tell them to help one another, to share materials to solve the problems belonging to performing the task and wait for the work to show up finished. It is crucial to strategically define a set of principles and rules and transmit them to the pupils, generating the conditions for them to respect and keep them, and, at the same time, to make all the partners become responsible for the best results possible (Johnson & Johnson, 1994; Johnson, Johnson & Holubec, 1994, 1999). Teaching the skills of the socialising process is also very important.

We have got experienced in using strategies of cooperative work according to the model of Johnson & Johnson – *Learning Together,* pretty flexible and adequate to the demand of the experimental work and where we tried to respect the demands needed for a good cooperation. The demands, which are interrelated, are the following ones: the existence of a positive interdependence; a considerable face-to-face interaction; the existence of an individual/personal responsibility, clearly perceived to meet the group objectives; the frequent use of interpersonal and small-group skills and frequent and regular evaluation of the functioning process of group work, to improve efficiency (Johnson, Johnson 1994; Johnson, Johnson, 1999; Johnson, Johnson, Holubec, 1994, 1999). These elements are shown on the following diagram (figure 1):

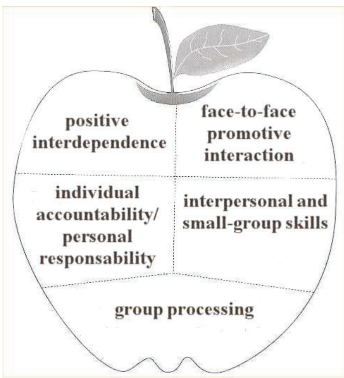

Figure 1- Essential components of cooperative work (Johnson, Johnson & Holubec, 1994, 1999, p. 38).

2.3 Constructivist and researching environments for learning

Taking into consideration the definition of a well-known theorist of learning environments, *B. Wilson* (1996), we can consider as a *learning constructivist environment* the environment where some "learners work together and support each other as they are using a variety of tools and sources of information following the way of learning objectives and problem-solving activities".

The objectives of a constructivist environment, according to *Cunningham, Duffy* and *Knu*th (1993), are the following ones: to make the pupils familiar with the process of knowledge building; to afford the chance for approaching the questions and the living experiences under multiple perspectives; to implement learning in realistic and relevant contexts; to encourage the pupils to cooperate in the building of their own learning objectives and to become responsible for their own learning process; to provide collaborative activities, implementing learning in favorable social conditions; to use multiple forms for representing the situations involved in learning; to encourage the perception of the very process of knowledge building by means of reflexive and metacognitive activities.

On the other hand, Savery and Duffy (1996) have established the following four principles that should underlie the constructivist environments: (i) learning as an active and involving process; (ii) learning is a building knowledge process; (iii) the learners should work upon a metacognitive level; (iv) learning should involve "social negotiation".

Following the ideas of Brooks & Brooks (1997, 1999) very close, we can say that in a constructivist environment the teacher will have to take into consideration the pupils' viewpoints about the subject being studied, to provide activities which challenge the pupils' assumptions, to discuss problems that the pupils think relevant, to develop strategies thought upon large and embracing concepts and to evaluate his pupils in the classroom context, on a daily basis and on a perspective as formative as possible. The pupils, in turn, should be active (but not hyper-active) researchers, intentional, dialoguing, reflexive and enlarging (Jonassen & Tessmer, 1996).

We have had direct and indirect experience that the metacognitive tools such as the concept map and the Vee of knowledge contribute to the establishment of good learning environments. When the concept maps are being made and remade and completed in a progressive way as the pupils are working within a teaching-learning unit, they are thinking in a metacognitive way, they themselves are regulating their own learning, and, at the same time, they are reflecting upon and building their knowledge in a collaborative way by means of negotiating ideas, and are evaluating themselves and the others, becoming co-responsible for their own learning's.

3 Empirical evidence about the teaching value of Concept Mapping

Within the Master's Degree in Science Teaching in the Open University different works were developed where there was the opportunity to research upon the effect of using concept mapping as a support for constructivist environments in the classroom, facilitating the meaningful learning. So, in a Master's thesis it was made a quasi-experimental research where the pupils in an experimental class were subjected to a constructivist strategy based on the making of progressive concept maps and on a process of forming evaluation, and that strategy proved to be more effective for the learning of concepts of Mechanics of the school ninth level than a traditional strategy used in the control class, identical at the starting point, subjected to a similar teaching, with the exception of using concept maps. Besides a cognitive enrichment, which was seen in the evolution shown in the progressive maps and about them, there were developed among those pupils more favorable attitudes than among the pupils in the control class, as it was confirmed using a Lickert scale and a questionnaire to the pupils (Conceição & Valadares, 2002, pp. 217 - 232). We show, as an example, two concept maps made by the same student (figure 2). After comparing, it is worth noticing the evolution of the cognitive structure, even though there remain a few difficulties such as, for example, the non-connection of the mass to the inertia property of bodies (Conceição, 2002).

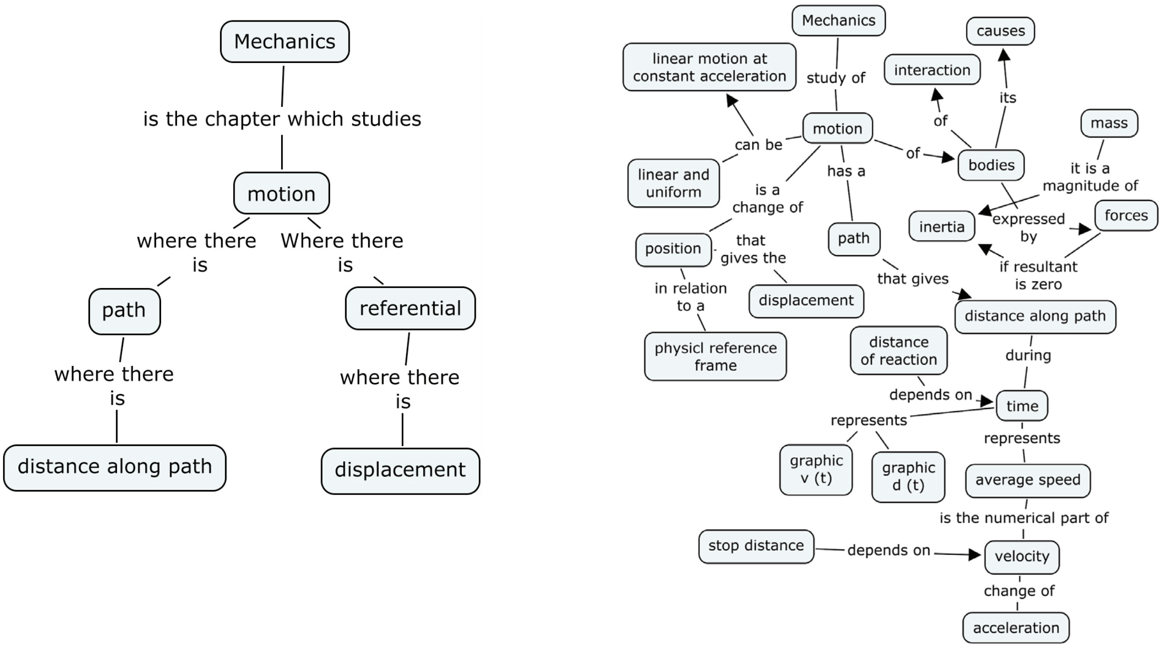

Figure 2- First and fourth concept map constructed by the same pupil (Conceição, 2002).

In another Master's thesis, a research was made based upon the use of progressive concept maps in lessons about human breathing for the Third Degree students of a Teachers' Course for the First Level of Primary teaching in a Superior School of Education (Ribeiro, 2004). The techniques and the researching tools were surveys made by questionnaire and interview, concepts maps made by the pupils as individuals and in a working method of cooperative group, observation grids, and the audio-taping of dialogues in a cooperative work context. Two groups were made, one experimental (n = 27) and another one of control (n = 27) and the researcher used a qualitative technique based upon the analysis of contents, either of concept maps or the answers to the surveys, with the purpose of cataloguing the misconceptions of the pupils in the two groups. Later she used statistical methods applying the SPSS Programme (Statistical Package for the Social Sciences) and Man - Whitney and Wilcoxon non-parametric tests.

While before the processing no meaningful differences between the two groups were found, after the activities with the progressive maps significative differences were found. And the comparison of the students' answers in the experimental group to the questionnaire after and before the activities of concept mapping showed significative differences in what refers to important features of breathing as the one of the ventilation, the lung capacity, the passage of the air in the body, the phenomena responsible for the alteration of the air and the substances that trouble breathing.

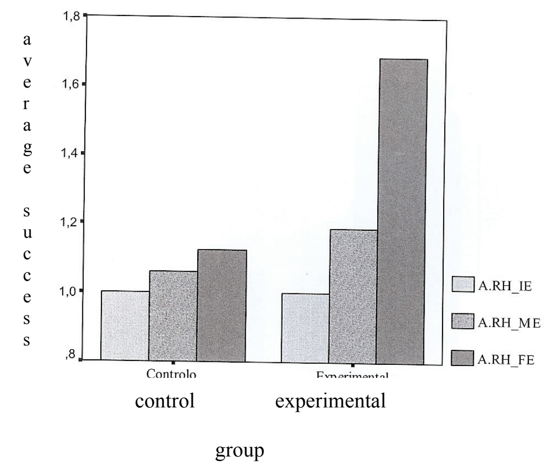

Figure 3- The success average in the sub-group questions "Substances which disturb breathing" in the first, second and third answering to the questionnaire. While in the control group the evolution was reduced, it was increased in the experimental group

The third research we refer to here was made in the Acoustics lessons, established by the curriculum of the Physical and Chemical Sciences of the Portuguese basic teaching level, and within a Ph. D. degree taken in the Open University. The data gathering was made according to the combination of a qualitative method, consisting of a remote and direct observation, with a quantitative method, based upon a quasi-experimental plan. The tools used for *data gathering* were these: a *pre-test* and a *post-test* about the contents of Acoustics; *questionnaires* answered only by the experimental class (EC), concerning the evaluation of performance during the group work, the evaluation of the global performance of the group work and, still, the evaluation of the activities made in the lessons; *observation grids*, one for collecting the data during the observation in the Acoustics lessons in both classes involved in the research, and another grid to evaluate the skills belonging to the cooperative work performed by the students in the EC, where this work took place. This grid was made following *Johnson & Johnson's* ideas (1999) about the cooperative work strategy "*Learning Together*", since this was the strategy used in fieldwork for this research; *the audio-taping* of the discussion held by the pupils in the work group; *concept maps* about Acoustics fundamental concepts; *the Gowin Vee* made in the experimental class to facilitate the constructivist environment; and, finally, a *semi-structured interview* with the teacher who was teaching Acoustics. These different information sources allowed data crossing.

On the following table we show the different steps of the concept mapping, the methodology we used, as well as the total number of maps made by the pupils in both classes (table 1):

Table 1- The making of concept maps by the pupils (Soares, 2007)

Moments	Methodology	Experimental Class	Control Class
Before teaching Acoustics	Individual	28 maps	27 maps
While teaching Acoustic	Cooperative work	30 maps	----------
After teaching Acoustics	Individual	28 maps	27 maps

As we can see on this table, during the research only the pupils in the experimental class did work in group and cooperatively, based on the concept mapping, while performing the proposed tasks concerning the Acoustics subject. The preparation of the pupils in both classes for the concept mapping was similar. Before the teaching of Acoustics, the pupils in both classes made concept maps about other subjects of Physics, so they could get familiar with this technique.

The Acoustics subject was divided into various sub-topics: the production of sound; the propagation of sound; the sound as wave; the sound properties; the sound listening. In the end of teaching each sub-topic, the pupils in each group made a concept map with the principal concepts in this topic whole, which was analyzed by the teacher and discussed in every one of the work groups in a cooperative way. The pupils' maps were being progressively self-corrected and enlarged with new concepts as they began studying new sections – progressive mapping – showing the process of structuring and restructuring of knowledge as the result of the discussion among the pupils, and between them and their teacher.

The introduction of the Vee into the empirical work of this research began to take place in a practical work to determine the sound speed, and after the pupils had become acquainted with the concept maps, as several authors suggest it, Moreira & Buchweitz (1993) among them.

The analysis of the concept maps made by the pupils was essentially qualitative and was focused on the features suggested by Novak (1998), Moreira and Buchweitz (1993), Valadares and Graça (1998), Novak and Gowin (1999) and Mintzes, Wandersee & Novak (2000), which are shown on the following table:

Table 2 - Qualitative evaluation of the concept maps individually made by the pupils (Soares, 2007)

	Before teaching Acoustics						**After teaching Acoustics**					
Avaliation	Weak		Acceptable		Good		Weak		Acceptable		Good	
Features	TE	TC	TE	TC	TE	TC	TE	TC	TE	TC	TE	TC
Hierarchising of concepts	✓	✓						✓	✓			
Linear structure versus ramified			✓	✓							✓	✓
Relative number of concepts adequate connected	✓	✓						✓	✓			
Links words	✓	✓						✓	✓			
Cross links	✓	✓					✓	✓				

Taking this analysis as a basis, we could observe the cognitive evolution of the pupils in the experimental class. However, this analysis showed some aspects where the pupils found some difficulties. One of them was in establishing cross-links between the concepts. It is not strange that for the pupils at this age the integrating reconciliation of the concepts studied in this area is not easy. Among other reasons, we emphasize the fact that in Acoustics there are not many super-organized concepts dealt with at such a basic level. Another reason for this result was the difficulty the pupils showed in discriminating some Acoustics concepts such as, for example, the intensity of sound and the amplitude of the sound waves. As to the scientific accuracy of the relationships established among the concepts, we concluded that, generally speaking, it was pretty acceptable. We show, as an example, two concept maps made by the same work group in the experimental class (Figure 4 and 5).

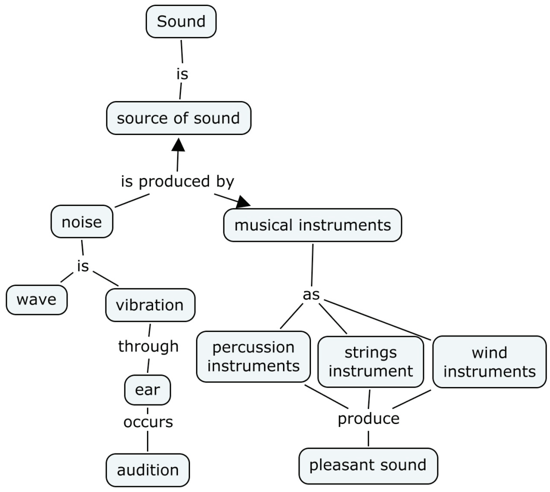

Figure 4 - A first map made by a group work after the teaching of the sub-topic sound production (Soares, 2007)

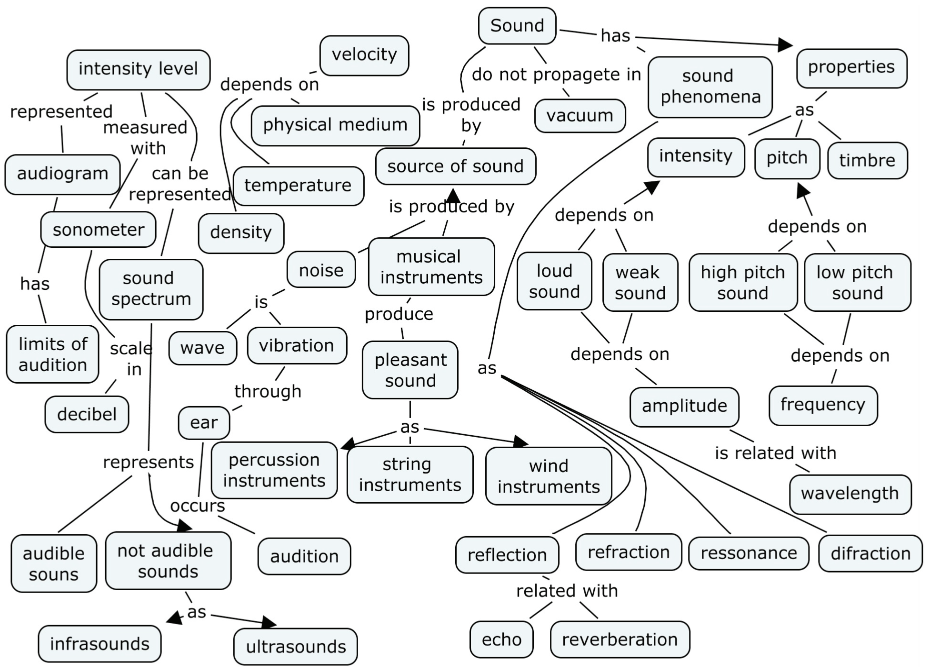

Figure 5 - A third mp made by the same group of students after study more subtopics about sound (Soares, 2007)

Both maps reveal some conceptual difficulties that have been discussed cooperatively in all the class. On comparing them, we found out that there was a reorganization in the second map of some of the concepts involved in the first one, as well as the introduction of new concepts, originated by the discussion among the elements in the group.

After the teaching of Acoustics, we compared the results obtained by the pupils in the two classes in the concept maps and in the pre-test, and we found out that the results in the experimental class (EC) were clearly positive and better than the ones in the control class (CC). As an example, we show on the following graph (figure 6) the departing situation of both classes and the arriving situation after implementing the constructivist and researching strategy in the EC and the traditional strategy in the CC.

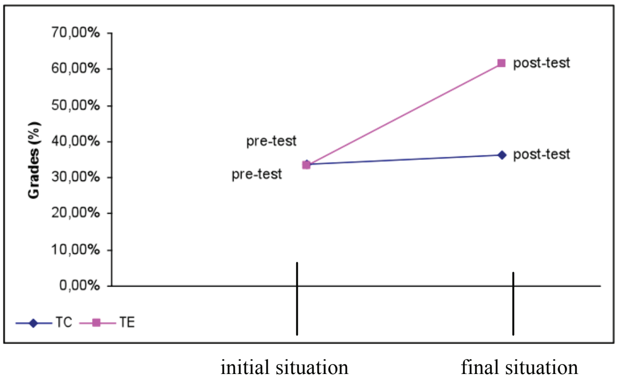

Figure 6 - Graphic presentation of the concept enrichment about the topic of Acoustics in the experimental class (EC) and in the control class (CC) (Soares, 2007)

On the graph we see an initial situation similar in the two classes and a final situation much more different in the same classes. The results of the post-test in both classes showed a better performance of the pupils in the experimental class.

Another of the collected results that confirmed the efficiency of the strategy used in the classroom were the answers by the pupils in the experimental class and in the control class to two questions in the post-test (questions 7.2 and 11), which were about the contents explored by making a Vee (sound speed). Then, the question 7,2 was formulated by this way: "A boat, being with difficulties of navigation, shot a rocket of advice. A lighthouse keeper, in the coast, heard a noise of the rocket 4 s after to have seen the flash. What is the distance of the boat to the coast?" To answer this question students would have to choose the correct answer in a group of four options, in this case the option D. The question 11 was this one: "It was produced a detonation in a quarry situated in front of a hill. The echo was heard just in the local of the quarry 3.0 s afterwards. At what distance was the hill?". Also in this question students had four options of answer. The correct option was C. The results of these two questions are shown on the following graph (figure 7):

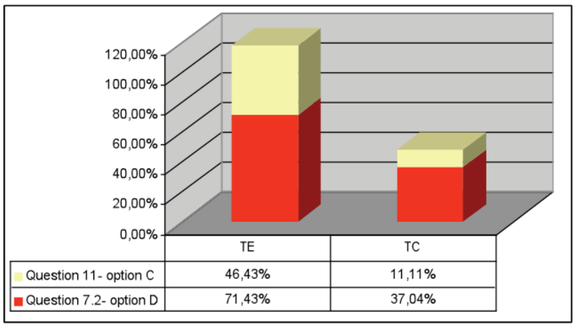

Figure 7 - Correct answers by the pupils in the experimental and control classes in questions 7.2 and 11 in the post-test (Soares, 2007)

As we can see on this graph, the pupils in the experimental class showed a better learning in any of the approached questions.

4 Conclusions

The main purpose of this paper was to show some research work made at the level of some Master's and Ph. D. degrees in the Teaching of Sciences by the Open University, which has given evidences that the teaching strategies developed in constructivist environments for learning, based upon the implementation of experimental activities and the use of metacognitive instruments, mainly progressive concept maps, but also Gowin Vees, lead to more meaningful learning than the use of strategies, even though experimental, in traditional environments. We think we can say that such strategies and environments, besides facilitating the meaningful learning of science, give the students a greater motivation for the study of sciences. As a matter of fact, beyond the results we have got, we have found out the commitment and the joy of the pupils in the experimental classes, while, in cooperative terms, they go on performing the proposed tasks. In spite of the evidences we have already come to, we think it is necessary to continue with more studies like these in other schools and other countries, considering the limited dimensions of the samples we have been working with, the result of the conditions of the very researches made in the classroom.

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THE USE OF CONCEPT MAPS IN PROFESSIONAL DEVELOPMENT AND IN TEACHING STUDENTS WITH LEARNING DISABILITIES: A RESEARCH AGENDA

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Abstract. Presenters will discuss two controlled randomized field trials that examined the effectiveness of concept maps on students' ability to comprehend text. The major theme will be professional development and teaching strategies that promote the solid use of concept maps for both teachers and students. The first study used concept maps as part of a unique professional development program, Teacher Study Groups. The purpose of the second study was to determine if middle school students with mild disabilities who are educated in general education settings can learn complex historical concepts when information is presented through videos and the use of research-based instructional strategies, such as concept maps and peer assisted learning.

1 Introduction

This paper discusses two lines of research that examined the influence of concept maps on student outcomes. Research has demonstrated that concept maps are useful tools for helping students develop an understanding of a body of knowledge, accessing prior knowledge, and exploring new information and relationships (Bulgren, Schumaker, & Deshler, 1988). The goal of the current research agenda was to establish that these outcomes could be accomplished in multiple contexts. The first study examined the use of concept maps as enhancements within the framework of Teacher Study Groups, a professional development activity. The second investigation uses concept maps and videos to teach complex social studies curriculum to students with disabilities. Taken together this research demonstrates how concept maps can be useful for both teachers and students, can be implemented across various curricula, and can be used with different populations.

2 Use of Concept Maps & Teacher Study Groups to Improve Student Outcomes

In recent years there has been an increased interest in the use of Teacher Study Groups (TSGs) or Teacher Work Groups as an approach to professional development because curricular coherence, content focus, duration/intensity, and collective participation are intrinsically integrated and explicitly used to link research to classroom practice (Carroll, 2005; Lambert, 2002; Meyer, Brown, DeNino, Larson, McKenzie, Riddler, & Zitterman, 1998; Murphy, 1992), there has been an increased interest in the use of TSGs as an approach to professional development. Teacher Study Groups are modeled after Japanese Lesson Studies, which emphasize collaborative lesson planning principles, structured discussions, and observations and evaluations of planned lessons.

Given the current emphasis on evidence-based instruction, there is a strong need for systematically evaluating the relative effectiveness of the Teacher Study Groups in promoting the use of the concept maps to enhance vocabulary and reading comprehension instruction. The purpose of the current study was to examine the effect of Teacher Study Groups that focus on the use of concept maps in improving classroom teacher practice and knowledge as well as student outcomes in reading, especially in the areas of comprehension and vocabulary. Specifically, our research questions were (a) What is the impact of TSGs on teacher knowledge and teacher practice compared to the professional development efforts being provide by the district and the State? (b) What is the impact of TSGs, particularly those that use concept maps, on student reading outcomes when compared with existing professional development efforts?

2.1 Intervention Program/Practices

TSG Condition: Teachers in the experimental condition attended 16 TSG sessions (2 per month) at their schools from October to mid-June. The first 8 sessions focused on vocabulary, while the remaining 8 focused on comprehension. Each session lasted approximately 75 minutes and was conducted either after or during school hours at the discretion of the principal. The research staff served as facilitators for all TSG sessions. Each session consisted of four distinct segments:

1. Debrief Previous Application of Research: The teachers report on the implementation of the lesson they planned collaboratively during the previous TSG session.
2. Walk through Research: Discuss critical instructional concepts from readings that were assigned at the previous TSG session.

3. Walk Through the Lesson: Examine the strengths and weaknesses of a lesson selected from their basal curriculum and determine how the lesson could be enhanced to reflect the critical instructional concepts identified during Walk through Research.
4. Collaborative Planning: Teachers work as a whole group or in pairs and actually plan the enhanced lesson that they discussed during the Walk Through the Lesson segment. These enhancements include concept maps to help students generate main ideas, understand story structure, and answer higher order questions.

Concept maps were used as a tool to aid in comprehension instruction. They were integrated into the Teacher Study Groups to help students generate main ideas, learn story grammar elements, and demonstrate cause and effect relationships. During the collaborative planning segments teachers developed lessons that integrated concept maps into their teaching practices.

Control Condition: Teachers in the control condition did not have access to the TSG sessions or materials. They participated in scheduled school and district professional development activities.

2.2 Research Design

Randomized field trials were conducted to assess the impact of the TSG intervention. Three school districts from three states agreed to participate in the study. Schools within each school district were matched on key variables such as performance indexes and ethnic composition. The schools from each matched pair were then randomly assigned to either the treatment or control condition. Overall, we had 10 treatment schools and 9 control schools. Participants were 85 first grade teachers from 19 Reading First schools. Seven students were randomly selected per teacher at pre-test and post-test time for evaluating outcomes at the student level.

2.3 Data Collection & Analysis

Data on all teacher and student measures were collected twice during the course of the study: once at the beginning of the study and once at the end of the study, with the exception of classroom observations, which were done only as a post-test. Our teacher measures included the *Reading Comprehension and Vocabulary (RCV) Observational Measure* (Gersten, Dimino, & Jayanthi, 2007) for measuring teachers' classroom reading instruction, the *Teacher Knowledge Assessment Measure* (based on the Teacher Knowledge and Attitude Survey) (Phelps, 2003) for measuring teachers' literacy knowledge, and the Professional Development Measure (based on a national survey of teachers' professional development in math and science and a Reading First Survey used in Califonia) (Birman, Desimone, Porter, & Garet, 2000) for determining teachers' perception of their professional development experiences and their thoughts on reading in general.

Student measures included subtests from two standardized tests that involved *Reading Vocabulary, Passage Comprehension, Oral Vocabulary,* and *Memory for Sentences*.

2.4 Findings

Impact Estimates on Teacher Measures: On the observational measure the impact estimates are moderate to large and statistically significant at the .01 level. Teachers in the experimental condition outperformed control teachers on the observational measure in both comprehension and vocabulary areas. As part of this measure we observed and calculated the frequency of concept maps used by teachers during or after a reading lesson. Teachers in the experimental condition used concept maps 75% of the time compared to teachers in the control condition who only used concept maps 35% of the time, a difference that was statistically significant at the .05 level.

On the Teacher Knowledge Measure of comprehension and vocabulary instruction, teachers in the TSG schools scored approximately .28 standard deviations higher on the measure of comprehension than control schools; this impact estimate was not statistically significant. However, teachers in TSG schools outperformed teachers in the control schools by approximately .68 standard deviations on the teacher knowledge measure of vocabulary instruction. On teachers' views about professional development in general and their thoughts on teaching reading, our findings suggest that teachers in the TSG condition expressed significantly more positive views toward professional development (*ES* = .40) than teachers in the control condition. Since there were significant differences in school variability on this measure, the multi-level model was the appropriate analytic strategy for estimating the impact on teachers' overall views toward professional development. However, there was no significant difference between groups on the scale measuring teachers' thoughts on reading. We replicated all analyses using MANOVA and obtained similar results.

Impact Estimates on Student Measures: For reading vocabulary, oral vocabulary, and passage comprehension, the results revealed no significant impact on the post-test WDRB measures of reading vocabulary and passage comprehension. However, the moderate effect size for oral vocabulary, ES = .44, was significant at the .10 level. Overall, the effect sizes were similar in magnitude to the estimated impacts for the reading accuracy and fluency measures. Children in the 16 schools located in California and Pennsylvania also took the California Achievement Test, 6th Edition, permitting us to estimate treatment effects on a widely used standardized test of reading comprehension and vocabulary. We found no significant impact on the CAT6 total reading score, reading vocabulary, and reading comprehension. However, the magnitude of these effect sizes (ES = .09 to .23) mirrored those observed for the reading accuracy, fluency, vocabulary, and passage comprehension outcomes.

2.5 Conclusions

Overall, our findings indicate that the TSG model is a promising professional development approach. TSGs have resulted in significant impact on proximal outcomes—teacher measures of instruction and knowledge. In general, these effect sizes are two to three times larger than student outcomes. While we saw significant impacts in teacher practice both for the areas of comprehension and vocabulary, the magnitude of the latter's impact is worth noting. We attribute the impact in comprehension to substantive discussions regarding explicit reading comprehension instruction and how concept maps can be used to bolstered students' comprehension of text.

Also encouraging are corollary gains we see in teacher knowledge. Given the explicitness of our TSG vocabulary sessions, which were based on Isabelle Beck's *Bringing Words to Life: Robust Vocabulary Instruction* (Beck, McKeown, & Kucan, 2002), this finding is clearly explicable. Although our student outcomes are not as significant as our teacher outcomes, they do fall in line with impact estimates from recent cluster-randomized trials of school-level interventions like Success for All (Borman et al., 2005). One limitation of the study is that we did not have enough power to detect significant impacts on students; we would need at least 40 schools to find effect sizes between .10 and .20. Another issue that needs to be addressed is the issue of scalability. Having researchers or staff developers spend significant amounts of time working alongside of teachers is not practical on a wide-scale basis (Putnam & Borko, 2000).

3 Thumbs Up: Using Video & Concept Maps to Teach Complex Social Studies Curriculum to Diverse Learners

Students with disabilities can learn complex history concepts in general education settings when provided with appropriate instructional support. The purpose of the study was to demonstrate how research-based instructional strategies, including concept mapping activities that required students to compare and contrast, dyad activities, inserted questions used to enhance student engagement, and film and videodiscs can be integrated to improve instruction in middle/secondary general education classrooms. With the reauthorization of IDEA, teachers are searching for ways to help students with disabilities access the general education curriculum.

Research-based instructional strategies such as concept maps and content enhancements in the form of material from popular media (videos/documentaries) were used as a foundation for teaching historical concepts. Through the use of a *formative experiment* methodology, these strategies were tailored to incorporate technology, to enhance comprehension, and to meet the needs of diverse learners.

3.1 Purpose of the Project

The goal of this investigation was to examine the effectiveness of specific instructional delivery approaches on the learning of a historical unit for students with LD as well as average-ability students in the classes. We believed that these specific instructional delivery strategies would increase student engagement and participation in the lessons, students' knowledge of the material, and students' understanding of a set of historical events.

The specific research-based instructional strategies included activities requiring students to complete concept maps in dyads to foster peer interactions and the use of inserted questions that highlighted the narrative focus of the information presented through videos. We thought the combination of these techniques would enhance active engagement of the students with LD in the lesson. For this objective, we employed rigorous research methodology (controlled randomized field trials). For this phase, the teaching unit was held constant, but the specified instructional delivery techniques varied from the experimental to comparison condition.

Our goal was overall understanding of the content of the unit, i.e. knowledge of the goal or causes of the actions, and an understanding of some of the long and short-range consequences of these actions. Our hypothesis was that by including activities such as concept maps using the compare-contrast structure, that required and supported active participation by students with LD, these goals would be accomplished.

3.2 Method

3.2.1 Participants and Setting

Seventy-six middle school students and two teachers participated in the study. Half of each intervention class were students with learning disabilities. On average, students with LD read at a level typical for third and fourth graders, i.e. three to five years below grade level (Hasbrouck & Tindal, 1992). There were 40 average-ability students (i.e., not receiving special education services): 20 in the experimental condition and 20 in the comparison condition. In terms of class size, one of our goals was to have class sizes that roughly paralleled what was typical in the local middle schools. Thus, in each school, we randomly assigned 18 students with LD and 20 average-ability students into one of two social studies classes for a six-week term.

3.3 Instruction in the Experimental and Comparison Condition

3.3.1 Materials

The primary mechanism for conveying critical information on the Civil Rights Movement was the documentary Eyes on the Prize (DeVinney, 1991). The documentary is 180 minutes in length. We showed the film in 18 segments throughout 4-5 weeks of instruction. In addition to the death of Emmett Till, the video highlighted about a dozen other critical events, which both expanded on the larger issues and focused on the consequences of powerful legislation.

3.3.2 A Typical Two lesson Sequence

Experimental Condition. We used a standard lesson format over a period of two days. On the first day of a new lesson, students watched a 6 to 12 minute segment of Eyes on the Prize. This would be followed by a series of questions about the segment. The series questions would range from “how would you feel if…” to questions that asked students to demonstrate their understanding of the event (e.g. “what happened to the protesters?”). Students might then watch another segment and answer a few brief questions. The next day would involve review of the earlier video and watching additional footage if there was any. Students completed a concept map activity in heterogeneous pairs (one LD, one average-ability).

Approximately, once a week, students would participate in concept map compare-contrast activities. Typically, these activities extended over two lessons. Teachers often modeled the first one or two comparisons, gradually fading their role as the course evolved. Concept maps were used to compare events, people, and concepts. Some examples of the specific comparisons students completed using concept maps included comparing the outcome of the Texas trial involving the racially motivated murder of an African American in 2000 with the trial of Emmett Till in the 1950’s, and comparing boycotts to sit-ins. It was an intentional decision to limit the number of types of concept maps as approximately half of the sample included students with special needs. The goal was to teach a few so that students could master and apply them to a variety of concepts.

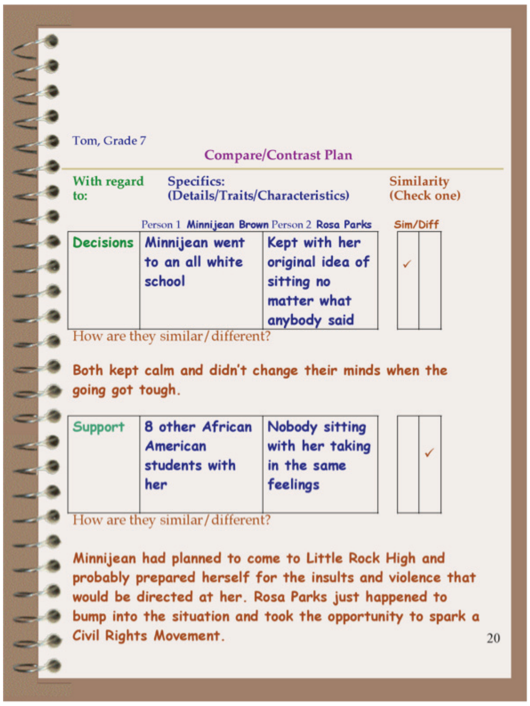

Figure 1. An example of a concept map compare-contrast activity

Figure 1 presents an example of a concept map compare-contrast activity. In this activity, students were asked to use the compare-contrast structure with (a) a black high school student named Minnijean Brown (one of the Little Rock 9 students) who was among the first to integrate a previously all-white school and (b) Rosa Parks, a black woman who refused to move to the back of the bus when ordered to do so by a bus driver (Rosa Parks' arrest is usually considered the event that triggered the Montgomery Bus Boycott). Then they were asked to identify specific issues or events associated with both Minnijean Brown and Rosa Parks that could be used for analysis. Finally the students had to determine, typically through discussion, whether the point being analyzed is the same or different in the two conditions.

Comparison Condition. Students in the comparison condition were taught the identical content as students in the experimental teaching condition; however, a more traditional approach was used in teaching the material. Students watched the same documentary video footage, but they did not answer the "how would you feel if…?" questions during various segments of the video like the experimental condition. Instead the teacher would set the stage with a brief mini-lecture and/or preview questions. The students would watch the entire video.

3.3.3 Measures

An important question for us was the extent to which students in the experimental condition, who were taught with activities that encouraged active cognitive engagement, would demonstrate deeper levels of understanding of the Civil Rights Movement than students who were taught the identical unit with more traditional teaching procedures. We were also interested in the extent to which teachers could work with students with LD in inclusive settings.

In all, we used three measures of content acquisition. Two of these were traditional measures of content acquisition: a vocabulary-matching task and a written exam measure that included both short answers and paragraph essays. As students with LD display consistent problems in writing (Baker, Gersten, & Graham, 2003; Thomas, Englert, & Gregg, 1987), and on multiple choice or matching tasks, we also used a third measure that did not rely on students' ability to articulate their ideas in these traditional ways. This third content measure was a Content Interview and it required students to verbally articulate their understanding of the Civil Rights Movement.

3.4 Findings

Posttest Performance: Students with Learning Disabilities. The difference between the experimental and comparison condition groups on posttest Matching was not statistically significant (F (1,34) = 3.07, p = .09). However, students in the experimental condition performed significantly better than students in the comparison condition on both the written exam measure (F (1,34) = 11.05, p = .002), and the Content Interview measure (F (1,34) = 5.12, p = .03).

Average-ability Students. On the matching test, the difference between students in the experimental and comparison condition groups was not statistically significant (F (1,38) = .99, p = .33). In noting the percentage of items answered correctly, students in both conditions had a mean score that was close to the highest score possible, indicating a potential ceiling effect.

However, on the Written Exam, which reflected students' ability to discuss historical issues, the difference was statistically significant (F (1,38) = 7.28, p = .01.) At .76, the effect size on the Written Exam measure is relatively large.

The results of this study demonstrate that students with LD can learn relatively complex and challenging material in American history when provided with instructional delivery and activity structures that support active involvement in the learning process. These students demonstrated superior levels of performance on both the written and oral examinations that asked them to discuss key issues and figures in the Civil Rights Movement. Effect sizes on both measures were large with values of 1.0 on the Written Exam measure and .72 on the Content Interview measure. Although the effect was not significant on the Matching test measure, which involved knowledge of definitions of key terms and key figures, the effect size was moderate (.56).

In addition, we concluded that use of the compare-contrast concept map throughout the unit was a strong vehicle in enhancing understanding of history, and retention of facts and concepts in a history unit.

Thus, this study indicates that the experimental condition is likely to be a viable approach in inclusive classrooms and seems to support our intuition that this would be a better way to teach history for the majority of middle school students. Students responded very well to the multiple formats (the interactive nature of class discussions, working with a partner, using compare-contrast concept maps to analyze content, and ongoing dissection of the video). These approaches seemed to make the content more engaging to students. In contrast, in the comparison condition, there was more traditional teacher lecturing and more independent student reading. Essentially, students had greater responsibility for learning the content in the comparison condition than they did in the experimental condition. In the experimental condition, the teacher had to play a more active role in making sure students were really understanding the content.

3.5 Conclusions

The pattern of significant findings on both the written exam and Content Interview did document that the instructional delivery practices (i.e., the use of concept mapping activities, peer-assisted learning, and the inserted questions during the video segments) led to significantly better understanding and recall of the content of the unit.

We would encourage teachers to experiment with using any or several of these techniques since we continue to think that all show promise and the combination was demonstrated to be effective for both the special education students and the students without disabilities. Future research can help unpack components that are particularly effective as well as examine the ease of implementation of the various techniques we used.

4 Summary

The results of these two projects indicate that, when used in concert with an array of effective strategies, concept maps can be an effective tool in teaching history to middle school students and in building comprehension in first graders. Teachers seem to require professional development to be able to use these tools effectively. If this is done, student learning, especially of conceptual material, appears to be enhanced.

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THE VALUE AND USE OF CONCEPT MAPS IN THE ALIGNMENT OF STRATEGIC INTENT

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Abstract: The paper explores the value and use of Concept Maps in the alignment process of the strategic intent of a business. The success of strategy is often determined by a leader's ability to translate sophisticated strategic intent into simple, actionable language and to cascade this to every level in the organization to ensure alignment. To determine the success of the communication and level of alignment between the various hierarchical levels with regard to vision, mission and strategic objectives, concept maps were used. Five case studies are presented where a computer-based concept-mapping tool, CmapTools, was applied for the visual representation and measurement of strategic alignment amongst three hierarchical levels (CEO, Executive team and Employees) of co-operative wine cellars in the Paarl district of South Africa. The results of the empirical research clearly indicated a serious misalignment of strategic intent amongst all hierarchical levels and amongst each section of strategic intent. Concept maps and CmapTools proved to be invaluable tools to determine the degree of alignment with regard to strategic intent.

1 Introduction

Business teams need to follow an overall aligned organizational strategy in order to meet and exceed stakeholder expectations and to gain sustainable advantage over the competition (Pycraft, Singh, Phihlela, Slack, Chambers, Harland, Harrison & Johnson, 2000). However, employees often find themselves without direction in making daily decisions as they have no comprehension of the organizational purpose or direction. The task of providing this direction or strategic intent rests with the company executive (LeadershipNow, 2006). Strategic intent is the relentless pursuing of the achievement of an ambitious strategic objective and desired business position and entails the careful interlinking and balancing of the company's vision, mission and strategic objectives (Campbell & Yeung, 1991; Thompson, Strickland & Gamble*,* 2005). Strategic intent provides the emotional and intellectual energy for the journey of discovery of a compelling dream that the company wants to achieve in the long term (Hamel & Prahalad, 1994).

Strategic implementation and execution is a matter of alignment and focus (Kaplan & Norton, 2001), requiring committed and inspiring leadership on all levels and in all contexts of the organization (Senge, 1997) that are able to translate sophisticated strategy into simple, actionable objectives and to cascade these objectives to every level in the organization. Alignment is the lynchpin between vision, mission and execution. Alignment means having a direction that is accepted and understood by all employees in order to increase employee motivation and to get everyone lined up to do what is needed in order to achieve the strategic intent of the organization (Baldoni, 2006).

Successful organizations are characterized by good communication (Drucker, 1974; Peters & Waterman, 1982; Hesselbein & Cohen, 1999). No strategic plan or vision, regardless of the cleverness or quality of its design, will work without enlightened leadership to communicate the vision and strategic objectives to the people who need to make it real and tangible (Wall, Sobol & Solum, 1999). Identifying and communicating a clear strategic intent is one of the most important functions a business leader can perform (Puth, 2002). The alignment process therefore relies on an internal multifaceted communication program where the leadership communicates the strategic intent to the employees in an understandable way (Dibble & Langford, 1994). Hence, synergy is created and the shared vision becomes a powerful motivator to propel people into action (Hess, 1987). However, the paradox in leadership communication is that although it is natural and easy to communicate, it remains difficult to communicate effectively to ensure that meaning is shared, with the result that the communication messages from leadership are often misunderstood (Puth, 2002; Robbins & Decenzo, 2004; Lewis, 1975). For the vast majority of companies, having well-defined vision and mission statements does not change anything in their performance due to a lack of a clearly communicated intent.

The abstract and complex nature of business strategy makes strategies difficult to describe, define and communicate to employees. Richards (2001) pointed out that there are few published methods for representing strategy - none of which can capture strategy rapidly, and display it immediately in a simple, readily understandable form. Bullet point lists, PowerPoint slides and written statements are not always the best ways to communicate complex and interrelated strategic ideas. Neither are these methods ideal for discussion of the strategic ideas by the management team. More preferable is a visualization technique where the interlinking relationships are clearly indicated. Visual representation can both simplify complex ideas like business strategy (Margulies, 1991), as well as facilitate transmission of these ideas from individual to individual, business unit to business unit and even amongst different organizational levels.

This paper will focus on the application of CmapTools, a computer-based concept mapping tool developed by The Institute for Human Machine Cognition (IHMC) (Cañas et al., 2004; Novak & Cañas, 2008), as a method to give visual representation to business strategies, with specific reference to the vision, mission and strategic objectives, as understood by the different organizational levels. Concept maps will be instrumental in the measurement of the alignment of the strategic intent between Chief Executive Officer (CEO), executive team and employees.

Concept maps are a two-dimensional representation of cognitive structures showing the hierarchies and interconnections of concepts (Martin, 1994). Novak developed it in the 1960's to visually represent the structure and relationships between different sets of information (Novak, 1991). Many experiments proved that understanding and knowledge retention improved with the use of concept maps (Mintez, Wandersee & Novak, 1998; Novak, 1998, 2002; Coffey, Carnot, Feltovich, P.J., Feltovich, J, Hoffman & Cañas, 2003b). Although relatively little has been written about the application of concept maps in the business environment (Leake, Maguitman, Reichherzer, Cañas, Carvalho, Arguedas, Brenes & Eskridge, 2003), concept mapping is increasingly being used in the business environment. It is ideal for strategy formulation, implementation and measurement; product development; training programs; operational planning and problem solving (Trochim, 2003). A study of the literature indicated that concept maps and –tools are used for knowledge management (Hoffman, Coffey, Carnot & Novak, 2002; Fourie, Schilawa & Cloete, 2004); to improve shared understanding (Bennett & Frazer, 1990; Freeman & Jessup, 2004); to enhance team or group performance (Trochim, 1989; Cannon-Bowers, Salas & Converse, 1993; Evans, Harper & Jentsch, 2004); to facilitate training (Coffey, Cañas, Reichherzer, Hill, Suri, Carff, Mitrovich & Eberle, 2003a); to manage projects and product innovation (Fourie, 2005); to generate ideas and communicate complex ideas (Plotnick, 1997), and to enhance product innovation and design (Novak & Iuli, 1994). However, until now concept mapping tools have rarely been applied in the formulation and alignment of business strategy.

2 Aim and methodology

Since concept mapping tools have a powerful capability to ensure that employees are on the same page, and could therefore enhance the alignment and shared understanding of the vision, mission and strategic objectives of the company (Novak, 1998; Fourie, 2005), this research endeavors to test this statement with regard to the alignment of strategic intent in business. Semi-structured interviews were used to interview employee and executive groups, as well as the CEOs of five co-operative wine cellars in the Paarl district of South Africa. Each interview gathered organizational information, as well as information on strategic intent (nature and status, internal communication, current strategy alignment measurement, vision, mission, and strategic objectives). During the sessions, the main concepts were recorded and CmapTools was used to construct visual representations of the perceptions of the organization's vision, mission and strategic objectives for each of the hierarchical levels. Frequently, "*placeholder*" maps, small segments that pertained to promising topics, were created to be revisited later (Cañas, Ford, Novak, Hayes, Reichherzer & Suri, 2003). The total amount of people interviewed was 30 of which 5 CEOs, 10 senior executives and 15 employees. The concept maps were eventually analyzed and compared to determine differences and alignment problems within each wine co-operative.

3 Research results

The results of the analysis and map comparisons amongst the different organizational levels are presented below. Only one example of each of the vision, mission and strategic objective maps are given.

3.1 Cooperative wine cellar A

The concept maps in Figures 1 to 3 below focus on the organizational visions of each of the three hierarchical levels. An analysis of the degree of alignment revealed that all three hierarchical levels identified the following concepts for the organizational vision: "Produce wine of excellence; quality wine for the international market and for South Africa; and wine that match the changing market needs." The CEO and executive team identified the following concepts: "Motivated and capable staff; and technological advanced facilities." Only the CEO mentioned: "To get an optimal balance between bulk and bottled wine sales; new focus area is bottled wine sales; values of innovation, social responsibility, and reliable supply; and to generate sustainable income for shareholders." The employees' perception of the organization's vision focuses only on the production of wine.

From the concept maps, it is clear that the communication of the vision to employees is not very successful, as the employees did not identify staff and technology as part of the vision. The CEO also clouded his vision with detailed aspects from the mission, which could have contributed to the misalignment and miscommunication that is occurring between the CEO and employee levels.

The same process was followed for the mission and strategic objectives of Cellar A. All three hierarchical levels identified "to generate sustainable income for members" and "to produce quality wine for South African and international markets" as part of the organizational mission. The CEO and employees identified "wine must match the different market needs" as part of the organization's mission, while only the CEO identified "to focus on a niche part of the international market." In addition, the employees identified "to focus on quality of grapes and wine recipes", which neither the CEO nor the executive team identified.

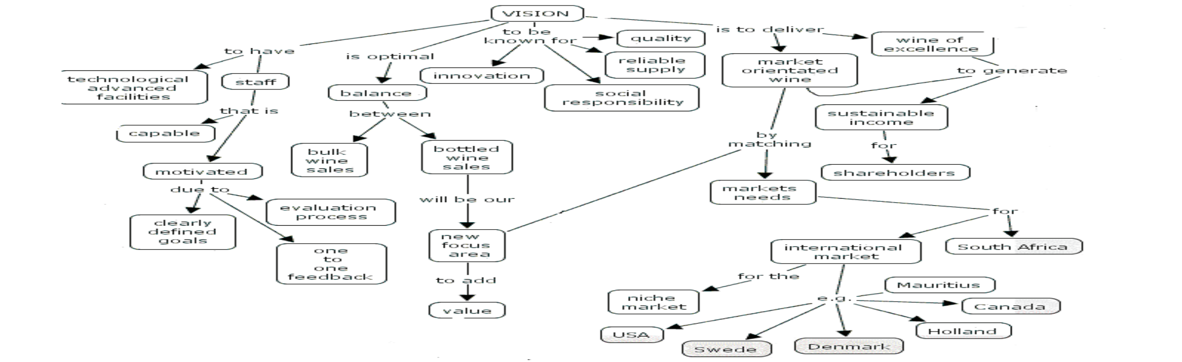

Figure 1: Vision section of cellar A's CEO map

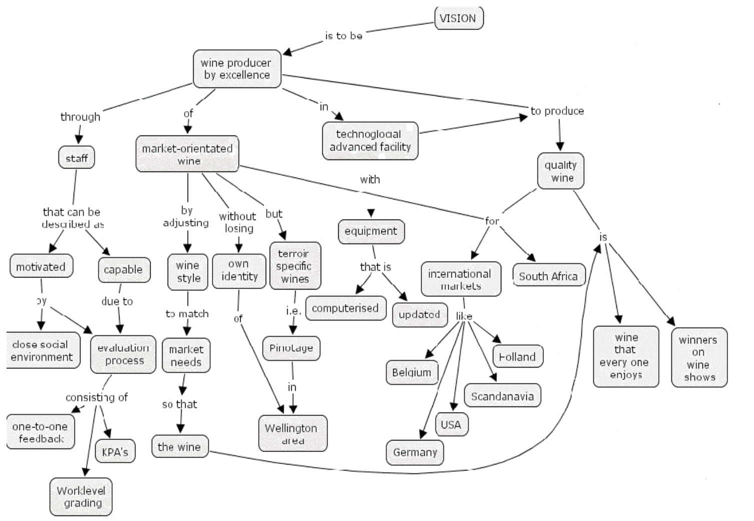

Figure 2: Vision section of cellar A's executive team map

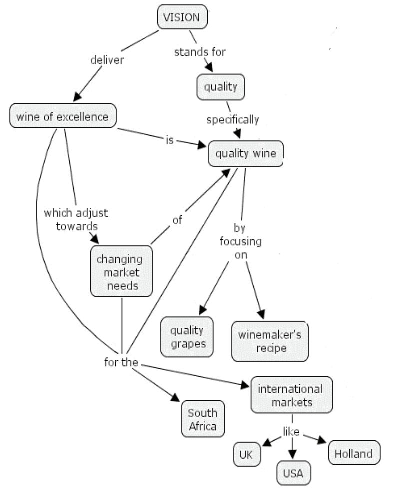

Figure 3: Vision section of cellar A's employee map

With regard to the organizational strategic objectives it became apparent from the comparison of the concept maps that the CEO of Cellar A identified more long term strategic objectives than the employees and executive team. None of the identified strategic objectives by any of the hierarchical levels were time-bound, casting a shadow of doubt on the level of commitment and buy-in into the cellar's strategic intent, most probably due to the inability of the CEO to clearly communicate the strategic intent.

All three hierarchical levels identified the production of quality wine as part of both the vision and mission. The CEO and employees indicated that the wine must match the market needs as part of both the vision and mission. It could thus be concluded that there is some confusion amongst all three hierarchical levels in distinguishing the organization's vision (its future positioning) from its mission (current positioning).

All corresponding concepts amongst the different hierarchical levels were counted and are depicted in Figure 4. The alignment amongst all three hierarchical levels for Cellar A is: vision (33,3%), mission (50%) and strategic objectives (20%). Amongst all three hierarchical levels, the mission sections of the maps obtained the highest percentage alignment. A comparison between the CEO and employee maps, as well as the executive team and employee maps, indicates that the mission sections showed the most alignment. The most alignment between the CEO and the executive team occurred in the strategic objectives section. The alignment of the vision was found to be the highest between the CEO and executive team members. The worst alignment of the vision occurred between the executive team and employee level. It seems as if the CEO (only 2 years in his current position) has fallen in the rut of crafting strategies without clearly communicating, implementing or aligning the strategy. The CEO will have to focus on the communication and alignment of the vision amongst all the hierarchical lev-

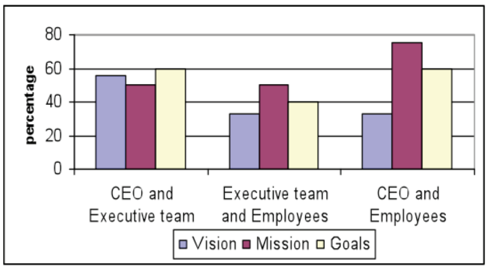

Figure 4: Alignment of strategic intent in cellar A

els. All the employees need to know where the organization is heading. A much clearer distinction between the vision and mission is needed.

3.2 Cooperative wine cellar B

Following the same procedure as above, concept maps constructed by the CEO, executive team and employees were used to determine the alignment of the vision, mission and strategic objectives of Cellar B.

From the vision concept maps it became clear that the focus of all three levels is on profitability. Quality was added by the CEO and the executive team; effectiveness by the executive team; and costs by the CEO.

In Figures 5 to 7 the mission maps that were used in the assessment of the alignment are presented. It is evident that all three hierarchical levels identified “to produce bulk and bottled wine” as the organizational mission.

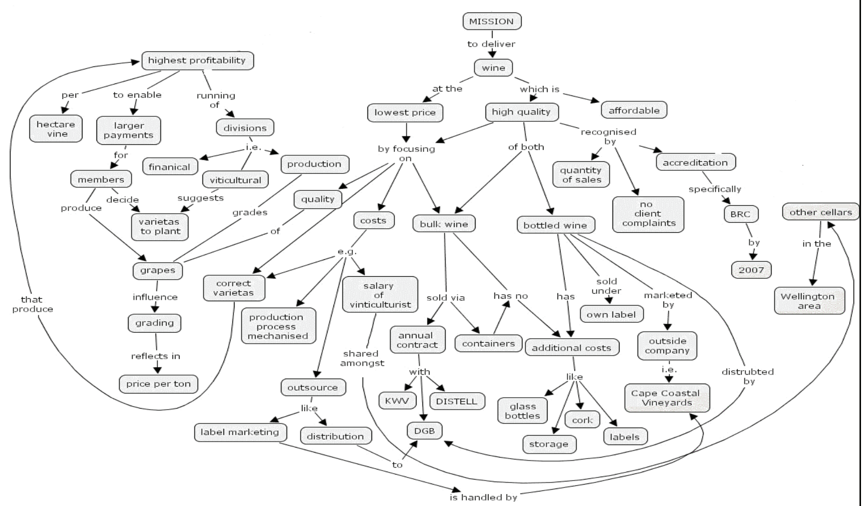

Figure 5: Mission section of cellar B’s CEO map

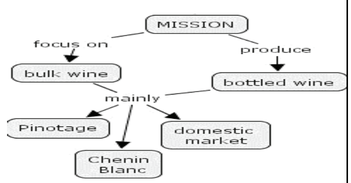

Figure 6: Mission section of cellar B’s executive map

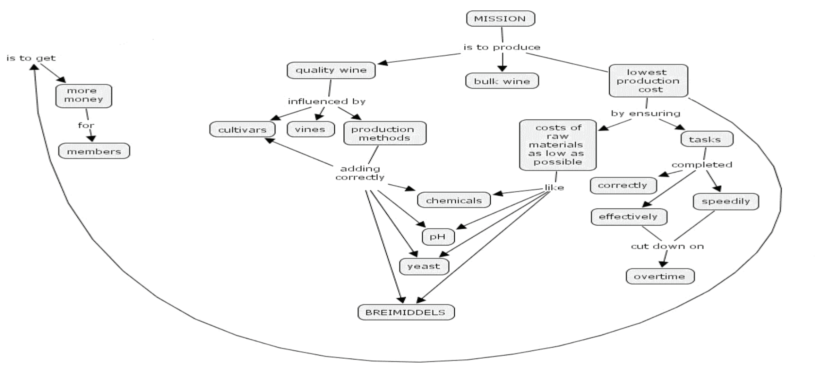

Figure 7: Mission section of cellar B’s employee map

The CEO and employees identified “wine must be produced at the lowest costs” and “to produce quality wine by managing vines, cultivars and production methods” as part of the mission. In addition, the executive team identified “the focus must be on the South African market.” Clearly, there is a difference in segmentation and focus of the targeted consumer market amongst the different hierarchical levels, which could result in poor decisions being made by management and staff.

The comparison of the organizational strategic objectives maps revealed that there is alignment between the strategic objectives of the CEO and the executive team, as well as the CEO and employees. However, it seems as if there is miscommunication and misalignment amongst the executive team and the employees as their strategic objectives are not aligned. This can be due to the CEO filtering the strategic intent and only communicating what he feels relevant to the specific hierarchical levels. This partial alignment of hierarchical levels and partial commitment to the strategic intent could result in mediocre performance and results of the company.

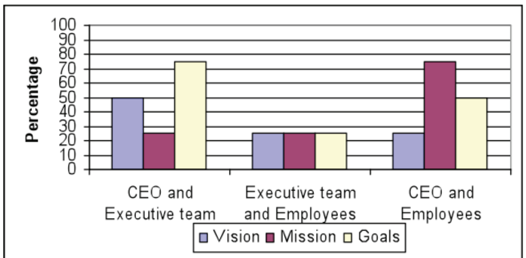

Figure 8: Alignment of strategic intent in cellar B

The alignment of the identified concepts between the different hierarchical levels appears in Figure 8. The alignment amongst all three hierarchical levels for Cellar B is: vision (25%), mission (25%) and strategic objectives (25%).The comparison of the CEO and employees maps reveals that the mission sections of the maps showed the most alignment. The most alignment amongst the CEO and the Executive team occurred amongst the strategic objectives section. The alignment of the vision was the highest between the CEO and Executive team members. It is evident that the CEO will have to focus on the communication and alignment of the vision, mission and strategic objectives amongst all the hierarchical levels. The alignment of the strategic intent amongst the three levels are very low probably because the CEO is more involved in operational rather than strategic management of the cellar.

4 Cooperative wine cellar C

From the comparison of the vision maps it became apparent that the communication and the alignment of the vision amongst the CEO and the executive team level is very high, but that the vision is not properly communicated to the employees by either the CEO or the executive team.

No single corresponding concept could be identified in the mission section of the maps of all three hierarchical levels. It seems as if there is considerable confusion on what the mission of Cellar C is. It became evident that the CEO's mission formulation focuses on the management of processes. The executive team's mission is more marketing related, while the employees are more quality and service orientated in the formulation of the mission. From a comparison of the mission maps it thus seems that there is confusion about the organizational mission and that it is not properly communicated or aligned except between the CEO and executive team level.

Figures 9 to 11 display the concept maps representing the organizational strategic objectives of the CEO, executive team and employees. The maps were carefully analyzed to determine the level of alignment of the strategic intent.

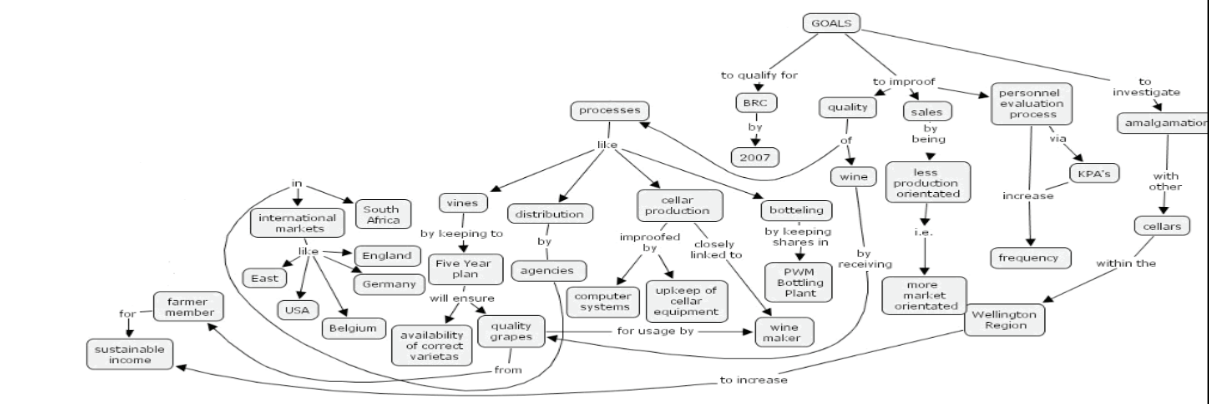

Figure 9: Strategic objectives section of cellar C's CEO map

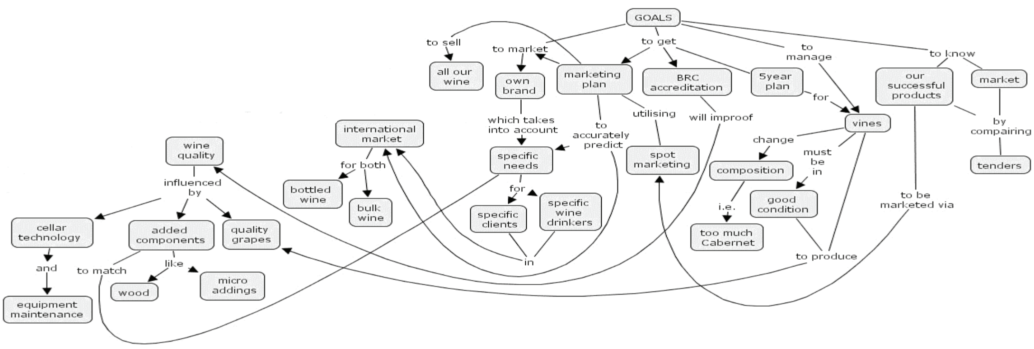

Figure 10: Strategic objectives section of cellar C's executive map

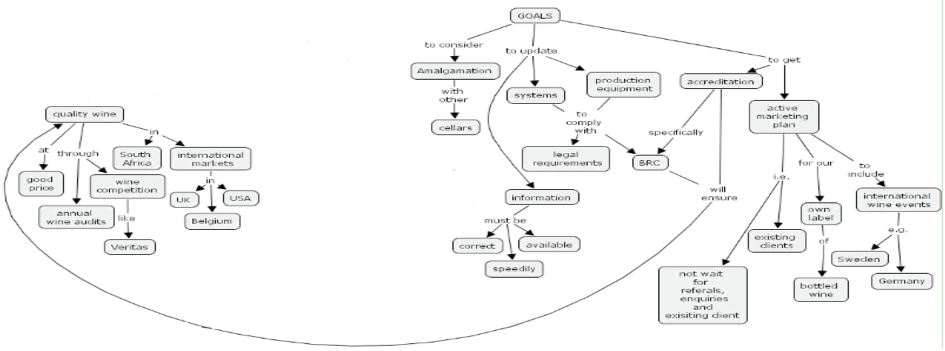

Figure 11: Strategic objectives section of cellar C's employee map

All three hierarchical levels identified "to get BRC accreditation" as part of the organizational strategic objectives. The CEO and executive team identified "to be more market orientated and not production orientated" and "to produce quality wine by managing and improving the production processes like focusing on viticulture, grape quality, and the winemaking process." Both the CEO and employee level identified "to consider amalgamation", while the executive team and employees identified "to get an active marketing plan". The CEO is the only level that identified "to improve the personnel evaluation process" and the executive team is the only level to identify "to know the market by comparing prices of accepted tenders." A comparison of the mission maps thus shows that the CEO does not communicate the organizational strategic objectives to all the hierarchical levels.

The alignment of the identified concepts per section of map between the different hierarchical levels is depicted in Figure 12. The alignment amongst all three hierarchical levels for cellar C is: vision (16.7%), mission (0%) and strategic objectives (20%). Amongst all three hierarchical levels, the strategic objective section of the maps obtained the highest percentage alignment. In the comparison of the CEO and employee maps, the strategic objective sections of the maps showed the most alignment. This was also the case for the comparison between the executive team and employee maps. The most alignment between the CEO and the executive team occurred in the vision section. The alignment of the vision was the highest between the CEO and executive team members and the lowest between the executive team and employee level. The CEO will have to focus on the communication and alignment of the mission amongst all hierarchical levels.

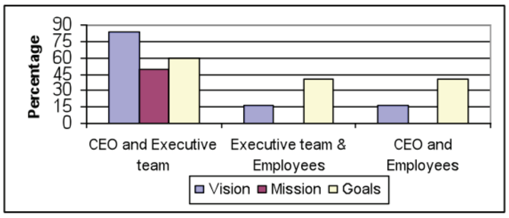

Figure 12: Alignment of strategic intent in cellar C

5 Cooperative wine cellar D

The same comparison of the vision, mission and goal maps of the CEO, executive team and employees were done for Cellar D and the results are summarized in Figure 13.The alignment amongst all three hierarchical levels for cellar D is: vision (50%), mission (16,7%) and strategic objectives (28,6%). Amongst all three hierarchical levels, the vision sections of the maps obtained the highest percentage alignment. For the comparison between the CEO and employees' maps, the vision sections of the maps showed the most alignment. This was also the case for the comparison between the executive team and employees' maps. The most alignment between the CEO and the executive team occurred in the strategic objectives section. The alignment of the vision was the highest between the executive team and employees. The worst alignment of the mission occurred between the executive team and employee levels. Communication and alignment of the mission amongst all the hierarchical levels thus need attention.

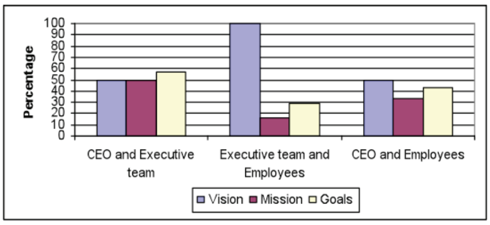

Figure 13: Alignment of strategic intent in cellar D

6 Cooperative wine cellar E

Again the alignment of vision, mission and objective maps of the CEO, executive team and employee were analyzed for Cellar E and the results are summarized in Figure 14. The alignment amongst all three hierarchical levels for Cellar E is vision (66,7%), mission (100%) and strategic objectives (0%). Amongst all three hierarchical levels, the mission sections of the maps were 100% aligned. From the comparison of the CEO and executive team maps, it became apparent that the vision and mission sections of the maps are 100% aligned, while the executive team and employee maps, as well as the CEO and employee maps, indicated a 100% alignment in mission. The alignment of the vision was the highest between the CEO and executive team. The worst alignment of the strategic objectives occurred between the executive team and employee levels. The communication and alignment of the vision between the executive team and employee levels and the CEO and employee level need attention, as well as the alignment of strategic objectives amongst the three levels as no single concept was identified amongst all three hierarchical levels. As strategic objectives serve as measurement and milestones of progress and also fulfill a motivational function, the CEO and executive team will have to focus on this.

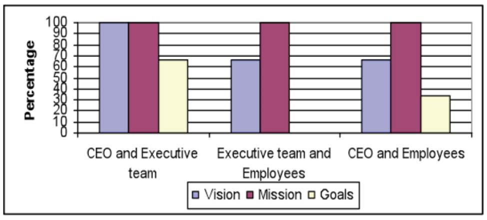

Figure 14: Alignment of strategic intent in cellar E

7 Comparative summary of alignment results

Figure 15 compares the combined results for the alignment of the vision, mission and strategic objectives for all the cellars, thus representing the current situation within co-operative cellars in the Paarl District. The highest alignment of the vision was 58,3% and occurred between the CEO and the executive team levels. The lowest alignment of the vision for the combined cellars was 33,3% and was measured amongst all three levels. The highest alignment of the mission for the combined cellars was 65,2% and was reached between the CEO and employee levels. The lowest alignment of the mission for the combined cellars was 47,8% as measured amongst the three hierarchical levels and the executive team and employees levels. The highest alignment of the strategic objectives for the combined cellars was 63% and was measured between the CEO and executive team levels. The lowest objective alignment for the combined cellars was 18,5% and was measured when measuring alignment amongst all three hierarchical levels. Only the alignment of the vision, mission and strategic objectives between the CEO and the executive team levels for the combined cellars all exceeded fifty percent. This clearly indicates that the communication and the alignment of the vision is the best between the CEO and executive team levels. This could be attributed to the close and frequent nature of the communication, work relationship and reporting structures for these two hierarchical levels. The highest alignment occurs in the mission section.

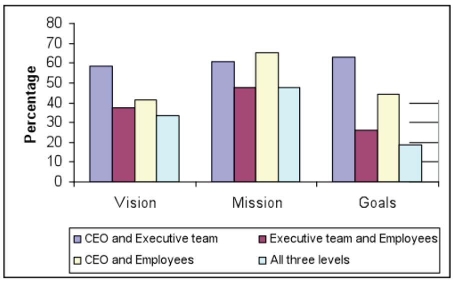

Figure 15: Comparison of combined results of the alignment of strategic intent for co-operative cellars

8 Conclusion

Based on study of the five wine cellars, as described above, the following major conclusions can be drawn:

- Serious alignment problems exist amongst the different hierarchical levels of the cellars' interpretation of the strategic intent as communicated in the vision, mission and strategic objectives. Interestingly, these alignment problems exist amongst all hierarchical levels, namely CEO and executive team, CEO and employees, and executive team and employees. Sixty percent of the cellars obtained less than fifty percent for the alignment of the vision. Eighty percent of the cellars obtained less than fifty percent for the alignment of the mission and all cellars obtained less than fifty percent for the alignment of the strategic objectives.
- The misalignment could mostly be attributed to a lack in visionary leadership and/or poor communication of the strategic intent.
- Concept maps are a valuable tool to visually represent the strategic intent of a business, namely vision, mission and strategic objectives. Participants found the construction of the concept maps extremely helpful in refinement of their own concepts around strategic intent. When the various maps were compared concept maps proved particularly useful in showing miscommunication and misperceptions of the strategic intent amongst the various hierarchical levels. It can thus be concluded that concept maps is a valuable tool in the alignment of business strategy by visually representing the strategic intent, alignment and misalignment amongst the identified concepts by different hierarchical levels of the organization. Concept maps can visually represent the complex and abstract nature of business strategy, making it easier to plan, describe, define, craft, communicate, implement and measure.

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TWO FIDDLES DON'T MAKE A STRADIVARI, BUT TWO MAPPERS ARE SOMETIMES BETTER THAN ONE: INDIVIDUAL AND COLLABORATIVE USE OF CONCEPT MAPPING AS A LEARNING STRATEGY IN SECONDARY LEVEL ECONOMICS AND BUSINESS EDUCATION[1]

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Abstract. Current research suggests that concept mapping and other forms of learner-generated graphical representations can be effective strategies for sustaining knowledge acquisition in various domains of learning. Moreover, contemporary scholars assume that the beneficial effects of these strategies might be increased if they are embedded within a collaborative learning environment. To further investigate these suggestions within the domain of economics and business education, an experimental study with 169 secondary level business school students was conducted. In this study, cognitive achievements of subjects from three treatment groups (text plus experimenter-provided graphic group, individually mapping group, and collaboratively mapping group) were contrasted. The results of this study indicate that learner-generated graphical representations are of specific use for promoting long-term retention of central text ideas. Furthermore, the collaborative learning setting is most profitable for students who can be considered as low-achievers in terms of prior economic knowledge.

1 Introduction

Subject-generated graphical representations such as concept maps, knowledge maps and mind maps do not only play a prominent role in sustaining knowledge management and performance in economics and business settings (e.g. Basque et al., 2004; Fourie, Schilawa & Cloete, 2004; Hampden-Turner, 1990) but are also receiving increasing interest with respect to educating people to become proficient in these domains. However, while in most of the research done here concept maps are used as a teacher-provided text adjunct or as an assessment device (e.g. Lawless, Smee & O'Shea, 1998), scholars in economics and business education have more recently begun to study concept mapping as a learning strategy for supporting the process of knowledge acquisition. This latter scope of application is the focus of the research study that will be presented in this paper. The purpose of the study was twofold: Based on the results of our prior research (e.g. Aprea & Ebner, 1999; Ebner & Aprea, 2002), our first intention was to further investigate the impact of learner-generated concept maps in the domain of secondary level economics and business education. Secondly, we sought to examine whether the effectiveness of these tools can be enhanced if they are embedded within a collaborative learning environment.

The paper on hand is organized as follows. In the next section, benefits and difficulties of using concept mapping as a learning strategy are delineated briefly, including a short justification of why collaborative map generation might be helpful in sustaining adequate strategy use. The method and the results of the study are then described. The paper ends with a discussion of the results and suggestions for future research.

2 Benefits and difficulties of using concept mapping as a learning strategy

Most of the inquiry pertaining to the use of graphical representations as a learning strategy is inspired by the ideas of Novak and his colleagues (e.g. Novak, 1998; Novak & Gowin, 1984), who invented the concept mapping technique. These authors highlight the constructive momentum of concept mapping in promoting what Ausubel (1963) has described as meaningful learning. In their view, student-generated concept maps are beneficial because they facilitate a reflective understanding of concepts and their relationships, and support deep and idiosyncratic elaboration of the material to be learned. Similarly, Weinstein and Mayer (1986) suggest that concept mapping may be of particular help for promoting cognitive processes such as organization and integration of incoming information. In our own research (e.g. Ebner & Aprea, 2002; Stern, Aprea & Ebner 2003), we - along with others (e.g. De Simone, Schmid & McEwen, 2001; Hanf, 1971) – additionally emphasize the metacognitive functions of generating a map. Based on an activity theoretical conceptualization of learning and instruction, we assume that 'modus transformation', i.e. the task of converting textual information into a graphical representation, not only helps students to focus their attention but also triggers planning and control processes, and thus supports self-regulation and learning. However, as with other learning methods, students' success in this kind of learning depends on the interaction of individual prerequisites (e.g. prior knowledge, motivation) and contextual factors (e.g. difficulty of text material, social organization of learning).

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With the adoption of concept mapping and other spatial learning strategies (e.g. Holley & Dansereau, 1984) in educational practice and research, much empirical work to investigate their impact has been conducted within the last three decades. These studies encompass different groups of learners (e.g. primary school children, high school students, adults) and are mainly located in the domain of science learning (e.g. Ault, 1985; Fraser & Edwards, 1987; Heinze-Fry & Novak, 1990; Novak & Musonda, 1991; Schmid & Telaro, 1990) but also in a variety of other fields such as teacher education (e.g. Beyerbach 1988) or (foreign) language acquisition (Chularut & DeBacker, 2004)[2]. The results of this research, including a meta-analysis by Horton et al. (1993), mainly confirm the supposed benefits of learner-generated maps. For instance, Barenholz & Tamir (1992) compared cognitive achievements of high school students (grades 10 and 11) who used mapping as a regular learning activity during the study of a new biology program with those of a non-mapping control group and found strong evidence in favor of the mappers. Similarly, other studies seem to indicate that concept mappers outperform learners who use alternative study techniques such as note-taking (Reader & Hammond, 1994) or outlining (Robinson & Kiewra, 1995). Moreover, some of the studies (e.g. Chularut & DeBacker 2004; Jegede, Alaiyemola & Okebukola, 1990) suggest that generating a graphical representation is not only advantageous in terms of cognitive learning outcomes but that learners seem to appreciate this strategy with respect to outcome variables that can be categorized as affect (e.g. anxiety, frustration, satisfaction), self-efficacy, and motivation.

However, apart from the delineated benefits of student-generated maps, the research literature is not conclusive and also reports some difficulties in using mapping as a learning strategy. For example, Lehman, Carter & Kahle (1985), in contrast to the above mentioned research, did not find any significant differences between students who used mapping strategies for biology learning and those who used outlining as a comparison study aid. The authors suppose that one reason that might have prevented success of the mapping group is students' (and teachers') lack of familiarity with spatial learning strategies. Thus, beginners are easily overwhelmed by the demands of the concept mapping task. This presumption is corroborated by several other studies (e.g. Reader & Hammond, 1994; Wandersee, 1988) and also reflects results that we have obtained in prior work (e.g. Aprea & Ebner, 1999). All in all, these findings give rise to the conclusion that there is no such thing as a 'concept mapping finger-tip effect', but that some form of scaffolding might be needed in order to ensure adequate strategy use. One way of addressing this need is to provide students with a mapping training. However, results of training studies, including our own research (e.g. Chang, Sung & Cheng, 2002; Ebner & Aprea, 2002), suggest that the success of this direct scaffolding method seems to be limited. At least for short time interventions, it proved helpful only for learners with high prior (domain and strategic) knowledge prerequisites. On the other hand, learners who do not already posses these prerequisites seem to need additional support. Given the current debate on the social construction of cognition and learning (e.g. O'Donnell, Hmelo-Silver & Erkens, 2006), one promising candidate for such an additional support is to embed the concept mapping task within a collaborative learning environment. For example, McThighe (1992) argues that this indirect form of scaffolding might enhance knowledge elaboration and metacognition mainly because it encourages students to expand their own points of view and helps to render the invisible processes of thinking visible. Similarly, Roth and Roychoudhury (1993) assume that collaboratively constructed maps may provide an ideal context for overt negotiation of meaning and construction of knowledge because they require individuals to externalize their propositional frameworks. Others (e.g. Nichols & Miller, 1994) have highlighted the motivational and affective support of collaborative learning. These suggestions concerning the collaborative use of concept maps seem to be supported by empirical research. For example, Basque & Lavoie (2006), who completed a concise review of research on collaborative concept mapping in education, conclude that "[c]ompared to individual CM or to other types of collaborative activities (e.g. producing an outline or a matrix representation) CCM has been found to be more beneficial for learning." In addition, this type of scaffolding seems to be particularly promising since some of the studies (e.g. Okebukola & Jegede 1988) indicate that collaborative map construction is specifically helpful for low level learners.

3 Method

The research reported in the former section raises the question of whether and to what extent the effects of individually and collaboratively generated concept maps might be transferable to the domain of secondary level economics and business education. In order to address this question, an experimental study – as one part of a larger research program (cp. Ebner & Aprea, 2002; Stern, Aprea & Ebner, 2003) - was carried out. The participants, design, materials, instruments and procedures of this study will be described next.

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[2] For an extensive review of the research literature on concept mapping and its various applications also see Cañas et al., 2003 as well as Nesbit & Adesope, 2006.

3.1 Participants and design

169 students from two urban secondary level business schools in Mannheim and Karlsruhe (Germany) participated in this study. They were completing their second year of a traineeship as bank employee (78 subjects) or as financial assistant (91 subjects), respectively. Fifty five percent of the students in the sample were female and the mean age was 20 years. Approximately one half of the students held a certificate of "Allgemeine Hochschulreife"[3], while the remainder had at least the so-called "Mittlere Reife".[4] In order to address the research issues mentioned, students were randomly assigned to one of the following three instructional treatment groups:

1. Subjects of the first group (text plus experimenter-provided graphic group; n = 52) received a text passage in combination with an already elaborated graphical representation. This experimental condition was intended to control for the general dual-coding effect of verbal and visual information provision (e.g. Clark & Paivio, 1991).
2. Subjects of the second group (individually mapping group; n = 59) received the same text passage without any visual adjunct. After a short mapping training (Aprea & Ebner, 2003) they were asked to individually read the text, identify the main ideas of the text and then to re-construct its content diagrammatically.
3. Like in the individually mapping group, subjects in the third group (collaboratively mapping group; n = 58) received a short mapping training and a text passage without any visual adjunct. They then were asked to first read the text alone and make a preliminary sketch. After that, they were requested to discuss their sketches with a learning partner and to draw up a shared concept map of the verbal information.

According to our assumptions, we hypothesized that the collaborative mapping treatment might lead to the best results in terms of cognitive learning outcomes, followed by the results of the individually mapping group and the results of the text plus experimenter-provided diagram group. Given the findings of our former studies (Aprea & Ebner, 1999; Ebner & Aprea, 2002), we additionally considered students prior economic knowledge as an important covariate.

3.2 Materials

In the study, the following materials were used: As instructional text, a passage of about 1.000 words was used. The passage dealt with the topic of environmental economics and introduced students to the core problem of external costs as well as to different principles and measures that national environmental policy can adopt against them. As far as content and style are concerned, the text was based on a currently available study book in business education. It was, however, condensed and modified in order to achieve more coherence. It contained 3 subheadings, but no other textual cues were given. For the text-plus-provided-graphic group, three expert-maps based on the text passage were developed. Out of these, one diagrammatical map was chosen and added to the text passage. The training materials for the two mapping groups consisted of the following components:

(1) *A list of steps that provides students with an algorithm of how to construct a map*: The conception of this algorithm has been inspired by a top-down mapping approach, which encourages students to first construct a gist of the text and then add relevant details.
(2) *A short text passage with a pre-made example map:* This text passage of approximately 170 words is supposed to illustrate the mapping procedure. It deals with different kinds and purposes of adverts in newspapers. The main idea and the central concepts are highlighted by bold print. From this passage, an example map was developed and printed on a separate sheet of paper.
(3) *A training text passage*: This passage consists of about 150 words and describes various forms and symptoms of inflation. In addition, the reader is informed about the distinction between causes and effects of inflationary phenomena. The text is a modified version of a study book passage. However, no further markings are given. None of the training materials contained information related to the test materials used for evaluation.

[3] Comparable to a senior high school diploma; German higher education entrance certificate.
[4] German intermediate high school certificate.

3.3 Instruments

In order to assess cognitive learning outcomes, an achievement test and a free recall test were used. The achievement test (*Knowledge Acquisition Test*; KAT) included six mixed-format (i.e. multiple choice and open-ended) questions. These questions mainly addressed detailed text recognition and encompassed content from the whole passage. As will be further described in the procedure section of this paper, the KAT was administered twice, namely immediately after the instructional treatments (subsequently referred to as KAT1) and approximately three weeks later (subsequently referred to as KAT2). For both test passes total sum scores were calculated. These sum scores took values between 0 and 9. Likewise about three weeks later, students were asked to write down all they could remember about the text content. This *free recall test* (FRT) was scored on the basis of a six degree rating scheme which ranged from "no recall at all" (= 0) to "very detailed and elaborated reconstruction of text content" (=5). All criterion measures mentioned before (i.e. KAT1; KAT2; FRT) were submitted to one-way ANOVAs and post-hoc tests, respectively. In addition to cognitive learning outcomes, students' prior economic knowledge was measured by using several items from the Test of Economic Literacy (TEL) (Soper & Walstad 1987). As with the KATs, total sum scores were calculated for these items. The sum scores for the TEL items ranged between the values 0 and 5.

3.4 Procedure

As already mentioned, the experiment consisted of two sessions. The first session lasted approximately 90 minutes, whereas the second session took about 45 minutes. At the beginning of the first session, students were briefly informed about the subject, duration and procedure of the experiment and assigned to the treatment groups. Students from the text-plus-diagram group were then asked to go to a separate classroom, whereas students from both mapping groups received the mapping training. The training consisted of the following steps.

(1) Initially, participants were briefly informed about the use and benefits of spatial learning devices for text comprehension and retention.
(2) Then, the advert text passage and the algorithm for applying the technique were handed out. Students were asked to start by skimming the single steps of the algorithm, to carefully read the text passage and then to imagine how a map might be constructed. After ensuring that each student had read the passage, the example map was administered to the students and they were invited to compare both representation formats. Additionally, the diagram was presented on an OHP transparency and the experimenter made some annotations indicating how it was created.
(3) Subsequently, students read the inflation passage. This passage was displayed on the OHP as well, and a concept map was constructed jointly according to the provided procedure. Finally, this map was compared to the text and alternative ways to see the meaning of the text were discussed. In addition, the experimenter pointed out to the students that at least one, sometimes two or three reconstructions of the map may be needed to show a good representation of propositional meanings as they understand them.

After the training activities the text passage and the corresponding task instructions were administered. Students were given 50 minutes to read the text and accomplish the task. As soon as the students had completed their respective instructional tasks, the experimenter marked the time on task, collected the text passages as well as students' notes and diagrams. Next the achievement test (in the following referred to as KAT1) was handed out. Approximately three weeks later, students were again asked to complete the achievement test (in the following referred to as KAT2). Furthermore, the free recall test (FRT) as well as the TEL-items were administered.

4 Results

A whole sample statistical analysis of the three criterion measures (KAT1, KAT2, and FRT) yields the following results (cp. Table 1):

- With respect to KAT1, only slight and statistically not significant differences between the treatment groups are identified, with the text-plus-graphic group in the first place followed by the collaborative mappers.
- In contrast, the hypothetical rank order is reflected by the data from KAT2 and FRT. In addition, post-hoc comparisons have revealed that collaborative mappers tend to outperform subjects from the text plus graphic group on the KAT2 ($p = .08$) as well as subjects from the individually mapping group on the FRT ($p = .10$), respectively. Furthermore, a significant effect ($\alpha = .05$) has been found for mean differences between the FRT scores of collaborative mappers and subjects from the text-plus-graphic group.

		KAT1			KAT2			FRT		
R^{exp}	**TG**	$M^{1)}$	(SD)	R^{emp}	$M^{1)}$	(SD)	R^{emp}	$M^{2)}$	(SD)	R^{emp}
1	**Collaboratively mapping group**	4,78 (n = 58)	(2,16)	**2**	4,08 (n = 49)	(1,91)	**1**	2,14 (n = 49)	(1,19)	**1** s*
2	**Individually mapping group**	4,63 (n = 59)	(2,21)	**3**	3,63 (n = 51)	(2,02)	**2**	1,76 (n = 50)	(1,27)	**2**
3	**Text + graphic group**	4,85 (n = 52)	(2,24)	**1**	3,37 (n = 46)	(1,82)	**3**	1,65 (n = 46)	(1,02)	**3**

Tab. 1: Mean test scores, standard deviations and empirical rank orders (whole sample)

KAT = Knowledge Acquisition Test
FRT = Free Recall Test
R^{exp} = Expected rank order (according to hypotheses)
R^{emp} = Empirical rank order (according to data)

1) Note that KAT 1 and KAT 2 could take values between 0 and 9.
2) Note that FRT could take values between 0 and 5.

The picture changes somewhat if one differentiates the sample with respect to prior economic knowledge as indicated by the Test of Economic Literacy (TEL) items. The results for subjects with high prior economic knowledge (i.e. TEL-scores of 4 or better) are displayed in Table 2.

- With respect to KAT1, individual mappers with high prior knowledge significantly outperform subjects from the collaborative mapping group (α = .05). Furthermore, they tend to achieve higher scores on this criterion measure than the text-plus-graphic group (p = .07).
- Regarding the KAT2, individual mappers with high prior knowledge come first again, followed by the collaborative mapping group. None of the mean differences proved to be significant, however.
- As regards the FRT, the empirical rank order in the high prior knowledge subgroup shifts in favor of collaborative mapping for the first and the provided graphic treatment for the second place, but as with the KAT2 no significant effects were found.

		KAT1			KAT2			FRT		
R^{exp}	**TG**	$M^{1)}$	(SD)	R^{emp}	$M^{1)}$	(SD)	R^{emp}	$M^{2)}$	(SD)	R^{emp}
1	**Collaboratively mapping group**	5,20 (n = 10)	(1,99)	**3** s*	4,40 (n = 10)	(2,50)	**2**	2,30 (n = 10)	(1,70)	**1**
2	**Individually mapping group**	6,91 (n = 11)	(1,30)	**1**	4,55 (n = 11)	(1,92)	**1**	1,91 (n = 11)	(1,51)	**3**
3	**Text + graphic group**	5,43 (n = 7)	(1,62)	**2**	3,57 (n = 7)	(1,81)	**3**	2,00 (n = 7)	(1,29)	**2**

Tab. 2: Mean test scores, standard deviations and empirical rank orders (high prior economic knowledge)

KAT = Knowledge Acquisition Test
FRT = Free Recall Test
R^{exp} = Expected rank order (according to hypotheses)
R^{emp} = Empirical rank order (according to data)

1) Note that KAT 1 and KAT 2 could take values between 0 and 9.
2) Note that FRT could take values between 0 and 5.

For subjects with low prior economic knowledge (i.e. TEL-scores of 2 or worse), the data show a strong trend in favor of the collaboratively mapping group. In particular, the following results are obtained (cp. Tab. 3):

- With respect to KAT1, collaborative mappers with low prior knowledge tend to achieve higher scores than the text plus graphic subjects and significantly outperform the individual mappers (α = .05).
- However, the relationship between individual mappers and text-plus-graphic subjects turns around with respect to KAT2 and FRT. Moreover, post-hoc comparisons have demonstrated that low prior knowledge

collaborative mappers tend to achieve higher KAT2 scores than subjects from the text-plus-graphic group ($p = .08$), and significantly excel this group on the FRT ($\alpha = .05$).

		KAT1			KAT2			FRT		
R^{exp}	TG	$M^{1)}$	(SD)	R^{emp}	$M^{1)}$	(SD)	R^{emp}	$M^{2)}$	(SD)	R^{emp}
1	**Collaboratively mapping group**	4,70 (n = 27)	(2,11)	1 (s* with 3)	3,81 (n = 27)	(1,39)	1	2,07 (n = 27)	(0,92)	1 (s* with 3)
2	**Individually mapping group**	3,42 (n = 24)	(2,22)	3	3,21 (n = 24)	(1,98)	2	1,88 (n = 24)	(1,30)	2
3	**Text + graphic group**	4,00 (n = 30)	(2,32)	2	2,97 (n = 30)	(1,63)	3	1,43 (n = 30)	(0,86)	3

Tab. 3: Mean test scores, standard deviations and empirical rank orders (low prior economic knowledge)

KAT = Knowledge Acquisition Test
FRT = Free Recall Test
R^{exp} = Expected rank order (according to hypotheses)
R^{emp} = Empirical rank order (according to data)

1) Note that KAT 1 and KAT 2 could take values between 0 and 9.
2) Note that FRT could take values between 0 and 5.

5 Discussion and suggestions for future research

With respect to secondary level economics and business education, the study on the whole does not show that concept mapping generally enhances students' cognitive achievements: The data only partly reflect the expected effects. However, the results seem to reveal an important relationship between the specific modalities of concept mapping on the one hand and learning outcomes as well as prior knowledge on the other. Thus, a more refined perspective on the operating conditions of concept mapping within our field of application might be needed. On the basis of the data, at least three directions for such refinements seem to be evident:

1. Firstly, the results yield the presumption that students who can be considered as high-achievers in terms of prior economic knowledge seem to profit most from an individually concept mapping task. In contrast, collaboration seems to be particularly helpful in supporting students with low pre-test scores. From these findings, which again confirm the substantial influence of prior domain knowledge on learning with concept maps (e.g. Chularut & DeBacker, 2004), it can be recommended to differentiate concept mapping assignments with respect to learner characteristics. As the results of van Boxtel (2007) suggest, further investigations within this strand of refinement might include studies that contrast the concept mapping task with a task that involves generation of analogues drawings since these drawings seem to be easier for low-level learners to construct.
2. Secondly, the results indicate that concept mapping in secondary level economics and business education seems to be of specific use for promoting long-term retention of central text ideas, whereas no such effect with respect to detailed text recognition could have been found. In accordance with researchers of learner-generated graphical representation in other domains (e.g. Lee & Nelson, 2005; Van Meter et al. 2006), we therefore deem it necessary to differentiate the effectiveness of concept mapping tasks with respect to intended learning outcomes. Following this line of argumentation, we plan to extent the quite simple outcome measures and to prospectively include more complex outcome variables such as problem-solving and strategy learning.
3. Thirdly, along with De Simone, Schmid and McEwen (2001) we feel that in order to gain a deeper understanding of the 'driving forces' and the specific benefits of concept mapping within our domain, we need to study in more depth the learning processes that are associated with the various treatment conditions.

Apart from the need for a more sophisticated account of learning with concept maps within secondary level economics and business education, analyses of the learner-generated graphics as well as informal conversation with the participants give rise to the assumption that many students are still not sufficiently accustomed and/or inclined to generate graphical representations. Thus, additional long-term training efforts as well as efforts to ensure an authentic and motivating instructional embedding of the concept mapping task are needed. We hope to achieve both these aims by extending the experimental studies by means of a design-based research approach.

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UNDERGRADUATE STUDENTS' ATTITUDES TOWARDS PHYSICS AFTER A CONCEPT MAPPING EXPERIENCE

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Abstract: Concept maps were first developed in the early 1970's as a data analysis tool. Since their introduction by Novak and his research team, they have been widely used for many purposes, including eliciting knowledge and evaluation of conceptual understanding. This paper highlights the benefit of Concept Mapping and describes the use of concept maps as a tool to improve students' attitudes towards physics in third level education. The fundamental question addressed is "do students' attitudes towards physics improve after an experience with Concept Mapping?" Concept maps were developed by students three times throughout the college semester. The students were then asked to complete a post-questionnaire to facilitate the determination of the effects the instructional tool had on their attitude towards physics and their learning. Qualitative and quantitative analysis of student maps was conducted to measure change in knowledge structure and also to examine the effects of students' attitudes on their cognitive development.

1 Introduction

Concept Mapping was originally developed by Novak and his research group as a means of representing frameworks for the interrelationships between concepts (Novak & Gowin, 1984). The philosophy upon which this new thinking is based is David Ausubel's theory of meaningful learning (Ausubel, 1968). Ausubel initiated the constructivist theory, which holds that students are not "vessels to fill" with ideas, but that they produce and develop their own knowledge with an active process. This knowledge is then structured and stored in "semantic maps" (Colli *et al*, 2004) that are constructed and restructured every time students learn new knowledge. Individuals are encouraged to relate new knowledge to relevant concepts and propositions they already know. To engage in meaningful learning students must identify specifically relevant concepts and recognise non-arbitrary relationships between the concepts (Bascones & Novak, 1985). The underlying technique involved is tying new knowledge to relevant concepts and propositions already possessed (Austin & Shone, 1995).

Concept maps have been defined as two-dimensional, hierarchical, node-linked diagrams that depict verbal, conceptual, or declarative knowledge in succinct visual or graphic forms (Quinn, Mintzes & Laws, 2004; Horton *et al* 1993). The maps provide a representation of knowledge and hence can be used to infer accuracy and depth of knowledge. In order to be effective, instructional concept maps should contain enough important concepts to characterize the subjects that are being represented (Schau & Mattern, 1997).

The concept maps have several components that as a whole represent the student's knowledge on a specific topic. The fundamental component of every concept map is the concept (node). Concepts are defined as "perceived regularities in objects or events that are designated by a sign or symbol" (Novak, 1991). They are generally isolated by circles and connected with lines (linking lines). These lines are labelled with "linking phrases", which describe the relationship between the two connected terms. The smallest unit of meaning of the concept map must contain two concepts and a linking phrase which is then identified as a "proposition". The process of constructing a concept map is a powerful learning strategy that forces the learner to actively think about the relationship between the terms. This makes Concept Mapping especially suited to studying science as the learner may perceive that studying science means simply memorizing facts (Dorough & Rye, 1997). Concept maps also allow the students to display concepts in both a horizontal and vertical fashion, thus facilitating the process of understanding interconnections and meanings in the map. Vertical linkages display how students differentiate concepts and the horizontal linkages display how the students connect and relate different areas of the topic.

Most of the studies conducted on the subject of Concept Mapping have been concerned with the use of the tool with instruction and assessment (Stoddert, 2006; Cassata *et al*, 2004; Ruiz-Primo & Shavelson, 1996; Austin & Shone, 1995; Horton *et al,* 1993). The tool has being used widely in primary and second level education, however very little in tertiary science education. Our research employed the Concept Mapping technique for studying the attitudes of third level physics students. We experimentally demonstrate the positive effects Concept Mapping has on the students' attitude towards physics.

2 Attitudes towards Physics

A plethora of research has being carried out in recent years concerning attitudes toward science/physics and the relationship between these attitudes and science achievement (Gungor *et al*, 2007; Papanastasiou & Zembylas, 2002; Reid & Skyabina, 2002). Several factors have been highlighted as main contributors to the negative attitudes that students possess towards the science subjects. These factors are related to school and science classes; the individual and even external factors relating to the status and rewards that different countries bestow onto physics-based careers (Woolnough, 1994).

For the purpose of this paper, attitude is defined as the favourable or unfavourable response to things, places, people, events or ideas (Koballa, 1995). In Ireland, students' attitudes towards physics have declined increasingly over the last two decades with the popularity of Leaving Certificate Physics declining from 21% to 15% since 1985 (Central Statistics Office). Students who decide to continue their studies in the field of physics are further hindered by the high drop-out rates within the discipline. Within the universities in the Republic of Ireland 22.2% fail to graduate in science courses, compared to 7.1% in the Law domain (Flanagan et al, 2001). Since only those students who take physics at senior level in secondary school and subsequently third level are eligible to pursue careers in the discipline, concerns have been raised about the nation's economic future.

To combat the negative attitudes towards physics and the enduring problem of high drop-out rates with physics courses new initiatives must be implemented into the classroom. Tinto, 2003 highlighted five conditions to help promote persistence within a course; expectations, support, feedback, involvement and learning. With the integration of these five conditions into the classroom the attainment of the students can be maximised. This paper highlights how the inclusion of Concept Mapping can offer the opportunity to integrate these five conditions into a physics classroom thus developing the students' knowledge and improve their attitudes towards physics.

3 Empirical Study

3.1 Profile of the Study Participants

This yearlong study was implemented during the academic years 06/07 and 07/08 in the University of Limerick. The study began in the spring semester of 06/07 and continued to the autumn semester of 07/08. During this period of time the students were enrolled in two physics modules; Light and Sound (Phase 1) and Electricity and Magnetism (Phase 2) respectively. Both modules were taught over a 15-week semester.

This study began with a cohort of eighty-eight first-year undergraduate students during phase 1 and dropped to seventy-nine in phase 2 as a result of non-completion. The cohort of students included a wide variety of abilities with students representing two courses; one for teachers of biological science and the other for teachers of physical science. Within this research group 75% of the students have not studied physics in school at senior level for the Leaving Certificate exam; hence have very little experience of the subject. Prior to this study the group completed one module in physics, Mechanics and Heat. As a result each student in the group possess a system of beliefs and intuitions about physical phenomena derived from extensive personal experience (Halloun & Hestenes, 1985). It is from these experiences that students develop a cognitive structure which may be valid, invalid or incomplete (Hanley, 1994). The learner will formulate existing physics structures only if new information or experiences are connected to knowledge already in memory.

3.2 Instructional Method

The instructional method employed during this study was based on the constructivist approach developed from Ausubel's theory of learning. The author believed that students must be active participants and engaged in their own learning in order for meaningful learning to occur.

This study was designed to be non-disruptive. The students were not assigned any extra hours during the week, with their weekly timetable consisting of 2 one-hour lectures, 1 one-hour tutorial and a two-hour lab session. Students were assigned into groups during their tutorials to promote well functioning groups. Roles of responsibility were allocated to students during problem solving, where typical roles included chair, timekeeper and a scribe.

At the onset of this research the students were given an intensive training course on the construction of concept maps. The training course included three components; 1) a PowerPoint presentation detailing the essential components of a map, 2) construction of concept maps both cooperatively and individually and finally 3) a discussion on the tool. Prior research indicates that Concept Mapping can be easily and quickly taught to students and that once taught, the techniques can be used with larger groups with minimal assistance from teachers (Quinn *et al*, 2004; Wallace & Mintzes, 1990)

For the purpose of this study concept maps were also used as "advance organisers" (Willerman & Harg, 1991). The concept maps were constructed by the researcher and presented to the students at the beginning of each new topic accompanied with an explanation of the relationships between the concepts. The maps provided the students with a greater direction for learning and a reference from which they could work from.

3.3 Data Collection

This study is of mixed method research design (Creswell, 2003). Data collections included students' concept maps and end of research questionnaires. During the course of the study students were asked to construct three concept maps individually. These maps were constructed during week 3, 7 and 11 of the semester. The level of direction provided to the students varied with each task (Ruiz-Primo, 2004). For each map the students were encouraged to make a list of all concepts that they believed important in the topic and to then generate a concept map linking these terms to form propositions.

Pre- and post-questionnaires were administered during phase 1 with only post-questionnaires administered during phase 2. The pre-questionnaire contained four parts; personal information, Concept Mapping training session, Concept Mapping instruction and finally the impact of Concept Mapping on the students learning. The post-questionnaire questions focused on examining the effect the tool had on students learning and whether or not their experience affected their subject choice for their degree.[1]

3.4 Data Analysis

A wide range of methods of scoring maps exist. The approach to concept map scoring employed in this study represents a distinct departure from traditional methods. In the past scoring of maps focused on characteristics such as hierarchy and branching (Novak & Gowin, 1984) however in this study the scoring system focused on the degree of accuracy of the relationships described in each propositions.

The concept maps were analysed using a criterion/expert map. The criterion map (Figure 1) for each phase of research was constructed by the author specific to the module and course outline. The propositions included in the maps were specific to the objectives set out in the module. Throughout the data collection, the students never saw the criterion map. A scoring rubric was generated where a three-point coding system was developed for propositions such that a correct link guaranteed a code 3, propositions that represented a lack in appreciation was coded 2 and links with no labels was awarded a code 1. In this study the principle underlying the development of a scoring rubric was that concept map scores should reflect the degree to which students mastered the expected learning outcomes. The maps were graded to examine the development of student knowledge throughout the course of the study, and were based on the number of correct propositions within the map. The students' attitudes towards physics were assessed using the questionnaire where they were asked both closed and open-ended questions to measure a change in their attitude, if any. (Figure 2)

After completing this Physics module, how do you feel about Physics in general?

____

Has you attitude towards physics: Improved
Disapproved
Remained unchanged?

Explain your answer:

____

____

Figure 2: Question used in post-questionnaire to determine if there was a change in attitude after the Concept Mapping experience.

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[1] The biological science students participating in this study were required to select a science major (Physics or Chemistry) at the end of their first year of undergraduate study

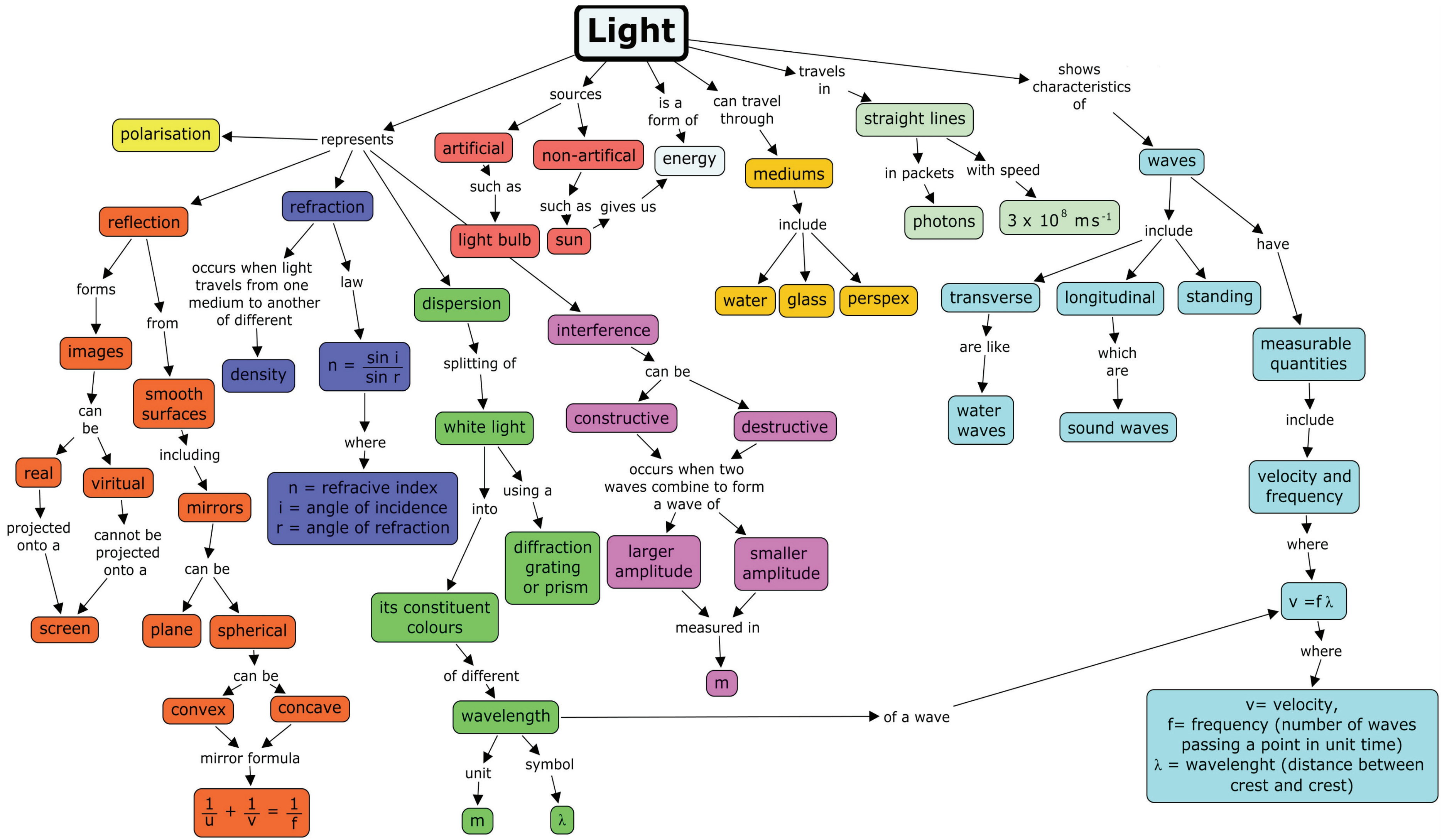

Figure 1: Criterion Map developed by the author on the concept of "Light" which was used during Phase 1 to score the students' maps.

4 Results

4.1 Effect of Concept Mapping on Students Attitudes

These results focus on research carried out over two semesters, each containing a phase of study, during which the students were enrolled in two undergraduate modules; Light & Sound and Electricity & Magnetism respectively. When asked to complete the questionnaire following their year-long experience of Concept Mapping, 59% of the cohort stated that they agreed that their attitude towards physics had improved after their experience, Table 1.

	Improved	Disimproved	Remained Unchanged
Phase 1 - Light and Sound Spring Semester 06/07	62%	7%	31%
Phase 2 - Electricity and Magnetism Autumn Semester 07/08	59%	8%	33%

Table 1: Students Attitudes towards Physics after Concept Mapping

Statistical analysis was carried out to determine if the results gathered in the change in attitudes were significantly different. In order to evaluate the data independent tests had to be carried out as there was a large difference in the number of students who completed the questionnaire following the second phase. There was not a significant difference in the percentages, ($p > 0.05$). However it must be stated that 62% of the students believed that their attitudes towards physics improved after their first experience of Concept Mapping.

The students were asked to expand on why they believed their attitude improved / disimproved / remained unchanged. Table 2 represents responses to the open-ended question.

Improved	Disimproved	Remained Unchanged
▪ I enjoy it more working with the maps, more interesting. ▪ Tutorials make it easier to understand because we could see how to connect up theory and equations. ▪ It was interesting; it's good to have something to look at rather than notes. ▪ I find it easier to understand and I find the calculations much easier to work out, I can see where the equations fit in. ▪ I always liked physics until the L.C results and now I'm starting to like it more (Got an E in the LC) ▪ At the start of the year I felt that physics was impossible, now although I still find it difficult I enjoy it. ▪ I am more interested in it now, before I just learned stuff off for the exam but now I'm actually interested. ▪ I never thought I would like physics because I am not very maths orientated but now I find it interesting. ▪ Maps make it look less complicated, they explain it better.	▪ The lectures put me off studying so I didn't try hard enough. ▪ The other physics module we are doing now is really turning me off physics (Modern Physics)	▪ I am no better or worse at physics this year than last year. ▪ It's still difficult. ▪ I always thought physics was alright, I can do it if I study. ▪ I still find it difficult to learn from the lectures but the tutorials help to put things into practice. ▪ I have not got a great interest in it, didn't do it for the Leaving Certificate. ▪ Still feel the same about physics, maybe would like it more if I studied it for the Leaving Certificate

Table 2: Sample responses on the effect Concept Mapping had on Students Attitudes

Within the questionnaire students were asked to comment on the use of concept maps in the physics classroom and to declare whether or not they believed them to be beneficial. Student responses were extremely positive and several students suggested that they would use the tool during their teaching practice. The following represents a sample of responses to the question “Do you feel that Concept Mapping is beneficial in the physics classroom?”

- Yes because it is a good form of revision and gives pupils an easily remembered chart.
- Yes because it is a good way of revising and reflecting on what you know
- Yes because it makes you gather your thoughts and link ideas together.
- Yes because it helps you piece all the concepts together and make sense of them.
- They are good visual aids
- Yes because you can link formulas, theory and diagrams together to see their relationship.
- Yes it helps join what you learn in tutorials and lectures
- Yes it helps in brainstorming
- Yes as it makes linkages between different aspects and topics
- Definitely because it provides a summary that is easy to read
- Yes because it connects prior and new knowledge
- Yes because it allows you to lay out everything you know on a topic and you will have it for revision.

4.2 Effect of Concept Mapping on Students Cognitive Development

The students’ cognitive development was evaluated based on the individual concept maps. Due to the large cohort in this study a sample of maps were chosen to facilitate appropriate analysis and evaluation. In order to include a sample of mixed abilities ten student maps were chosen at random. The author ensured that from the sample group analysed the ratio of male to female was 1:1. Table 3 represents the percentage scores the students achieved in their maps over the two semesters. Sex of the students has being identified as male (M) and female (F).

	PHASE 1			**PHASE 2**		
Student	Map 1 (%)	Map 2 (%)	Map 3 (%)	Map 1 (%)	Map 2 (%)	Map 3 (%)
A (F)	5	18	28.5	6	18.5	35
B (F)	10	15	25	8	16.5	25
C (F)	12.5	14	20	12	17.5	30
D (M)	11	41	49	19.5	16.5	36
E (M)	14	20.5	41	14	15	26
F (F)	12.5	16	29	2.5	15.9	33
G (M)	9	9	28.5	5	16.5	25
H (M)	14	19	31	7	19	24
I (F)	3.5	20	28.5	11	28	25
J (M)	12	14	37.5	12	28	41

Table 3: Concept Map scores for both phases

5 Conclusions

The relationship between Concept Mapping and attitude towards physics was explored for a group of college science education students over two semesters. The main findings from this year-long study suggest that there is a strong indication that students’ attitudes towards physics improve after working with and experiencing concept maps. Following their experience of the tool 59% of the students stated that their attitude towards physics improved, with 8% stating it disimproved and 33% of the students identifying that their attitude remained unchanged. Those students whose attitude disimproved had not studied physics at Leaving Certificate level. From those students who believed their attitude remained unchanged, only one had studied physics at Leaving Certificate. It may then be argued that the students’ attitude towards physics improved because of the incorporation of Concept Mapping into the modules as all those whose attitudes improved had not studied physics at Leaving Certificate; their only experience of physics prior to this study was their first year module Mechanics and Heat.

The second finding that emerged from this study is that the improvement in cognitive development, as can be seen in the map scores, is not directly related to the reported improvement in attitudes. From the ten sets of student maps analysed there was an increase in the cognitive development, irrelevant to the students' attitude towards physics. Statistical analysis was carried out on student map scores and results indicate that there was a significant difference in map 1 and map 3 scores for both phases, ($p < 0.05$).

Further analysis of the questionnaire reveals that students believe Concept Mapping is very beneficial in the physics classroom and that they will use the tool themselves during their own teaching practice. They felt that it would be a very "useful resource that could be used summarising classes or as a study aid". Students also expressed concern about time constraints. Some felt they could not give it enough time to construct the maps during the half hour session, 'It took a lot of work, with making a list of concepts first and then drawing the map". The author could not afford to give the students any more time to construct the maps as it would take from their scheduled tutorial times. Providing the students with the concepts is a possible solution to this and would provide the student teacher with further opportunities to develop their mapping skills and hence their teaching abilities.

This paper's preliminary findings suggest that the Concept Mapping method employed is effective in increasing students' attitude towards physics in third level, providing beneficial teaching and learning opportunities to student teachers. This study presents initial investigations in the field and research is ongoing, with a much more data available which have not et received analysis. Further work into quantifying the effect of Concept Mapping on the development of student's cognitive knowledge is at hand.

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USE OF THE CMAPTOOLS RECORDER TO EXPLORE ACQUISITION OF SKILL IN CONCEPT MAPPING

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Abstract. This article presents results from a study that explored skill acquisition in computer-mediated concept-mapping by Panamanian schoolteachers being trained at the Conéctate Project. The CmapTools Recorder was used for the first time as a research tool, and provided copious information concerning the human-machine interaction taking place during Cmap construction. Subjects were found to greatly emphasize form over content: most of their efforts were directed towards moving objects, experimenting with styles, and making relatively inconsequential alterations to text which had no substantial effect on meaning. Moreover, the probability of significantly altering a concept once it had been placed in a Cmap was computed and found to be quite slim, suggesting little rethinking of ideas. All of these results held true independently of level of computer expertise. Such behaviors are consistent with what would be expected from rote learners who begin training in concept mapping.

1 Introduction

Since the development of concept maps in the early 70's, a vast body of research on their use and impact in educational settings has accumulated. This research has provided much evidence that concept mapping can indeed support meaningful learning in many different ways (Coffey, et al., 2003; Novak & Cañas, 2006; Novak & Gowin, 1984, Ch. 2). And yet, aside from the fact that effective concept mapping requires time and practice (Lin, Strickland, Ray, & Denner, 2004; Pankratius, 1990; Wandersee, 2001, pp. 135-137), little else is known about how learners actually acquire this skill. To the best of our knowledge, no formal studies have expressly investigated this question, though anecdotal information has been collected and in some cases has been published (e.g., Pines et al., 1978).

The time required for learners to become proficient concept mappers and thus be able to accurately represent their knowledge and understanding of a topic in a concept map is also unknown (Coffey et al., 2003). Pankratius (1990) considered the 8-week period of his study too short. Novak et al. (1983) concluded that after more than five months experience, more than half the students participating in their study still did not master the strategy. Novak (in Pankratius, 1990) recommended as long as six months to master the skill.

Evidently, attention needs to be paid to the concept mapping training phase. This article is based on a research program that explored the question of skill acquisition in computer-mediated concept mapping. Progress in skill acquisition was measured along three dimensions, one pertaining to Cmap[1] *construction process*, and the other two to *completed* Cmaps. This article reports on findings with respect to the first dimension, namely, the human interaction with the concept mapping program CmapTools (Cañas et al, 2004), and gathered via the CmapTools Recorder.

2 Cmap construction process data

Educational researchers (e.g., Kozma, 2001; Siegler & Crowley, 1991) have pointed out that understanding cognitive changes requires going beyond the products of educational interventions to examine the processes that led to these products. With regard to concept mapping in particular, this was pointed out by Dutra, Fagundes & Cañas (2004), who note that in spite of the voluminous amount of research on concept maps, "there is a need for studies that consider the mechanisms involved during the construction process" (p. 218). Our work took advantage of the development of the CmapTools Recorder, which afforded us the possibility to observe and analyze many details of the human-machine interaction that occur during Cmap construction. This in turn provided an opportunity to gain a better understanding of cognitive processes taking place in our subjects while acquiring skill in concept mapping.

2.1 CmapTools Recorder and log files

The CmapTools Recorder is a relatively new feature of CmapTools. It generates a record of every action taken by the user in the process of constructing his or her Cmap. The entire recording can be played back, thereby

[1] The term "Cmap" is used to refer specifically to computer-mediated concept maps.

giving a visual reconstruction of the Cmap creation process. Simultaneously, the Recorder generates a text log file that can be imported into a spreadsheet or statistical analysis package for data processing.[2]

The Recorder logs include eight different data categories of which two are particularly relevant in trying to understand the events that take place during Cmap construction: action type and entity type. Action type refers to the actual operation carried out (adding, deleting, moving, modifying text, etc.), whereas entity type refers to the object upon which that operation was performed (concepts, linking phrases, connecting lines, and Cmaps, principally). Since we were interested in being able to trace simultaneously both the action performed and the entity upon which it was performed, we concatenated the data in these two categories into a single new *entity-action* category. For simplicity, however, we will refer to this combined category as the *action type* category.

Within the action type category we focused on the 9 mechanical operations considered most necessary to create a reasonably good Cmap: *concept addition*, *concept text modification*, *concept deletion*, *linking phrase addition*, *linking phrase text modification*, *linking phrase deletion*, *object movement*, *styles addition*, and *resource addition*. Most of these are self-explanatory; however, two require some clarification. First, concept and linking phrase text modification refer to writing actions within concept and linking phrase boxes, respectively, regardless of whether text is being modified or written for the first time. Second, concerning linking phrase addition it should be noted that linking phrase boxes appear automatically whenever two existing concepts are joined. The process of joining two concepts requires a certain amount of care, though. If not done carefully, one might end up either moving a concept box or creating a new one.

3 Methods and procedures

Subjects for this study consisted of in-service Panamanian public elementary schoolteachers participating in the Conéctate al Conocimiento Project (Tarté, 2006), where they are being trained in concept mapping as a means to foster meaningful learning. Workshops at Conéctate last for 2 consecutive weeks. The first week is devoted almost exclusively to concept maps, while the second week focuses on collaborative projects, using concept maps as a tool to plan, organize, and make public these projects. The first concept map is usually created on day 1 using pencil and paper. CmapTools is introduced, and the first computer-mediated Cmap is created, on day 2, when teachers are deemed to be less apprehensive about the workshop. From then on, all[3] other concept maps are constructed using CmapTools. The study at hand recorded and analyzed the first and last Cmaps. The first map was constructed individually in all training groups, and with the exception of 4 groups, the topic freely chosen by the teachers.[4] The final map was individually constructed and free-topic for all 18 training groups.

The initial Cmap gave us a sense of teachers' starting point and served as baseline against which skill acquired in the course of the workshop was measured; comparison with the final Cmap allowed us to determine progress during the workshop. While teachers were engaged in building these two Cmaps, facilitators were required to abstain from providing any help concerning Cmap structure or content. Facilitators could offer comments and suggestions for Cmap improvement only *after* the completed maps had been saved. However, questions or problems concerning the use of the computer itself and/or the software program could be answered during Cmap construction.

Several factors limited the scope of our work. First, subjects represent of a fairly restricted universe: Panamanian teachers from public elementary schools. This population may well have a great deal in common with elementary schoolteachers in other countries, particularly, underdeveloped countries with similar educational systems; in general, though, care must be taken in extrapolating results to other populations. Secondly, our setup was quasi-experimental. We had no control over the way schools were chosen to be included in the Project, or over the way participating teachers were grouped. Furthermore, different training groups were exposed to different facilitators, and once again we had no control over the assignment process. And thirdly, the two concept mapping tasks we analyzed were "one-shot deals." It would have been preferable to have been able to follow the evolution of teachers' concept maps over the course of two or more sessions, rather than a single map-construction session; however, this would have required facilitators not to offer teachers any feedback, which evidently was not an option given the purpose of the workshops.

[2] All the data gathered during the course of our studies were processed using a combination of Excel and STATA.
[3] The only exception is a team map created using paper cards for concepts and linking phrases, and wool string for connecting lines.
[4] These training groups based their first Cmap on an assigned reading.

4 Results

A total of 350 teachers in 18 training groups participated in the study. Ultimately, though, the set of teachers for whom recordings of their first and final Cmaps were available was reduced to 258. Thus, our sample contained 516 Cmaps, half corresponding to the initial Cmap and half to the final one. Teacher background information confirmed earlier data by Miller, Cañas & Novak (2006). By and large, schoolteachers in Panama are familiar with concept maps (97%). However, most of them have misconceptions regarding their correct structure and usage, and thus work with them in ways that tend to reinforce rote learning modes. For instance, a majority (72%) of teachers either give students concept maps they themselves have built or build them in class, with some student input, and then ask students to memorize these "correct" maps for their exams. When using concept maps as an evaluation tool, most teachers (68%) provide partially-filled-in structures and asked students to fill-in blanks from a given list or from memorized concepts, linking phrases or both. These facts are perhaps not too surprising given the prevalence of rote learning among Panamanian schoolteachers themselves, as reported by the National Council on Education (Consejo Nacional de Educación [CONACED], 2006).

Previous experience with computers was an important variable to control for. Assuming that greater experience corresponds to higher frequency of use, and considering the possession of an e-mail account as indicative of frequent use, teachers were classified as *experienced* if they possessed an e-mail account and *inexperienced* if they did not. With this characterization, 23% of teachers turned out to be experienced users.[5]

4.1 Teacher interaction with CmapTools

As previously mentioned, our study measured acquisition of skill in computer-mediated concept mapping along three distinct dimensions, one of which was the human interaction with the concept mapping program during the Cmap construction process. This interaction was captured via the CmapTools Recorder. The resulting log files, containing over 250,000 lines of data, furnished information about all actions performed, as well as the times at which they took place. We now describe our results.

Analysis of the CmapTools logs revealed that the average construction time was 1hr 32 min for the first Cmap and 1 hr 58 min for the final Cmap.[6] The total number of actions performed on the initial Cmap ranged from a minimum of 71 to maximum of 2028, with an average of 483 actions per map (5.25 actions per min); on the final Cmap the range went from 82 to 2431, with a mean of 750 (6.36 actions per min). Figures 1 and 2 below summarize our findings regarding the 9 basic actions types. Values in the figure 1 represent mean number of actions performed in each category. It is clear from the graph that most of the increase in the total number of actions on the final Cmap came from object movement[7] and especially styles addition. The mean number of concept boxes added remained essentially the same on the first and final Cmaps; linking phrase addition, however, decreased significantly,[8] as did concept box deletion and linking phrase box deletion. Concept text modification, linking phrase text modification and resource addition increased slightly but significantly. It should be noted that resources are not discussed until day 3 sometimes day 4 of the workshop, hence we did not expect them to appear on initial Cmaps.

Given that the total number of actions varied greatly across individual teachers, in order to compare behavior patterns we looked at mean percentages relative to the total number of actions. Inspection of the bar chart in figure 2 reveals a great similarity between the patterns in figures 1 and 2. As before, we note the low percentages associated with the first 6 categories, notably modifying text, both of concepts and linking phrases. Patterns for initial and final maps are very similar. However, comparison tests produced statistically significant differences for all 9 categories, even though differences were just a couple of percentage points.

[5] Again, this percentage is similar to the 20% statistic obtained by Miller et al. (2006).
[6] It should be noted that although facilitators determine a general time frame during which a given Cmap construction activity takes place, teachers are free to stop earlier, if they wish. Sometimes they might go a little over as well.
[7] Objects being moved were generally concepts and linking phrases; though other objects, like annotations, were included as well, these would have been few and far apart.
[8] All results were considered "significant" at the 0.05 level.

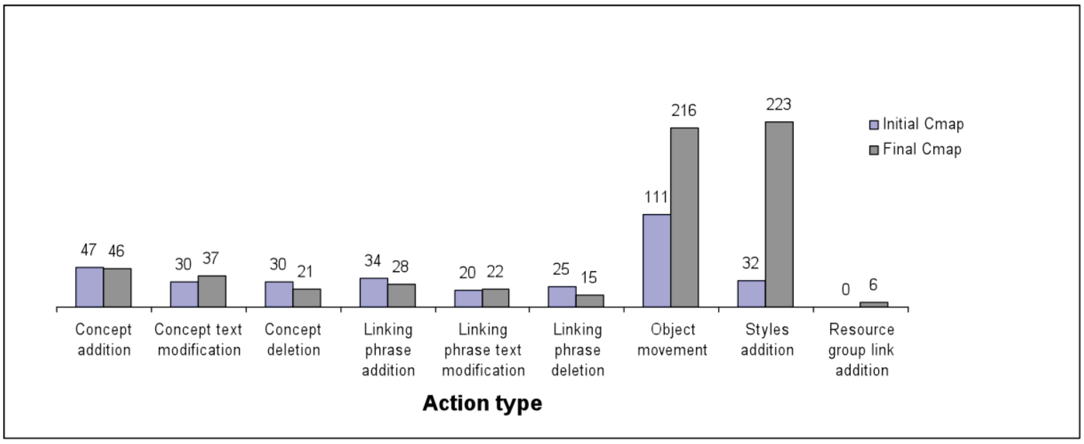

Figure 1. Mean number of actions in each of the 9 action type categories

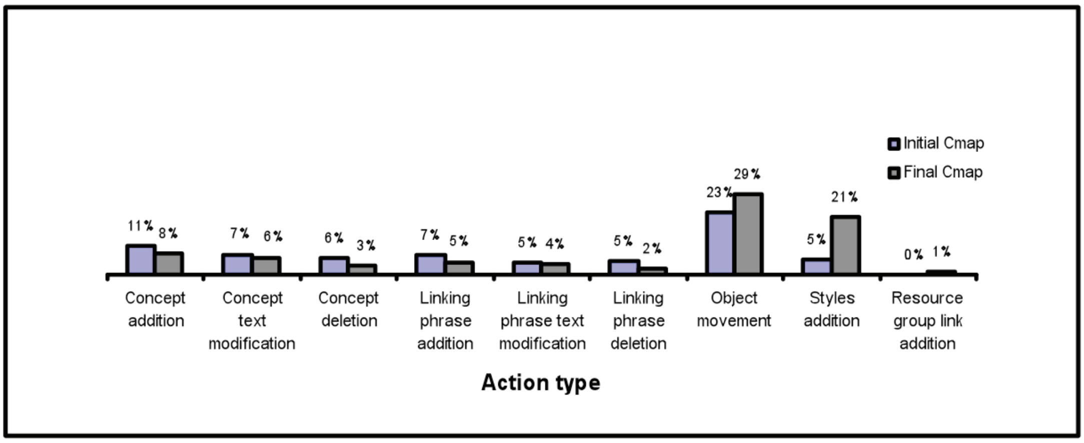

Figure 2. Mean percentages with respect to total number of actions of each of the 9 action type categories

4.1.1 Action type versus computer experience

It seems evident that the more experience one has had with computers, the easier it becomes to acquire the necessary skills to operate comfortably, at a mechanical level, with a new program. Hence, that experienced users performed significantly more actions (on average) than their inexperienced counterparts, and that differences showed up in both Cmaps with respect to many action type categories, was no surprise. Most of these could be explained by either emotional factors, difficulties with the fine motor skills required to manipulate the mouse (specifically, the ability to click, double click and drag-and-drop), or both

Indeed, what caught our attention were not the *differences* but the *similarities* between the two groups. On the first Cmap linking phrase text modification and resource group link addition were statistically equivalent for experienced and inexperienced users. These similarities persisted on the final map, and two more appeared in the categories of concept text modification and object movement. Similarities with respect to resources probably result from the fact that resource addition represents a very small fraction of the total number of actions, and that at the time the first map was constructed neither group knew that resources could be attached to Cmaps.

The fact that percentages of text modification, be it of concepts or linking phrases, ended up equivalent in the final Cmap is more intriguing, and suggests that neither experienced nor inexperienced users were particularly inclined to rewriting their concepts or linking phrases once they were placed in the map. Two factors that might contribute to this lack of interest in modifying text are a rote style of learning and, related to that, an emphasis on form over content. Learners accustomed to learning by rote generally do not question, and do not attempt to relate new information to previous knowledge; hence one would predict little or no modification of text once it has been written down. On the other hand, rote learners may prefer to deal with the way things (propositions, in this case) *look* rather than with what they actually *say*. This would appear to be supported by the fact that the most common actions performed by all subjects, regardless of their experience with computers, were moving objects and adding styles.

4.1.2 Transformation sequences of concepts and linking phrases

So far, the analysis of our data has shed some light on what goes on in computer-mediated concept mapping when teachers are first acquiring the skill; however, the picture that emerges is still rather vague. For instance, we may know what fraction of a teacher's actions corresponds to writing text within a concept box, but we cannot distinguish between text that was written for the first time and modifications of previously written text. This is an important distinction if one is interested, as are we, in understanding thought processes occurring during Cmap construction.

To better infer the cognitive processes taking place during the concept map creation process, one must follow the progression or evolution of each and every concept box and linking phrase box. The enormity of this task, compounded by real time constraints, forced us to limit our analysis to a subset of the full sample set. A sub-sample of 25 teachers was selected at random from the original pool, for a total of 50 Cmaps. Every single concept and linking phrase box created in these 50 Cmaps was followed, from its initial appearance in the map, through all text modifications, to its final form in the completed map. Since we were interested mainly in following semantic transformations, we overlooked style and layout modifications performed on the box. Altogether, 2499 distinct concept boxes (1334 in the initial map and 1165 in the final map) and 1533 distinct linking phrase boxes (893 in the initial map and 640 in the final map) were tracked.

Table 1 describes the six different evolution patterns that were possible (for concept boxes as well as linking phrase boxes), and shows the results of our analysis.[9] The numbers in this table are quite revealing. We note for instance that 54% of concept boxes were created and deleted with no writing in them in the first Cmap; this value decreased to 35% in the final Cmap. The large decrease (approximately 20 percentage points) suggests that many of these boxes may have been created unwittingly, perhaps due to lack of manual dexterity in using the mouse. Of course, it is also possible that some of these boxes were created purposefully, but were deleted for some reason, (for instance, wanting to move the concept box somewhere else and finding it easier to delete and start again, than to drag the already existing box). An identical pattern, with very similar percentages, is observed for linking phrase boxes.

EVOLUTION PATTERN	CONCEPT BOXES		LINKING PHRASE BOXES	
	Initial Cmap (n=1334)	Final Cmap (n=1165)	Initial Cmap (n=893)	Final Cmap (n=640)
Box created, left empty	1%	1%	1%	1%
Box created, deleted with no writing	54%	35%	54%	30%
Box created, text written never modified	25%	43%	19%	40%
Box created, text written, text modified (once or more)	5%	10%	4%	7%
Box created, text written, box deleted	14%	9%	20%	19%
Box created, text written, text modified (once ore more), box deleted	2%	2%	2%	3%

Table 1. Percentages of concept and linking phrase boxes following each of the 6 possible evolution paths in the initial and final Cmaps.

Also worth noting are the percentages of concept and linking phrase boxes written in exactly once: in the first Cmap, 25% and 19%, respectively. These percentages actually increased on the final Cmap to 43% and 40%, respectively. Much more modest are the numbers associated with boxes written in more than once, i.e., boxes in which original text was actually modified. Finally, we observe the nontrivial percentages of boxes written in and subsequently deleted, around the order of 10% for concept boxes and 20% for linking phrases. None of the above numbers were found to vary in a statistically significant manner between experienced and inexperienced users; nonetheless, this result must be interpreted with some caution, given the small fraction (16%) of experienced users in the sub-sample.

[9] Percentages represent averages per map.

4.1.3 Specific text modifications of concepts and linking phrases

Next we focus our attention on those boxes in which text was written and subsequently modified, but not deleted. Pooling together the maps in the sub-sample, we identified a total of 151 distinct sequences of text modifications, 56 in the initial and 95 in the final Cmap. Inspection of these modifications suggested a classification scheme, ranging from trivial changes of format to deep alterations of content. Results are presented in table 2.[10]

As table 2 makes clear, more than half of all changes (59% in the first and 52% in the final Cmap) fell into the first 5 categories, corresponding to changes that essentially have no effect on a concept's meaning.[11] Substantial modifications involved increased concept specificity, which rose from 9% to 18%; complete change in concept, which increased from 11% to 14%; and better concept definition, which decreased from 18% to 9%, presumably as a result of a better understanding of the notion of "concept" by the end of the workshop.

An analogous categorization was carried out for 74 distinct text modification sequences of linking phrases found in the pooled sub-sample (table 3). Classification categories were again suggested by our observations, and are similar but not identical to the ones for concepts. Compared to concepts, modifications of linking phrases were somewhat more substantial: 59% of changes in the initial map, and 68% in the final map, actually modified semantic content. Furthermore, on the order of 10% of all modifications corresponded to a complete change of the linking phrase.

CONCEPT TEXT MODIFICATION	Initial Cmap (n=56)	Final Cmap (n=95)
No change at all[12]; changes in text format (e.g., font size, upper and lower case)	21%	18%
Add or remove article	5%	17%
Spelling changes	16%	10%
Gender and/or number changes; changes between infinitive and conjugated form of verbs.	11%	6%
Concept rewording	5%	4%
Increase in concept specificity	9%	18%
Improve concept definition	18%	9%
Complete change in concept	11%	14%
Other (less specificity, worse definition, etc.)	4%	5%

Table 2. Nature of concept text modifications in initial and final Cmaps.

LINKING PHRASE TEXT MODIFICATION	Initial Cmap (n=33)	Final Cmap (n=41)
No change at all; changes in text format (e.g., font size, upper and lower case)	6%	12%
Improved reading of proposition	6%	12%
Spelling changes	12%	2%
Articles; gender and/or number changes	15%	10%
Linking phrase rewording	9%	7%
Removing concepts from linking phrase; introducing verbs	3%	10%
Add greater detail to linking phrase	26%	22%
Complete change in linking phrase	9%	12%
Other (linking phrase does not improve or worsens)	15%	12%

Table 3. Nature of linking phrase text modifications in initial and final Cmaps.

[10] Those cases in which original text was modified more than once, the variation between the original and final form of the text determined the category into which the sequence was placed.
[11] It might be argued that changes of format can impinge upon the intended meaning of a concept or linking phrase, as when italics or bold face or colors are used for emphasis. For this study, however, meaning has been considered as disjoint from format, since the meaning that could be implied by a given format has no objective reference for interpretation.
[12] Text is rewritten exactly as it was originally.

4.1.4 Concept permanence

An interesting question that emerged from analyzing text modifications of concepts is the following: How likely is it for a concept to remain in a map after being created? We will refer to this notion as "concept permanence." In order to calculate this probability, we considered the complementary event, "concept removal." Once a concept has been placed in a map, there are two mutually exclusive events that result in a concept being permanently removed: 1) the concept box is deleted, and a new concept box with that same concept or its equivalent is never created again; and 2) the concept is modified so that its meaning is completely transformed, and a new concept box with the old concept or its equivalent is never created. The sum of the probabilities of these two events yields the probability that a concept is permanently removed; the probability of a concept remaining in a Cmap is 1 minus this probability.

The likelihood of permanence was calculated for all concepts on each of the 25 initial and 25 final Cmaps of our sub-sample, and averaged to find the *mean concept permanence per Cmap*. Computations yielded values of 88% (83%, 93%) on the first Cmap, and of 95% (93%, 97%) in the final Cmap. The unequivocal conclusion is that once a concept is put down in the concept map, as far as meaning is concerned, it becomes fixed. These results provide further evidence for what we already noted above, namely, an unwillingness to change ideas once they have been put down in writing.

5 Discussion

Two things stand out from our results. First, during Cmap construction, subjects tended to emphasize form over content. At a purely mechanical level, this assertion is supported by the types of actions carried out. In the final Cmap, for instance, form-related actions accounted for 50% of all actions; in contrast, actions related to content constituted only 29%. Moreover, considering that about a third of concept and linking phrase boxes were added and deleted without ever writing any text in them, the percentage of actions ultimately associated with content ends up closer to 23%. At the semantic level, our claim is supported by results concerning the nature of text modifications. For example, of the 10% of concepts in the final Cmap whose text was modified once or more and not deleted, 55% of all modifications were changes in format which had no bearing on the concepts' intended meaning. A similar analysis for the 7% of linking phrases whose text was rewritten once or more and not subsequently deleted, revealed that 43% of changes altered form without affecting meaning.

Second, our data suggests that during Cmap construction there is little rethinking of concepts and linking phrases, and hence propositions, being put forth. This assertion is based on the fact that writing and rewriting of text constituted a minimal fraction of the total actions performed – between concepts and linking phrases, text writing took up on average around 10% of actions – and that much of the rewriting involved relatively unsubstantial changes to content. It would seem that inexperienced users might be more reluctant than experienced users to modify text, owing to lack of ease with the machine, typing difficulties, emotional factors, or any combination of these; however, mean percentages turned out to be similar for the two groups. Hence, technological difficulties and/or issues involving affect would not appear to be responsible for the low percentages of text modification. Of course, it is possible that much of the thinking took place before Cmap construction and hence there was no need for rewriting. However, the fact that the average semantic quality of the final maps was low (Miller, 2008) does not support this argument. We believe something else is at work here, namely, an inclination towards rote learning on the part of our subjects. Further evidence of this comes from the fact that approximately half the time text rewriting involved trivial modifications; along with the high concept permanence, 88% and 95%, on the first and final Cmaps, respectively.

6 Conclusions

Computer-based learning environments give us the opportunity to examine, in addition to "finished" products, the individual steps taken to produce them. In the case at hand, the CmapTools Recorder proved an invaluable instrument, allowing us to examine specific actions performed by teachers in the course of constructing their Cmaps. For the population of schoolteachers considered, the results presented in this paper indicate that beginning mappers dedicate most of their effort to form-related actions, with little revising of propositions. This is consistent with what might be expected from subjects accustomed to learning by rote. This kind of detailed information is valuable to programs such as Conéctate since it provides feedback that can help redirect training efforts towards strategies that can indeed engage teachers in the rethinking of the meanings being expressed (or omitted) from their concept maps.

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USING CONCEPT MAPPING AS ASSESSMENT TOOL IN SCHOOL BIOLOGY

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Abstract. The science topic of human body systems is important for students academically and for understanding and maintaining a healthy lifestyle. Teaching middle school students about the digestive and excretory system can be a challenge for a teacher when she/he wants to overcome rote learning of facts without a deeper understanding. It is suggested (e.g Ulerick, 2000) to use and learn some alternative ways from textbooks. Graphic strategies, such as concept mapping and related techniques, can assist students in visualizing how key ideas are related to each other. This paper examined the research question: how concept mapping as an assessment tool can improve the instructional practices and can be used for identifying middle school students' misunderstandings about the human digestive and excretory system. For assessment the topics of human digestive and excretory system construction of concept maps was used. An analysis of the 29 concept maps created by the 9th grade students in biology lesson revealed that student demonstrate an understanding about focus question: how the nutrients are absorbed into blood, wastes leave the body and urine is formed by sixteen central concepts. This study reports that students' basic knowledge about their internal body parts is on expected level. Students' terminology for the identification of the organs' functions after studying this topic were quite good. In creating the maps, student clarified concepts and became gradually aware about interconnections.

1 Introduction

Science education aims far more than the ability to recall information of facts and names. The studies about students` learning problems in science reveal that they have a large number of misconceptions even after receiving formal instruction. To encourage meaningful learning and to minimize the students' alternative ideas about the explanation of complex body processes, teachers especially should recognize the importance of assessment. Teachers can assess what students have learned at the end of the lesson, using different techniques such as writing, concept tests, concept map etc.

2 Theoretical background

Studies have showed that students have problems in understanding key topics of biology such as internal organs, organ systems and processes of their own bodies (e.g Bahar, Johnstone & Hansell, 1999). Toyoma (2000) have evaluated young children awareness of biological transformations associated with eating and breathing and showed that young children seldom refer to biological transformation. Results from an international study (Reiss et al, 2002) about 15 year-olds students´ (from 11 different countries) understanding of different organ systems show that the generally best known organs belong to the digestive system, the gaseous exchange system and the skeletal system. Student had better knowledge of their internal organs, most of them revealed little understanding of their organ system. Tunnicliffe (2004) found that 9-10 year old students had greater difficulties in understanding the excretory systems than the digestive. In this study concept mapping has been used as a tool to identify middle school students' misconceptions about the human digestive and excretory system.

A variety of methods have been used to examine students' understandings and to detect alternative conceptions in science education and in biology such as multiple choice items (e.g. Odom, 1995), construction of concept maps (e.g. Novak & Gowin, 1984), using analogy in teaching (e.g. Rule & Furletti, 2004), using the drawing (Özsevgec, 2007), and so on.

School is mentioned as a source of knowledge by secondary pupils rather than ones of primary age, and then not very often (Tunnicliffe & Reiss, 2000). In Estonia the science is taught as an integrated subject from the 1th to 7th grade and from the 7th grade biology is taught as a separate subject. The basis for the study of the human muscular, skeletal, digestive, excretory, respiratory and circulatory, reproduction, nervous, endocrine, immune, systems is currently presented in Estonian National Curriculum (Estonian Government, 2002). Within the primary science syllabus, the subject matter of digestion, respiration is introduced progressively from grade 2th to grade 4th. In grade 2th, pupils are introduced to the concept that livings need air, water and food to survive; they are taught life cycles of plants and animals. Each of systems (skeletal, digestive, circulatory, respiratory, excretory and nervous) and their organs' function and locations are taught simply at grade 4th. Different aspects with greater depth of understanding are covered in human anatomy lessons in grade 9th. According to the National Curriculum the students should have knowledge about the following content at the end of the 9th grade (aged 15/16) students should: be able to identify human organs and organ systems and explain the relations between their structure and function; follow the principles of a healthy and sustainable way of life; put the knowledge acquired in biology lessons into practice and to relate it with knowledge acquired from other sources, plan and carry out simple biological experiments; make observations, record the results and present them…" (Estonian Government, 2002). In Estonian lessons the human organs are taught individually, but it is emphasized that these organs are parts of systems and then have been going into more detail.

A more traditional approach to teaching is practiced in Estonia. Students are expected to master an understanding of basic concepts, content, and vocabulary in biology. Previous study has showed, that student do not do so much laboratory investigation and experience applying scientific methodology (Henno & Reiska 2007). The relatively strong "academism" has its positive side and perhaps is one of the possible factors that explains the Estonian students' success in TIMSS 2003 and in PISA 2006. In TIMSS 2003 according to mean scores Estonia ranked sixth in life science and in PISA 2006 fifth in science and on the basis of the mean score on the living systems' scale of scientific knowledge, third after Finland and Hong Kong – China. In TIMSS 2003 it was revealed, that on average 80 % of Estonian students taught by teachers reported using a textbook as primary basis of their lessons (Martin *et al.,* 2004: 308).

The science topic of human body systems is important for students academically and for understanding and maintaining a healthy lifestyle. Teaching middle school students about the digestive and excretory system can be a challenge for a teacher when s/he wants to overcome rote learning of facts without a deeper understanding. It is crucial to realize that Estonian current biology textbooks have some shortcomings and cannot be relied upon to provide the inquiry instruction for biology at the middle school level. Teachers must contextualize the role of textbooks within effective instructional practices. The students use their teachers' terminologies and teachers should pay attention their words used in their lessons.

Acknowledging the difficulties in learning from textbooks, Ulerick (2000) have suggested some alternative ways to use and learn from textbooks. She suggests using graphic strategies, such as concept mapping and related techniques, to assist students in visualizing how key ideas are related to each other. Given the particular weakness of textbooks in promoting the connections among ideas, this seems a particularly important strategy.

In Estonia homework is an important part of teachers` instructional strategy. Homework assignments can reinforce classroom learning and encourage students to extend their understanding of the biology. In the end of concrete themes/courses the students have summative science tests.

Assessment is an integral part of teaching and learning, providing feedback on progress through the assessment period to both learners and teachers. Concept map can be used for showing the topics/contents, in introducing a topic to the students and for evaluation or assessment (Rice, Ryan & Samson, 1998).

This paper examined the research question: how concept mapping as an assessment tool can improve the instructional practices and can be used for identifying middle school students' misunderstandings about the human digestive and excretory system?

3 Methods

In this research concept mapping has been used as a tool to collect the data and as a student assessment tool. Data for this study include 29 middle-school students from Science High School – constructed concept maps showing how student integrate information about the human digestive and excretory system. The sample included the students in the 2006/2007 study year. 9th grade students were taught during one study year (70 week) and assessed normally by written tests. The types of test formats for biology were mostly constructed-response biology tests. On average the students had a biology tests about once a month. For assessment the topics of human digestive and excretory system was used the construction of concept maps.

Concept maps were created using CmapTools program from the Institute for Human and Machine Cognition. At first, students were explained in the subject classroom about the bases of concept maps. After the classroom instructions the students constructed maps for the first time in their practice about human nervous system using the biology textbooks (biology textbook published by publisher AVITA in Estonia) in computer class.

After two weeks of studying (four lessons) the digestive and excretory topics and monitoring the homework assignments from textbooks the summative assessment was taken place in computer class, where during 45 minutes students mapped individually their understanding about interaction of the digestive and excretory system by heart, by using the software CmapTools. The focus question for concept mapping was: *how the nutrients are absorbed into blood, wastes leave the body and urine is formed.*

This report describes a quantitative content analysis of 29 students` concept maps. For this survey the 9th grade biology textbook texts about the digestive and excretory topics were scanned and a list of concepts and meaningful propositions was compiled. 60 new full word/ concept names and 58 new semantic propositions connected with the topics of the digestive and excretory system were accounted in the biology textbook material for students.

For this study, a quantitative approach is adopted. Students' concept maps are assessed mainly, using counting, in terms of the concept names, linking words used in between the concepts and valid and invalid propositions, list of concepts and meaningful propositions from the biology textbook. Valid propositions are formed by connecting valid nodes with suitable linking words. The content of the concept maps is summarized in Table 1.

Table 1. Number of contents, propositions and cross-links and students´ mean score of biology test of study year.

No of student	Mean score of biology tests	No of invalid concepts	No of correct concepts	No of invalid prop.	No of valid prop. according to textbook	Number of valid propositions	Cross-links	No of links of central concept	Central concepts (with number of links)
1	4,25	0	15	0	9	20	0	3	blood (3), kidneys (3)
2	4,25	1	17	1	10	20	0	5	food (5), excretory system (4), kidneys (4)
3	4,75	0	26	0	19	32	0	3	focus question (3)
4	5	0	29	1	16	30	1	5	wastes (5), digestion (5)
5	3,75	0	21	0	15	24	0	4	wastes (4)
6	5	0	47	0	29	37	0	5	blood (5)
7	5	0	25	0	14	24	0	5	wastes (5), kidneys (4)
8	5	1	31	1	20	22	1	7	digestive system (7), wastes (5)
9	4,5	2	14	0	10	18	0	4	small intestine (4), blood (3), stomach (3)
10	4,5	0	14	0	6	12	1	4	bloodstream (4), kidneys (3), renal corpuscles (3)
11	4,5	1	23	0	10	27	0	6	nutrients (6), excretory system (5)
12	5	0	30	0	20	28	0	4	small intestine (4)
13	4,25	0	22	0	13	18	1	5	wastes (5)
14	4,75	0	19	0	9	18	0	5	wastes, urine (3), small intestine (3)
15	5	0	14	1	9	21	0	4	small intestine (4)
16	4,75	0	15	0	9	17	1	4	nutrients (4), renal corpuscles (4)
17	5	0	13	1	9	17	0	4	blood (4), prourine (3)
18	4,25	0	9	0	6	12	0	3	focus question (3)
19	3,75	3	20	0	9	18	0	7	digestive system (7), kidneys (4), wastes (5)
20	5	1	26	1	15	21	0	4	nutrients (4)
21	4	1	8	0	7	8	0	2	0
22	4,25	0	14	0	8	15	1	4	blood (4), kidneys (3), nutrients (3)
23	4,25	1	23	2	12	25	0	4	nutrients (4), kidneys (4)
24	5	1	19	2	15	22	1	4	nutrients (4)
25	4,5	0	19	2	14	16	0	4	focus question (4)
26	5	0	16	2	9	22	1	4	excretory system (4), tubular system (4)
27	4,25	1	10	1	9	12	0	3	focus question (3)
28	4,25	0	11	2	6	12	0	2	focus question (2)
29	4,5	0	23	0	12	28	0	5	food (5), wastes (5), kidneys (5)

In this study the mean of test scores (the study year) were compared with the number of contents, propositions and cross-links in students´ created concept maps. The correlation coefficient between these was measured.

4 Results

Concept mapping was used in the biology classroom to assess students' conceptual frameworks by analyzing the ways students organize and present knowledge. It was intended to determine whether the use of concept maps in the classroom as an assessment tool can identify and address specific misconceptions.
An analysis of the 29 concept maps created by the 9th grade students in biology lesson revealed that students demonstrate an understanding about focus question: *how the nutrients are absorbed into blood, wastes leave the body and urine is formed* by sixteen central concepts (blood, bloodstream, digestion, digestive system, excretory system, food, kidneys, nutrients, renal corpuscles, small intestine, stomach, theme, tubular system, wastes, urine, prourine). The most popular concepts were: *blood* and *focus question* (was used as central concept by five students), kidneys and wastes (was used as central concept by eight students) and *small intestine* was used as central concept by five students).

The all concept maps were structured by hierarchically. An example of the best constructed concept map is presented on figure 1 and the purest is on figure 3. It seems at first that the best map has several cross-links, but by restructuring the same map by the linear way we can not find any cross-links (figure 2).

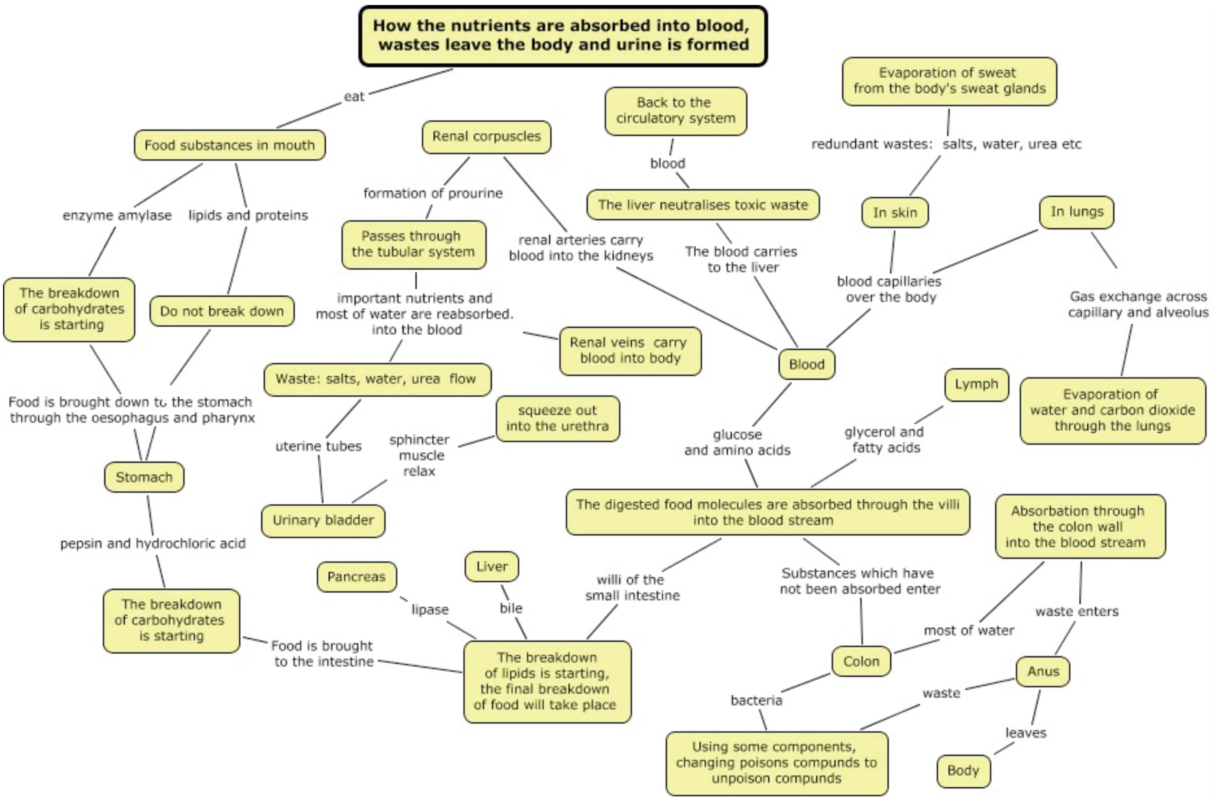

Figure 1. An example of a student: best constructed concept map to show how the nutrients are absorbed into blood, wastes leave the body and urine is formed

The digestive and excretory topics were taught to the students and student created maps do not reflect the previous deficiencies. Students have gained broader knowledge and were able to relate new concepts to more general ones. Students' daily life experiences may cause some alternative conceptions. There were some typical invalid propositions done by students. Students used "the food is absorbed into the blood" instead of "the digested food molecules are absorbed into the blood". They used "excretion of air" instead of "elimination of carbon dioxide and water". Some students also ascribed to the stomach, *digesting of proteins and carbohydrate,* some believe that fatty acids are absorbed through the villi into the blood stream.

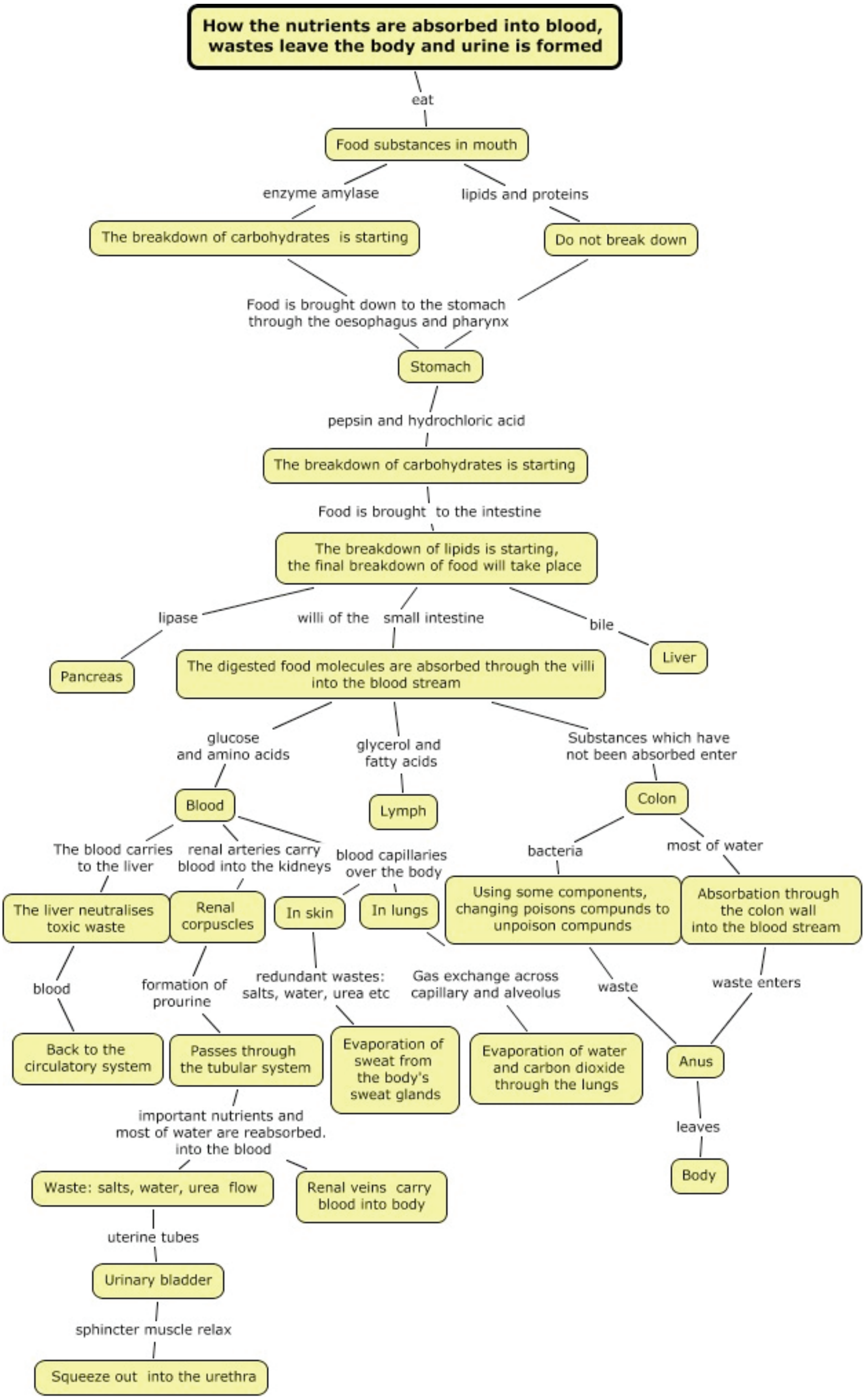

Figure 2. Example of the best concept map reconstructed by linear way

The correlation coefficient was measured between the mean of test scores (the study year) with the number of contents, propositions and cross-links in students´ created concept maps. Table 2 shows the results.

Table 2. Correlation coefficients

Correlation coefficient between	Correlation coefficient
Mean score of biology tests and number of invalid concepts names	-0,34
Mean score of biology tests and number of correct concepts names	0,44
Mean score of biology tests and number of invalid propositions	0,23
Mean score of biology tests and number of valid propositions according to textbook	0,46
Mean score of biology tests and number of valid propositions	0,45
Mean score of biology tests and number of cross-links	0,25
Mean score of biology tests and number of links of central concept	0,16

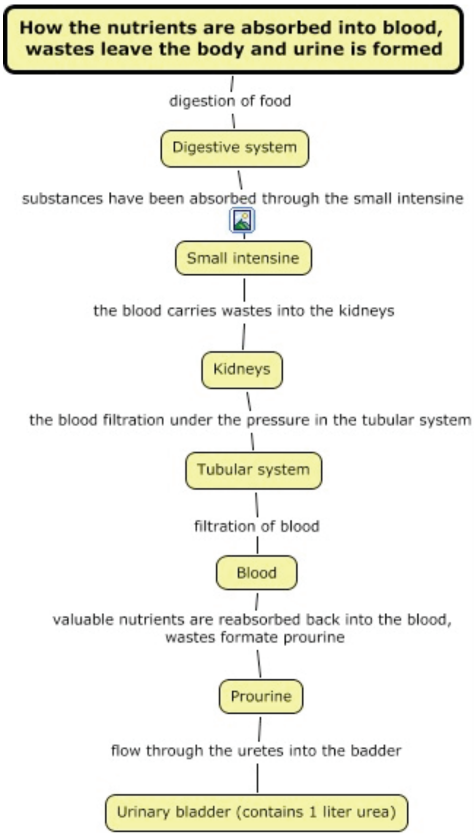

Figure 3. Example of the purest concept map

5 Summary

This study reports that students' basic knowledge about their internal body parts is on expected level. Students' terminology for the identification of the organs' functions after studying this topic were quite good. In creating the maps, students clarified concepts and became gradually aware about interconnections.

Generally, students demonstrated their ability to draw interconnections between digestive and excretory systems.

Teachers must be informed about students' understandings and they should design their science lessons according to these points. Teachers also should be informed about different teaching methods depending on the students' active learning.

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USING CMAPTOOLS FOR INTEGRATION OF CONCEPTS AND A HOLISTIC GEOGRAPHIC UNDERSTANDING

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Abstract. The potential and the powerful uses of concept maps as a learning tool is well exhibited in an inter-disciplinary subject like Geography, where integration of progressively developed concepts, incorporation of field experiences and data, and integration of location-specific applications of learned concepts lead to a holistic understanding of otherwise potentially segregated geographic processes. Two undergraduate courses in Physical Geography used CmapTools to integrate various classroom-based and Field-based knowledge in order to develop a meaningful holistic understanding of many concepts, which otherwise fail to bring the much desired connectivity among the many facets of this inter-disciplinary subject domain.

1 Introduction

Geography, as a subject, is interdisciplinary in nature, with facets taken from the various sciences to study the environment on Earth. Many of the geographic processes, therefore, require the learner to integrate multiple concepts for developing a holistic understanding, to develop the much talked about 'Big Picture' about the environment and the operating processes therein. As a discipline Geography also requires learners to integrate and apply learned concepts to examine and assess field observations and specific case studies, which provide the much required real life relevance to learning. This requirement for an integrated understanding create a niche for a system that provides the learner a platform to park previously learned concepts, direct field experiences, case studies, relevant resources of various nature for reorganizing them in order to create a new concept map which help create an integrated understanding of the issue at hand. Such tasks leading to a dynamic knowledge development are deemed to be possible through the use of CmapTools, a concept mapping tool which was used in two undergraduate Geography courses for this study. The courses chosen were a second year module on Biogeography (AAG232) and a Third Year module on Catchment Management (AAG331). The rationale for choosing these two modules lies in the very character of the two courses. Biogeography is an extremely inter-related discipline, which draws on concepts from disciplines such as Geomorphology, Hydrology, Biology, all covered by students prior to taking this module. Catchment Management is another module which is an application module following the modules on Geomorphology and Hydrology understanding and application of which is essential for examining catchment management issues. Therefore, both these courses were ideal for integrating and mapping of many concepts.

Objective of using the concept mapping technique was to facilitate a holistic understanding of inter-related concepts, incorporating knowledge gained through classroom-based lecture-style and lab-based experimental-style learning, field-based enquiry, group work and self-exploratory methods. At the end of the exercise, learners were expected to integrate previously acquired knowledge from earlier/ other related Geography modules, available resources, own research, group fieldwork investigation (surveys, data, observations) to develop concept maps, using CmapTools, with appropriate nodes and linkages, which indicate their ability to integrate concepts for a holistic understanding of the environment, the inter-related processes and links.

2 Background and justification for use of CmapTools

As De Simone et al (1999) point out, college/ university learners are assumed to be proficient readers. However, in line with other findings (Bransford, 1979; Novak and Gowin, 1984; De Simone et al, 1999), it may be reaffirmed that such learners are still not proficient enough to abstract information and formulate a coherent understanding of the inter-related issues as much of the learning may be taking place as separated nodes or bodies of knowledge, without any integration or organization. Modular systems followed in the universities serve to create this artificial division among originally inter-related disciplines and unless conscious efforts are made to integrate these learning objects, the learner goes through the system unobstructed and without comprehending the inter-dependences that naturally exist among these disciplines.

While in the course of the planning and delivery such integration may be incorporated, unless the learner is made to have the experience of integrating himself/ herself, much of this effort on the part of the curriculum developer/ facilitator is lost. One example is the spiraling system of curriculum which takes a student of Physical Geography at the university (National Institute of Education, Nanyang Technological University, Singapore), from first to third year, similar to other universities in the world, as shown in Figure 1.

The pre-requisites are emplaced to ensure that students come with the required prior knowledge to be able to assimilate and organize their prior experiences for a more effective learning in the subsequent courses. However, since the courses are delivered as separate modules, students tend to process information as discrete units, rather than as linked continuum of knowledge, as is intended in the curriculum. This leads to less than optimum learning integration.

Year One:
Introduction to Physical Geography
(Pre-requisite to take Physical Geography courses in Second Year)

Year Two:
Geomorphology (Semester One)
Biogeography (Semester Two)

Year Three:
Catchment Management
(requires students to take Geomorphology in Second Year)

Figure 1. Structure of courses in Physical Geography from First Year to Third Year

Geographic learning also requires students to apply their knowledge from more than one discipline to analyse real-life environment. This is instituted in field work which requires students to apply their prior knowledge to carry out investigations and also to analyse the collected data. However, very often the students tend to disregard the connections between previously learnt concepts and dwell in the current course content to process information as discrete unit outcome, rather than as linked ideas. This leads to less than optimum learning as well.

Thus an additional objective of this study was to examine how students can be initiated to incorporate what they have learnt before (in previous modules) to analyse what they observe in the field to answer some focus question, which is aimed at providing a holistic understanding of the issues under study. For the Second year course this was done through the use of Field investigations and field data collection, while for the Third Year course case studies were used to involve students to use and organize their past knowledge. Both the groups were involved in organizing the knowledge through concept maps using CmapTools to draw up the Big Picture and establish the linkages. Fensham et al (1994) mention that conceptual change is often an accretion of information that the learner uses to sort out contexts while Gunstone and Mitchell (1998) proposed that conceptual change is coordinated with the learner recognizing, reconstructing, reviewing and restructuring relevant aspects of their understanding in a way to provide consistency in learning. These required cognitive actions are essential to making sense of field-derived and case-derived components. Thus it was perceived that such exercises provided a suitable platform to initiate students to learning through concept mapping.

3 Planning and execution of the study

As Novak and Gowin (1984) point out, concept mapping is among the most promising methods for promoting relational conceptual change where students make use of various symbols to determine the relationship between the concepts. Such concept maps have been in use in all facets of education and training to foster learning (Novak and Cañas, 2004). These maps are hierarchical diagrams providing a graphic display of interrelationships among concepts. For the present study the students from the two courses used concept mapping to understand and establish relationships between concepts and demarcated to and fro links to indicate the linkages.

A CmapTools-based learning activities model used by Novak and Cañas (2008) was adapted to suit this present study (Fig.2). It shows the various components of activities supported by the exercise, and is classed as (1) Scaffold, (2) Student-led research, (3) Student-generated resource building, (4) Student-led exposition, and a final outcome, (5) Multi-disciplinary conceptual integration and understanding. At the end of the course, a digital portfolio was created by each student, using the CmapTools.

This scheme adopts Novak & Cañas's (2004) model following Vygotsky's (1978) idea of 'Zone of Proximal Development', with the lecturer providing same opportunities of a higher level of understanding to all students in the class through the common lectures, lab sessions and assignments and providing the direction through generating the focus question, an idea also confirmed to have positive outcomes of learning by Bransford et al (1999).

Justification for using the concept mapping technique lies in the discipline which is more effectively delivered with graphic representations, both for the knowledge structure as well as for the supporting resources that can be organized thematically and hierarchically. Graphs, maps, photographs, other visuals such as videos are common resources used in Geography, particularly since this is a field-oriented discipline and an effective way of bringing relevance to the topics is by using ample illustration and graphic representation of the quantitative components. The ability of CmapTools to organize concepts hierarchically is particularly useful as one Geographic concept is built on several smaller concepts and together they form the big picture which the

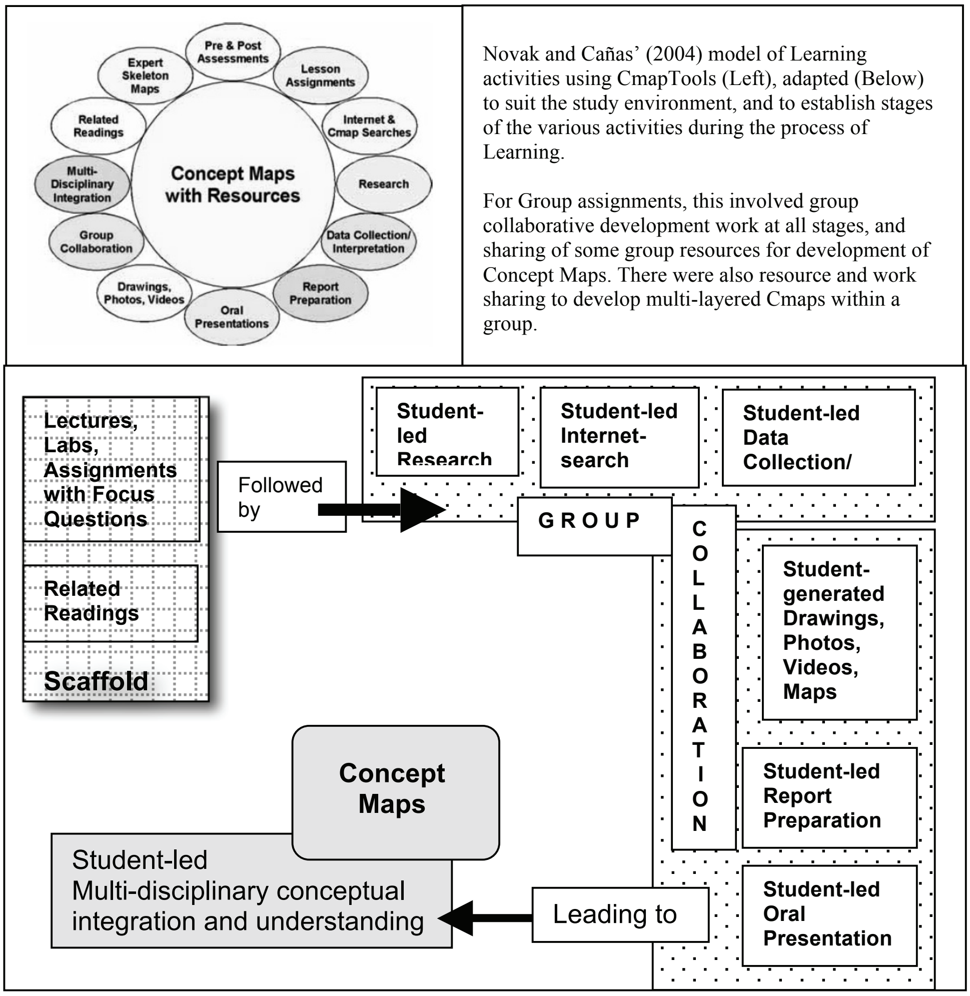

Figure 2. Spectrum of Learning Activities for the study, based on Novak and Cañas' model (2004)

learner needs to assimilate to understand the inter-relationships. The nesting and collapsing of concepts and expansion of such, when required is an aspect of immense usefulness in Geography. This may be referred to as the 'High Ceiling' capability of the tool, as individual concepts can be progressively developed, as the learner goes deeper into the learning environment. Thus while a basic concept map might only show one level of hierarchical, linear development, a more advanced learner can continue to build up the concept map with many layers of added concepts, supporting resources, comments etc. and the complexity of the understanding depends on how far the Cmap has been developed. Thus a learner may be able to develop and re-develop the concept map as he/ she goes through the course. This aspect was well-used during the present study, with students developing and redeveloping or reorganizing previously learnt concepts (from earlier relevant but other modules) and also incorporating previous knowledge as they went through the course. This framework for assimilation and incorporation of previously learnt concepts to develop new ones is in line with Ausubel's (1963, 1968, and Ausubel et al, 1978) fundamental idea that meaningful learning takes place by assimilation of new concepts with the learner's existing concepts. The entire framework of the courses supports this idea of progressive learning, based on prior relevant knowledge (with the study courses placed on the pre-requisite foundation courses in previous years). The aspect of providing motivation for learning meaningfully was provided by the requirement in the course to make meaningful integration of classroom learning with direct observation and quantitative data collection in the field around some focus questions and also the need to interpret conditions in the case studies, which reflected no single concept but an amalgamation of multitude concepts, as it appears in the real world. By trying to make sense of these integrated environments, the students were faced with the need to be able to integrate old and newly acquired knowledge, and also to do the own research to build and reorganize available information to suit the requirement of the focus question. Thus the scheme supported meaningful learning, which required (integration of old and newly acquired knowledge, reorganization of all relevant knowledge, representation of acquired information in ways deemed appropriate by the learner (providing the learner control), freedom to initiate new research and new ways of representing findings, all of which gave the much-needed commitment and motivation for 'Meaningful Learning' to take place and provided opportunities for creative products at the end of the course.

4 Organisation of the coursework

Course work for both courses focused on progressive development of knowledge acquisition: 1st phase was to connect present and prior learned concepts to integrate their understanding of the biogeographical and geomorphological processes. The 2nd phase was to integrate these relevant concepts to understand and assess a given real-life environment from field observations and from case studies. Both the groups were given one assignment each, for each phase, as group endeavours, where the students negotiated together in pairs, to revise and reconnect prior knowledge and collectively worked on development of the conceptual models to answer the given focus question. In both cases, students were given the Focus questions and all groups used CmapTools to develop the linked concept maps using the computer. Links were developed after much negotiation. Figure 3 sums up the processes followed throughout the courses to incorporate conventional classroom processes with the student-centred knowledge organization, to create new and meaningful knowledge which is not just derived from real world situations, but also helps to develop knowledge dynamically that is closer to one's own experiences and, therefore, can be seen as more relevant.

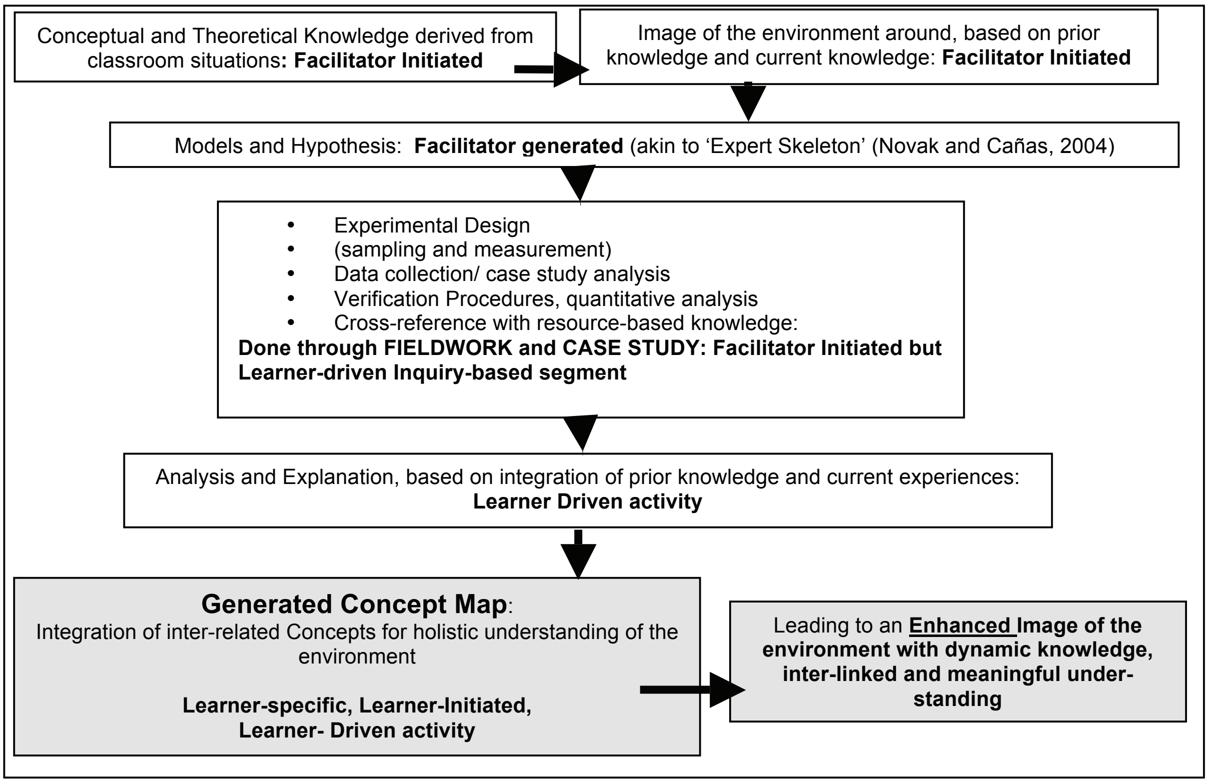

Figure 3 Flow of work during the courses to develop Geographic Understanding by using CmapTools

Assignment 1 for Group 1 was to create ground work to prepare them for the subsequent more in-depth exposure to interconnected concepts, as experienced in the field-based work (Assignment 2). This also provided the link between theoretical concepts and Lab procedures and analysis. For Group 2, Assignment 1 related to assessment of some controlling processes that impact the Catchment environment, in response to developmental activities in the catchment area. This initiated them to find the inter-related nature of the various controlling factors, with each pair concentrating only on one or two processes, but during group presentation in the class the processes operating in the entire catchment were discussed and established, to provide the complete picture (The Big picture) and the linkages. The idea was to illustrate the interdependences of all the processes in the catchment, which, in earlier modules were taught/ learnt separately. The second assignment was on case studies where application of al relevant conceptual understanding was required to interpret the given environment.

In this course design fieldwork and the case studies provided the exposure to help generate the new image of the environment which was reflected through the concept maps. Thus the concept maps were used as a continuum for the development of explicit holistic geographic understanding. The much-required linked-meaning-making between the conceptual understanding and the explicit real-world relevance was expressed using the concept maps. It thus forms a vital link in the knowledge development of the learner. Such an integration of the real world within a cognitive framework enables students to develop an awareness and relevance of Geography and as Burt (1989) emphasizes, helps students to gain a perspective within which they can place local, national, and international issues which have a Geographical dimension. It may be said that there is a much-needed '*Niche*' for concept maps to assimilate the various components of the given environment, to understand and establish the links to create a deeper and self-driven meaning of the given environment through linking relevant learned concepts with the observed, researched, and analysed information. The outcome is a higher level of cognition.

Vallega (2000) cites Buttimer's (1993) four approaches to the understanding of places and spaces: *ergon* (responding to social and scientific stimuli), *poiesis* (discovering and creating), *logos* (systemizing), and *paidaia* (educating). Vallega (2000) refers to these as the components of a '*mandala*', within which geographic education becomes increasingly important and includes impacts from society and science, uses globalizing tools, and shares experiences. Using this concept, the present study emphasizes knowledge building and meaning making through the use of concept maps in order to create a holistic geographic understanding from a shared fieldwork/ case study experience.

5 Processes and Stages of work

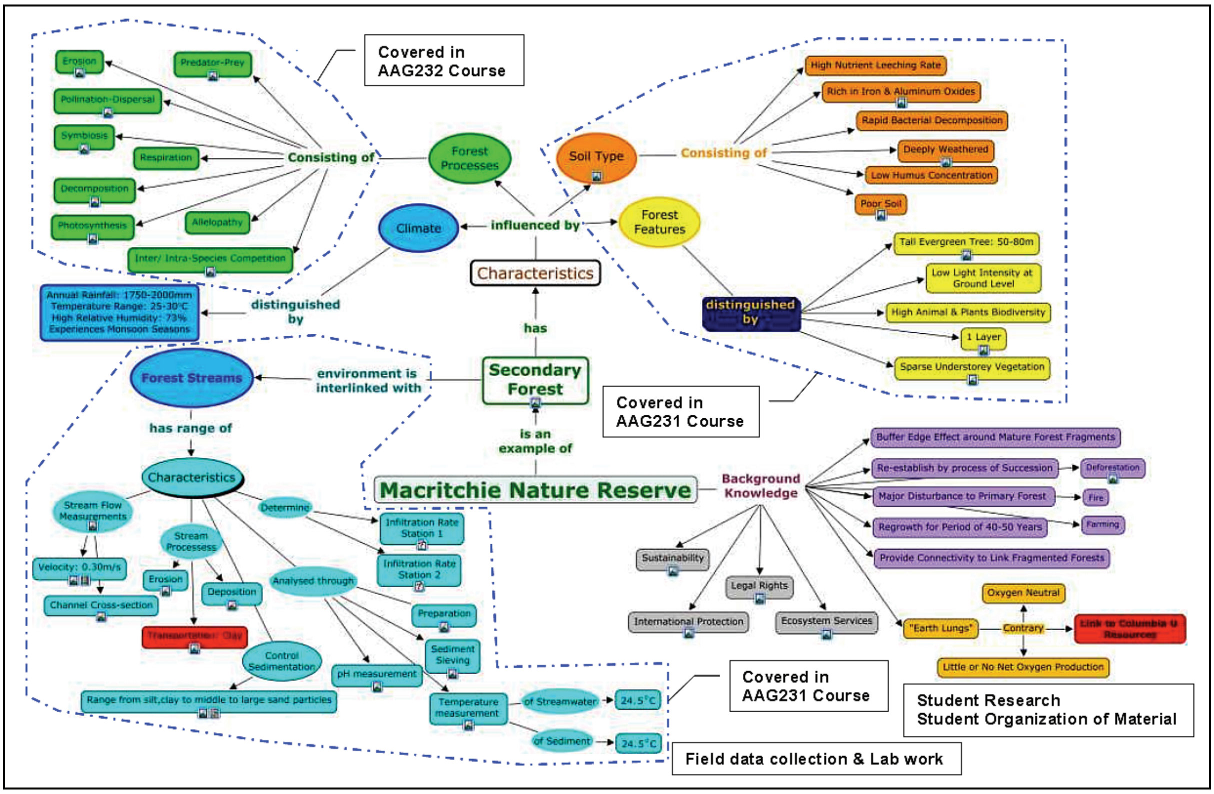

Fig 4 Integration of prior knowledge, fieldwork, course materials, own research using a Cmap drawn by students

Stage 1: Initial lectures, Lab sessions and some introductory readings were provided by the lecturer to introduce the various concepts related to the main theme of the courses: Biogeographical environment of a Tropical Rainforest (Group 1), Geomorphological and Hydrological Processes in a Catchment Basin undergoing urban development (Group 2). This stage of knowledge development can be parked under the banner of Buttimer's *ERGON: response to a stimulus.* Instructions were also given to draw up concept maps for these courses, using CmapTools, introduced earlier in a previous course, instead of a written assignment. The usefulness of concept maps in subsequent revision work before examinations was also pointed out. Students were given the choice of using as many types of resources as they preferred and were asked to be creative in the productions. Similar instructional procedures were followed by Czuchry and Dansereau (1996).

Stage 2: Field work (Group 1) and Case Study research (Group 2) was done to investigate site-specific details that corresponded to learned concepts. This led to discovery of interdependent processes and creation of new artifacts and knowledge, and dynamic meaning making of observed processes in a real-world environment and provided relevance to the concepts previously learnt: termed *Poiesis*.

Stage 3: Logos or *systemizing of information* was achieved by organizing the collected information by doing lab analysis, data manipulation, graphing, research, collating of relevant information by all groups, in both courses. The Learning Management System (BlackBoard) of the University was used as a platform for organizing and sharing of resources and information among the students.

Stage 4: Paidaia or *educating stage* was achieved by both groups through development of Concept Maps (using CmapTools) and by presenting these in the class for discussion. This is where the learners shared their learning experiences, re-negotiated their understanding of the respective studied areas, made connections with the findings of others, and as a whole made meaningful connections to create a holistic image of the entire environment under discussion. Figure 4 shows one such Cmap drawn by a student group, which shows the integration of prior knowledge, field experiences, course materials and own research for developing the final holistic understanding and assimilation. Clearly, this is an indication of knowledge integration.

Finally, one extra achievement was the sharing of all concept maps for future use and possible re-organisation of information.

6 Analysis of student responses

All students using CmapTools for the courses under study were exposed to concept mapping and the CmapTools software in earlier modules conducted by the author and, therefore, all had some prior knowledge and experience regarding the process of both concept mapping as well as maneuvering within the mapping environment. All students were also exposed to various computer-based learning environments. These ensured two things: the learning curve, for most, was near flat and there was no novelty in the use of the software to cloud the learner's views on it. Following are some of the salient points that came out from the anonymous student survey conducted after the course was over (Table 1).

The survey reveals that all learners found concept mapping beneficial to their learning and all felt that it was useful to organize their learning as 'smaller concepts' could be organized inside 'bigger concepts', indicating that the use of hierarchical knowledge organization was useful to them. The multi-layered structure of the various inter-related concepts helped students to arrange information in manageable sizes. All students also felt that aspects learnt in the field work could be well-organized and linked with resources and theoretical concepts through the use of Cmaps. The students used the platform to organize many types of resources, some even linked to videos taken during the field work. More than 80% students mentioned that they will use this concept mapping for future learning and most said it helped them revise learned concepts before exams.

Observations by students	Group 1	Group 2
Group1 (Second Year students): n=16; Group 2 (Third Year students): n=6; Total n=22		
Prior knowledge and exposure to software and concept mapping	16	6
Easy to use	16	6
Learning the details of the software: **Self-exploration**	16	6
Easy to see the connections in the concepts	16	6
Shows the Big Picture	16	4
Sharing the concept maps helps	12	-
Helps Visual Learners	8	2
Helps Revision before exams	12	4
Links the smaller concepts together under a bigger concept, making understanding easier and more meaningful	16	6
Different resources from field work can be linked to concepts, providing relevance	16	5
Resources added: Photographs	16	6
Resources added: MS Word files	16	6
Resources added: MS Excel files	16	6
Resources added: PDF files	12	6
Resources added: Websites	16	6
Resources added: PPT slides	8	6
Resources added: annotations and comments	12	6
Resources added: animations/ video clips	8	2
Will use for future learning	14	4
Cooperative knowledge building through group work	12	4

Observations by students	Group 1	Group 2
Can be dynamically enhanced	8	-
Promotes creativity	6	-
Free to use	4	-
Supports Student-centred Learning	12	4
Links are lost when moved from PC to PC	16	6
When nested nodes are opened, the whole picture looks messy	1	1
Prefer writing on paper than on PC	2	1
Very time consuming to develop and create the links	1	2
Prefer learning from texts	1	1
Prefer materials in PPT format/ Lecture notes	1	1
May not suit learning styles of all	2	2
Prefer using other learning techniques (did not specify)	1	1

Table 1: Student Views on the use of CmapTools and Concept Mapping as a learning tool

However, some resistance to the idea of using concept mapping was observed. The exercise of using concept mapping was imposed on these students and, in general, the younger students (Second Years) responded more positively to the exercise than the Third years. This might be because of the Seniors' reluctance to use something new, as these are the students who preferred using written notes and PPT slides to Cmaps. Interestingly, while the Second Years used Cmap directly to present their findings, the Third Years resorted to PowerPoint, only linking to Cmaps when required, although the Cmaps were already developed by them and submitted as class assignments. The third years also resisted the use of the linking words between the nodes, keeping them unmentioned. It is felt that they were not yet ready by themselves to express the connecting processes explicitly, although during verbal presentations they were mentioning all the correct processes. Some (from both groups) did mention that initially they were perplexed by the 'small box with question marks' and did not know how to use them and so found it easier to 'just delete them'. With progressive use, this problem was avoided. However, just as Edwards and Fraser (1983) found out, a number of students saw this as a lot of extra work, which they would happily avoid, if possible, although they did accept that using Cmap helped them to make the correct links in the concepts.

More students from Second Year (75%) saw concept mapping as useful for dynamic knowledge building (50%) and sharing (75%). But both groups agreed that it is good for group work. It was generally agreed that, given adequate time, concept maps are useful for knowledge building, but it has to be preceded by lectures. In general, students from both the courses seemed to be able to use CmapTools to conduct their research and organize their findings, without much problem. But some negative aspects were pointed out.

The most common problem students had was the difficulty of transferring Cmaps from one PC to another which delinked most links with the resources that were created painstakingly earlier. This caused some disruption as re-linking takes some time and has to be done one by one. However, this, in no way, undermines the usefulness of the framework on which CmapTools rests. Complicated and inter-related concepts were effectively presented with all links for both the courses and were useful for the summing up of the entire course for revision. Most students appreciated this summing up exercise through CmapTools and commented that it was useful for exam revision.

7 Conclusion

In conclusion, it can be said that CmapTools does have a 'Low Threshold' (Cañas et al, 2004), and students are able to use it by probing around and using the Help Tool of the software. Students learnt that not only can they organize the information and concepts but they can also use creative ways to highlight and map their own views and issues, using the software and this was done through self-exploration alone. Collaboration was also useful for the knowledge development and organization and concepts could be slowly developed as the group work increased and the as the course progressed. Therefore, the 'High Ceiling' is also proven. Some students also mentioned that the 'Views' window helps to see all the resources available, making it very useful for student-controlled learning, allowing control over the access of learning resources.

For courses where concepts are intricately linked, a linear delivery of a series of concepts may not provide the optimum outcome of learning and may produce segregated understanding of the concepts. The learning outcomes of earlier foundation courses may also be lost as students progress from year to year, if such prior knowledge is not incorporated consciously into the knowledge concepts in any course. From this respect, the courses under study were ideal for incorporating CmapTools-based concept mapping. As Ault (1985) comments, concepts signify patterns in events and connect experiences. This strength of Cmaps makes it useful for integration of geographic concepts. Classroom processes of group presentations and Cmap submissions suggest that using CmapTools to draw up connectivity of several concepts proved to be useful for integrating prior knowledge and to develop and reinforce integrated conceptual knowledge among the university students under study, and from the student responses, it appeared that the learners were encouraged to use this learning strategy for future ventures into knowledge domains.

8 Summary

Students in two Undergraduate courses in Geography used CmapTools to progressively integrate relevant prior knowledge, knowledge derived during lecturer-generated sessions and incorporated their own experiences during field-based research. This helped them to develop a holistic understanding of the many inter-related processes operating in the complex real-world geographic environment**.**

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USING CONCEPT MAPPING IN VOCATIONAL EDUCATION

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Abstract. In recent years concept mapping has become a powerful tool that is widely used in different contexts in education. This paper describes the using of concept mapping in professional education. Concept mapping is a graphic technique that represents ideas, helps to think, solve a problem, plan a strategy or develop a process. Concept mapping is used in professional education, although not so widely as in science education. The main areas of using are learning and knowledge assessment. There are many different subject fields of using concept mapping e.g. learning in veterinary and law of real property, medical and accounting education. The analysis of 311 scientific articles about concept mapping shows that in professional education this method is more used in the subject fields which are directly connected to natural or exact sciences. In professional education concept mapping is most often used in medical education and engineering education. The main area of use is as an learning tool, often combined with assessment tool. In most articles the faculty and students feedback has been positive and the authors suggested the method of concept mapping for both - further use in classroom and research.

1 Concept mapping in education

"Concept mapping is a process of meaning-making. It implies taking a list of concepts – a concept being a perceived regularity in events or objects, or records of events or objects, designated by a label, – and organizing it in a graphical representation where pairs of concepts and linking phrases form propositions. Hence, key to the construction of a concept map is the set of concepts on which it is based" (Cañas et. al. 2003).

Today concept mapping is widely and successfully applied in many different fields of education, e.g. concept mapping is widely used in science education (Behrendt et. al. 2000; Fischer et.al. 2001; Reiska 1999, 2005).

Much success has been achieved by the application of concept mapping in the teaching process to integrate new concepts into the existing system of knowledge (Novak 1990).

Beside the acquisition of new knowledge the testing of achievements is another frequently used area where concept mapping has been applied to teaching process. Outside of teaching process brainstorming and knowledge management are the most used areas of concept mapping.

2 Using concept mapping in professional education: data and method

We researched 311 scientific articles about concept mapping and found 18 in which the using of concept mapping in professional education was described. We categorized the articles based on the subject field in vocational education (e.g. accounting education and medical education) and also based on the area of use (e.g. teaching and achievement testing). Based on this information we made conclusions about using of concept mapping in different subject fields and using areas.

3 Subject fields of using concept mapping in professional education

3.1 Law education

As a learning and assessment tool in law of real property the concept mapping is used in one study with second year diploma students (Fong, E. L. S., 1999). The concept mapping method was used first by persons as the bases of discussion and then in a group work. At the end of the lecture series the concept mapping was used for assessment in final examination. Fong also studied the students' attitudes to concept mapping as an learning and assessment tool. Three fourth of the students (74%) agreed that concept mapping made learning easier for them. Fong explains the disagreed 26% with the time that students need to be able to construct the good map. For majority of students (74%) it was difficult to find the best linking word for the map. The similar majority found that concept maps helped them to understand how the different concepts in the Law of Real Property are related. Fong comes to conclusion that using concept maps assisted students in understanding the subject and revising for the examination. For using concept mapping as an assessment tool the response was not clearly positive.

3.2 *Medical education*

In professional education the method of concept mapping is mostly used in the field of medical education. Below are described several studies about using concept mapping for assessment, learning and other purposes in medical education.

McGaghie (McGaghie et al, 2000) uses concept mapping as an assessment tool and compares the medicine and veterinary students' knowledge structure gathered with concept maps with their final examination scores. They could not find the correlation between structural knowledge in concept mapping and knowledge assessed by standard examinations.

West (West at al, 2000) uses concept mapping as an assessment tool to enable teachers to find out students' knowledge at different points in training. They expected that concept mapping assessment shows changes in the conceptual framework of resident physicians during the training and they also compared the concept mapping scores with the scores of standard in-training examination. West got evidence that concept mapping assessment reflects differences in the conceptual framework (Fig. 1). However his research group could not find correlation between concept mapping scores and the standardized testing. They came to conclusion that concept mapping and in-training examination could measure different cognitive domains.

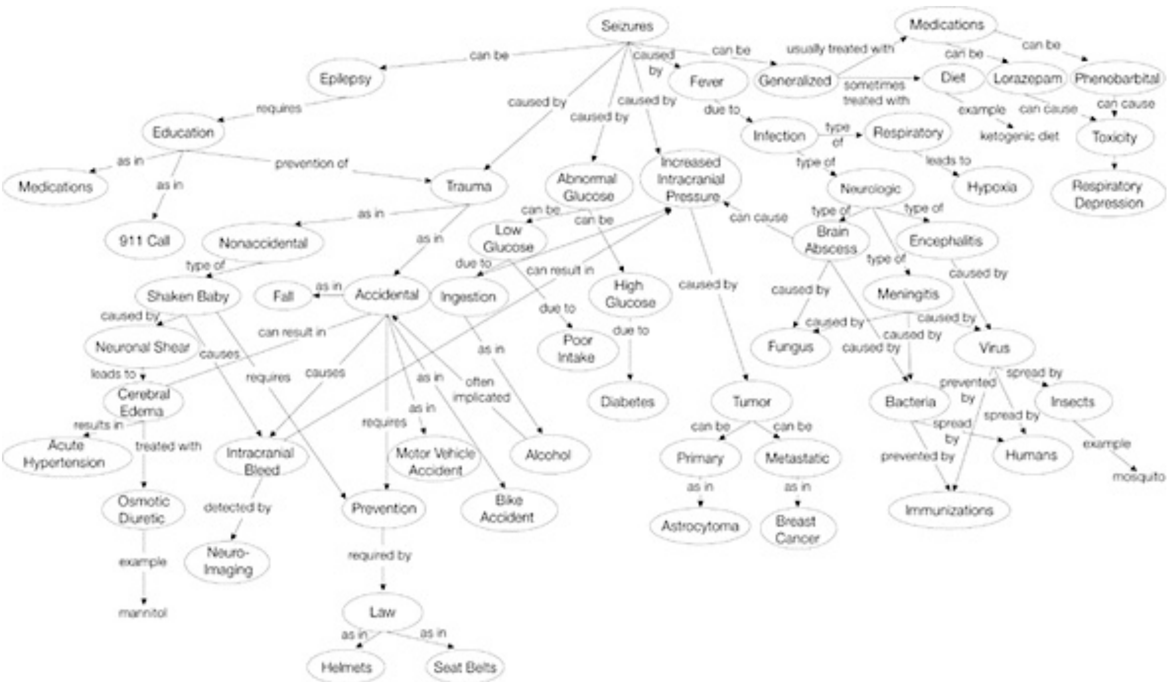

Figure 1. Reproduction of a hand-written high-scoring concept map of seizures by a resident (West at al, 2000, 1108p).

Schmidt (2006) comments the reliability and validity of concept mapping of two different above mentioned approaches using concept mapping as an assessment tool in medical education (McGaghie, et al, 2000 and West at al, 2000). Based on studies of Bordage (1994), Ericsson (1980) and others she agrees that "knowledge organization influences the efficiency and effectiveness of recall and problem solving within a domain, and that domain experts have more coherent, well structured knowledge than novices" (Schmidt, 2006, 69p). However she shows many problems connected with the reliability ("concept mapping can provide a reliable measure of something – but just what that something is remains in question") and validity ("There is no convincing evidence in any of the studies that the differences in the concept maps are actually related to differences in the ability to retrieve knowledge or problem solve as would be expected based on the theoretical foundations." Schmidt, 2006, 72p) of using concept mapping as an assessment tool. She arises couple of further research questions from which some are relevant not just for medical education (e.g. how does pre-given concepts or stimuli influence the nature of maps and are the more complex maps associated with better problem solving ability). Nevertheless the raised skepticism about the reliability and validity she admits that concept mapping as the method of developing meaningful assessment and approaches to teach can substantially advance medical education.

Jitlakoat (2005) used concept mapping as a learning tool with forth year nursing students. The purpose of use concept mapping was to develop students critical thinking skills including gathering and selecting relevant information and relating this information to the care of patient. The study was based on assumption from literature that the concept mapping is an appropriate for undergraduate and graduate students, it can be used individually or in groups and the method is useful for assisting student to think critically about relation of new information and old one. The pre- and post-test design with concept mapping as supporting learning instrument between these tests was used in the study. The result was that the differences in all scores were highly significant. Jitlakoat came to conclusion that "concept mapping is a good education innovation for assisting nursing students to summarize their own concepts and improve their nursing core competency in primary medical care." (Jitlakoat 2005, p120). Jitlakoat recommended nursing instructors to adopt concept mapping into theoretical and practical teaching process.

Ford, Coffey, Cañas et al. (1996) used concept mapping in a knowledge-based expert system NUCES. This system was developed to aid interpretation of radionuclide imaging in the hart. They used NUCES also to train clinicians. Concept maps are guides to traversal of logical linkages among clusters of related objects and they help to solve the navigation problem in hypermedia system. NUCES is intended as a diagnostic expert system and a training environment.

Daley (1996) used concept mapping to determine how first year associate degree nursing students can apply they theoretical knowledge to clinical practice. She compared three different kinds of concept maps: maps developed form students interviews, maps developed from instructor interview and maps developed from the course syllabus. After the construction of maps on the bases of students' interviews each student was asked if they like to change some concepts or linking phrases. Just one of them wanted to change the map. Daley also mentioned that using concept mapping helped to reduce the 20 page volume of one interview data to a manageable form of one concept map. As the results of the study Daley found that students had missing links between elements of nursing process, clinical preparation was not linked to preparation for the unit of oxygenation and basic anatomy and psychology concepts were also missing. From initial of the study she came to conclusion that concept mapping can be used in nursing education to bridge the gap between theory and practice by integrating basic science concepts with nursing practice. Concept maps can also be used to assess and evaluate students, to plan the curriculum.

Schuster (2000) described the using concept mapping as the tool for clinical care planning. Concept mapping helps to promote learning and critical thinking about patient problems and problem solving. Based on clinical data the students compose concept maps and the faculty can review and discuss the maps to evaluate the students' understanding. The method has been successfully used with students in their early hospital experiences. Both the students and faculty were very pleased with the results of using concept mapping in care planning.

Baugh and Mellott (1998) developed the method of clinical concept mapping (CCM) to help nursing students learn concepts and help them to apply these concepts in clinical situations. Based on Novak and Gowin (1984) they assume that concept mapping promotes critical thinking and prepares students for clinical experiences. Clinical concept mapping should help students to organize complex patient data and process complex relationship. Baugh and Mellott asked in their study the students to develop at least one clinical concept map per week for their patient clinical settings. By the evaluation of students' concept maps faculty could assess the level of their understanding and also to recognize how the students see the big picture. As conclusion of their study they suggest clinical concept mapping as effective tool to improve meaningful clinical learning and encourage both application and synthesis.

Parker-Jones and Pilkington (2002) used concept mapping as a support tool for medical students when learning from simulations. The main learning goals were to develop better conceptual understanding and diagnostic reasoning skills amongst students. They used research design with pre and post tests and experimental and control groups. Experimental groups used also simulation methods between two tests. Beside the traditional assessment method with multiple choice questions pre and post concept maps were used. After analyzing the maps it appeared that students improved their scores in post tests irrespectively if they used simulation or not. The researcher came to conclusion that although they used concept mapping as a performance measure, it has also a role in promoting reflection.

Edmondson and Smith (1998) report on efforts to facilitate meaningful learning within the context of veterinary medical education. They used concept mapping to develop an integrated veterinary curriculum, to develop case based exercises for problem based learning and as a learning tool for students working individually or in small groups. They used concept mapping for both - to design and delivery of the course and in the final examination. The use of concept mapping was well received by students and also by faculty. Students said that concept maps greatly facilitated their understanding of relevant pathopsychological mechanisms. From the faculty feedback it appeared that concept maps can help to make conceptual relationship explicit and identity errors and misconceptions in students' understanding.

Laight (2004) found in his study with pharmacology students that there was no statistically significant association between the usefulness of concept maps (self-reported by students) and preferred learning style dimensions (e.g. sensing vs. intuitive, visual vs. verbal, active vs. reflective, sequential vs. global). For that reason Laight came to conclusion that concept maps may offer flexible teaching and learning opportunities in large class teaching by teaching to all types of learners and may promote deeper student engagement and learning.

3.3 Engineering education

Turns, Atman and Adams (2000) used concept mapping for both - course-level and program-level assessment in engineering education. The goal was to demonstrate that concept maps can be a valuable tool for addressing assessment issues, which arise in engineering education. Although the authors came to conclusion that concept maps are not the "perfect assessment solution" because they require extensive time to interpret and can still give an ambiguous result, they agree that concept mapping is a flexible tool and it should be seen as a "valuable component of an assessment toolbox".

Besterfield-Sacre et al. (2004) investigated the use of concept maps to assess knowledge integration by engineering students. For analyzing the maps they used traditional counting metrics proposed by other researchers but also a holistic approach developed for these studies themselves. The holistic approach was based on results of two experts reviewing each map. From the experts' comments on the maps three categories were emerged: comprehensiveness, organization, and correctness. The holistic approach was very useful and indicated that students improved through the program but the holistic approach also enabled faculty to identify weaknesses in program. Consequently they suggested that concept maps can be an effective way to measure a student's conceptual understanding in a meaningful, reproducible and efficient manner.

Darmofal et al. (2002) used concept maps in aerospace engineering in a multidisciplinary engineering course to identify and organize main engineering concepts and to map the relations between several key ideas within and between engineering areas (e.g. materials and structures, signals and systems, dynamics, thermodynamics, and fluids). As the result of current use they assume that with the extended use of concept maps in teaching process, more systematic assessment of student conceptual understanding will be implemented.

Walker and King (2003) carried out two pilot studies to investigate the use of concept mapping for assessing students' knowledge at a given point (novice-expert comparison) and over time (comparison among students). In first study faculty generated networks were higher-order while students generated fewer connections among concepts. In the second study concept maps showed growth in individual students' conceptual understanding across time: later maps were more integrated and more differentiated. Walker and King came to conclusion that concept mapping is a useful tool to portrait the process of knowledge transformation from novice to expert. They find also concept mapping an appropriate tool of student assessment and instruction while introducing them model-based reasoning within the domain of bioengineering.

3.4 Accounting education

Leauby and Brazina (1998) adapted concept mapping to the field of accounting education. They assumed that incorporating concept mapping into accounting courses benefits both the teachers and students. They used concept mapping in teaching process but also as an assessment tool. Usually first the students constructed their own maps and after that they could compare these maps with the instructor's map. To evaluate the students' maps they used a scoring method which included quality and quantity of relations, concepts and they also took account of the hierarchy. Leauby and Brazina got generally positive reactions from students: concept maps helped students to see better the relationship among concepts and thereby supplement other learning approaches. They also came to a result that concept maps may have helped the lower –performing students to do better. Finally Leauby and Brazina pointed out eight benefits of using concept mapping which are similar to other educational areas.

Maas and Leauby (2005) described their own experiences with concept mapping in accounting classes. They introduced a step-by-step approach for implementing concept mapping in accounting education. They focused on the use of concept mapping as a conclusion to a unit of instruction. For this purpose they developed a number of ready to use maps for accounting educators. The developed step-by-step approach includes eight steps for successful concept mapping exercise in class. In their study Maas and Leauby compared traditional instructional methods with the instruction method that involves end-of-unit concept mapping activities. As a result of the study the group, which used concept mapping achieved significantly higher scores as the control group. In conclusion Maas and Leauby mentioned two constraints of using concept mapping in accounting education. The main is the big amount of time that instructors need to implement concept mapping in the classroom effectively. The second constraint is related to nature of concept mapping activities: mapping is highly individual and creative process. To discuss and evaluate the students` maps requires the ability of instructors to accept and gain comfort in this creative process, it requires instructor to become more visually oriented and possibly develop their own creative abilities.

4 Using concept mapping as a learning and as an assessment tool

In professional education the method of concept mapping is used mostly for teaching and for assessment. In one article the use of concept mapping for curriculum development in veterinary was described.. We could not find the use of concept mapping for brainstorming or knowledge management.

In most studies, which were about using concept mapping in professional education the method was used as a learning tool. The main idea of using this method is to develop meaningful learning by students. The concept mapping method was used in very different ways, instructional phases, activity forms etc. In most cases the feedback for concept mapping was positive. The main constraint of using concept mapping the time consumption was mentioned.

Besides the learning tool the method of concept mapping is in professional education widely used as an assessment tool. In some of the above described papers concept maps were used just for achievement measure but in most studies concept maps were used for both - learning and assessment.

5 Conclusions

Concept mapping has been used in professional education, although not so widely as in science education. The main areas of using this method are learning and knowledge assessment. There are many different subject fields of using concept mapping e.g. learning in veterinary and law of real property, medical and accounting education.

The analysis of 311 scientific articles about concept mapping shows that in professional education this method is more used in the subject fields which are directly connected to natural or exact sciences. In professional education concept mapping is most often used in medical education and engineering education. The main area of using the method is as an learning tool, often combined with assessment tool.
In most articles the faculty and students feedback was positive and the authors suggested the method of concept mapping for both - further use in classroom and research.

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USING CONCEPT MAPPING TO CONSTRUCT NEW KNOWLEDGE WHILE ANALYZING RESEARCH DATA: THE CASE OF THE GROUNDED THEORY METHOD

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Abstract. The paper exemplifies the use of concept mapping during the analysis of qualitative research data, and demonstrates the advantage of concept mapping to derive a grounded theory by highlighting the macrostructure of the research data. Concept mapping serves here to construct new knowledge within the framework of research data analysis and it functions as a model map, in which the map represents existing information and enables the emergence of new understandings and models.

1 Introduction

Concept map is a diagram showing interrelationships among concepts (Novak, 1995). It can make the macrostructure of information more salient, by providing a spatial representation of a body of knowledge. Within education, the literature lists three main uses of concept maps: to support learning (including its assessment), to guide teaching (planning educational content and as an instructional tool), and to organize and present information (Cañas et al. 2003). In many different studies concept mapping has been found to support and promote the exploration of concepts, thinking processes, problem solving, information recall, peer discussion, learning transfer, motivation, and more (see, for example, Nesbit & Adesope, 2005; Novak, 1998; O'Donnell, Dansereau & Hall, 2002). Can concept mapping function also as an aid to analyze qualitative research data, specifically within the grounded theory method?

Grounded theory is a qualitative research method that uses a systematic set of procedures to develop an inductively derived grounded theory about a phenomenon (Strauss & Corbin, 1990). This inductive approach follows three stages for coding and analyzing research data. The stages move from the specific to the more general: identifying key elements of the phenomenon, using an open coding (stage 1), grouping the elements into categories and identifying the interrelations among them, using an axial coding (stage 2), and creating the propositions to offer an explanation (the emergent theory) of a phenomenon, using a selective coding (stage 3).

2 Purpose

The following paper exemplifies the use of concept mapping during the analysis of qualitative research data, and demonstrates the advantage of concept mapping to derive a grounded theory by highlighting the macrostructure of the research data.

3 Study Context

The original study was a self-study on the use of "think-alouds" in teacher education, conducted by the first author. Pinnegar defines self-study as "a methodology for studying professional practice settings"(Pinnegar, 1998, p. 31). Studying teacher education practices via self study is geared towards developing a better understanding of particular pedagogical situations. Self-study methodology has "used various qualitative methodologies and has focused on a wide range of substantive issues" (Zeichner & Noffke, 2001, p. 305). Being teacher educators and researchers, we examined in this study the use of think-alouds (during class and in an electronic blog's posts), and also examined their contribution to the learning of the student-teachers (The self-study on the use of think-alouds by teacher educators was conducted in collaboration with Tom Russell from Queens University, Canada and Amenda Berry from Monash University, Australia).

Think-aloud is a meta-cognitive strategy in which a person thinks explicitly about his thinking processes. Teacher educators use think-alouds to assist their student-teachers to understand how teaching and learning interact by overtly presenting aspects of their pedagogical decision making and putting these forward for discussion, analysis and criticism (Loughran, 2006). In the current study, we examined the use of think-alouds and their contributions to the learning of student-teachers, who participated in a course on learning disabilities taught by the first author during the school year of 2007-8.

4 Procedure

We collected protocols of the think-alouds done by the first author in her class, using audio-recording. The think-alouds and her reflections about them were re-written as electronic posts and were published in a "think-aloud blog" that she opened on the internet (www.takaye.blogspot.com). Her student-teachers were invited to enter the blog site and add their comments to each of the teacher educator's posts. Their comments reflected their thoughts, feelings and insights regarding the issues the teacher educator raised in her posts, the value of the think-aloud to their learning to teach, and whether they used, or consider using think-alouds in their practice, when and how. One of the posts, and the students' comments to it, served as the basis for the data analysis in the current paper:

On March 25, 2008 the electronic post on the "think-aloud blog" was titled "between rigid planning and flexible response" and it dealt with the tension between planning and being responsive in a teaching situation. Berry (2007) describes this tension as emerging "… from difficulties associated with implementing a predetermined curriculum and responding to learning opportunities that arise within the context of practice" (p. 120). In this post the first author described a class event in which her teaching plan for the lesson was found to be inadequate (many of the students did not bring with them their textbooks, on which class discussion was planned to follow). Although some class murmurs were evident, the teacher educator kept reading out loud the text as the basis for a further class discussion. In her post she described the event, detailed her considerations to follow the original lesson plan and ended with the following reflection and question: "In my think-aloud in class I brought up my thoughts and my considerations to follow the original lesson plan and not to change it. I was also aware of the contradiction between my planning and my inflexible response. I think that I should have been more responsive to what was happening in class and make on-the-spot changes to my lesson plan. As new teachers would you consider involving your pupils in your considerations to change (or not to change) a lesson plan? Which difficulties do you expect to encounter using such think-aloud in class?"

5 Data analysis

To qualitatively analyze students' comments to the above post, we chose to use concept mapping. Eight student-teachers commented to the post, and the analysis of their comments facilitated our understanding of their perceptions regarding think-aloud as a teaching method. Each step in the qualitative analysis procedure followed the coding stages for analyzing research data using grounded theory method (Strauss & Corbin, 1990):

Stage 1 - **Identifying key elements**: We identified the key elements in each student-teacher's comment, using an open coding. For example, in Comment 1 we identified the following eight elements: (1) Readiness to use TA (think-aloud), (2) TA may allow more attention to the pupils' reactions and suggestions, such as getting feedback from pupils regarding instruction; (3) TA may increase collaboration with pupils, which can improve them as pupils and people (4) TA may increase the pupils' activeness, attention, and responsibility (5) Expressing increased willingness to use TA in class (6) Not sure about introducing TA in the teaching practicum: should or should not, as (7) The teaching occurs under the supervision of another teacher, and in her home class (8) Should consult the mentor- teacher if considers using TA in the practicum. (See Table 1 for the translation of the Comment into English. It was originally written in Hebrew).

Stage 2 - **Grouping into categories and identifying interrelations**: We grouped the elements in each comment into categories, and identified the interrelations among the categories, by drawing a concept map. The following concept map was drawn for Comment 1 (Figure 1). The starting element in the map was element 1, which was supported by reasons in elements 2, 3, & 4. Element 1 led to element 5, following the explication in the comment, and so forth. All the interrelations are explicit in the comment, except the relationship between elements 5 and 6, which we inferred. Also, the categories (a) and (b) were inferred. The following map indicates the inclusion of each element using the numbered key elements.

The comment was written by a student teacher in response to a post about the tension between planning and being responsive in a teaching situation. The post was part of a teaching blog published during the school year of 2007-8, in the internert (www.takaye.blogspot.com). The following comment was written in Hebrew and was translated into English

"In response to your question, I will be glad to use think-aloud about aspects of planning the lesson. Why? Because I would like to listen to the reactions and suggestions of my pupils, so I could internalize what they had to say and listen to their suggestions. I think that by doing so I can achieve two purposes:

1. A feedback from my pupils about my instructional method, which can be always beneficial
2. I grant them responsibility for their learning. When I give them the power to speak up and to suggest, they become responsible for what happens next.

My thinking (the internal one this time) about it increases my will to try it in class: to think-aloud in front of my pupils about the instructional method and then to apply some of their suggestions and to check in the following lesson whether the power granted to them regarding which instruction to use would actually improve their activeness and attention in the next lesson.
My hypothesis is: yes. If we, the teachers, cooperate with our pupils regarding the instructional methods via our think-alouds, we will change their status to become responsible and serious partners for their learning. This way we will change them into better pupils and even better persons in the future. Also, these things connect to self advocacy and reciprocal teaching – taking responsibility, giving pupils the power and all that it means.
Now I am left to ask: will I be able to try it in my practicum class, or maybe I cannot add new/innovative teaching methods to a class of another teacher? I will have to consult about it with my mentor-teacher, of course.
In case she will say that I can do it, I will be glad to try it in my next language arts lesson and share with you in the blog the consequences."

Table 1: Comment 1

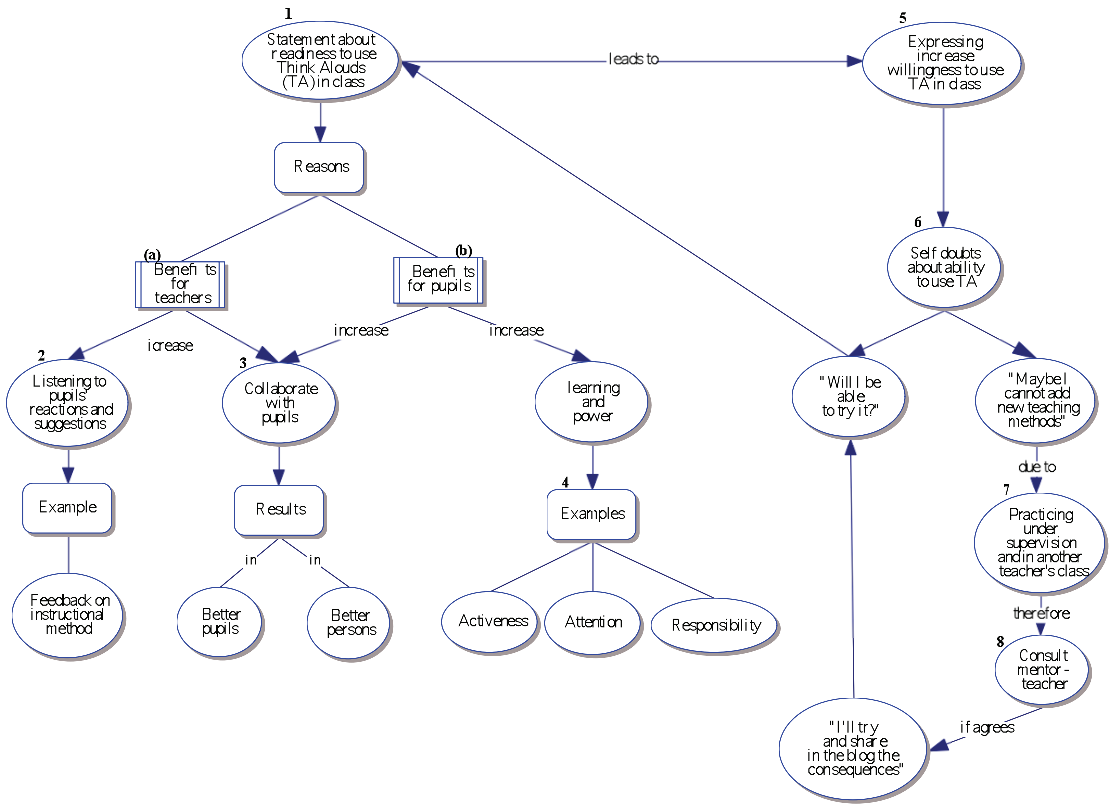

Figure 1: Concept map of comment 1: Using think-aloud in class

To verify the reliability of the procedure we followed stages 1-2 with two independent coders. In stage 1 the first coder identified seven elements and the second coder identified eight elements (of which seven elements overlapped with the first coder), resulting in an agreement of 88%. In a conference we decided to accept the second coder's set of elements. Based on these elements, each of the two coders constructed independently her own map. The first coder's map included 38 objects (nodes + relations), and the second coder's map consisted of 47 objects, resulting in an agreement of 81%. In a conference the two coders accepted the second coder map which is presented in figure 1.

Stage 3 - Creating the propositions to offer an explanation: We followed stages 1-2 again, but now the basic "texts" were the concept maps we drew for each of the eight comments. From these maps we extracted a list of four propositions/themes that served to construct of the macro-structure, the grounded-theory map. The propositions were those themes that appeared in several students' comments, and consisted of: (1) TA means to engage pupils in the pedagogical reasoning and decision making of the teacher (2) TA enables changes in student-teachers' attitudes about teaching, such as: (2a) recognizing the complexity of teaching (tensions within the practice, advantages & disadvantages of an instructional method) and (2b) identifying with the teacher's role (teacher is vulnerable and she can make mistakes) (3) Teacher's TA signifies her teaching ownership, which is based on (3a) holding her own classroom, (3b) feeling confident about the lesson plan and (3c) showing competence using teaching strategies (4) The role of the teacher within her teaching context is an important factor influencing the perceived feasibility to enact TA in class: whereas teacher educator (4a) and practicing teachers (4b) are perceived as presenting a sense of teaching ownership, and therefore can practice think alouds in their classes, the student – teacher (4c) is perceived as not holding this sense of teaching ownership and therefore needs to consult the mentor teacher about the possibility of using TA while practicing teaching.

Constructing and linking these themes within a concept map facilitated the emergence of the grounded theory, and assisted in forming an explanation to the studied phenomenon, that is: the use of think-alouds in teaching as an issue of teaching ownership. The following map (Figure 2) illustrates the emergence of a grounded-theory about "teaching ownership".

6 Discussion

One of the common uses of concept mapping is to organize and present information for instructional purposes (see Cañas et al. 2003). This paper shows a new use for concept mapping, in which it functions to *construct new knowledge within the framework of research data analysis*. The concept map does not only represent existing information but it also enables the emergence of new understandings and models. Creating a concept map facilitated our ability, as researchers, to internalize the new information; to deepen our understanding of the emerging themes; and it enabled us to look for the interrelations among those themes towards building a model. This process guided us to make inferences, beyond those articulated on the surface. By constructing the stage 3 map, we were able to provide a possible explanation to the phenomenon of using think-alouds by teachers, and that led us to develop an emergent grounded theory about the sense of teaching ownership as a factor in learning and in using new teaching methods, such as think-alouds.

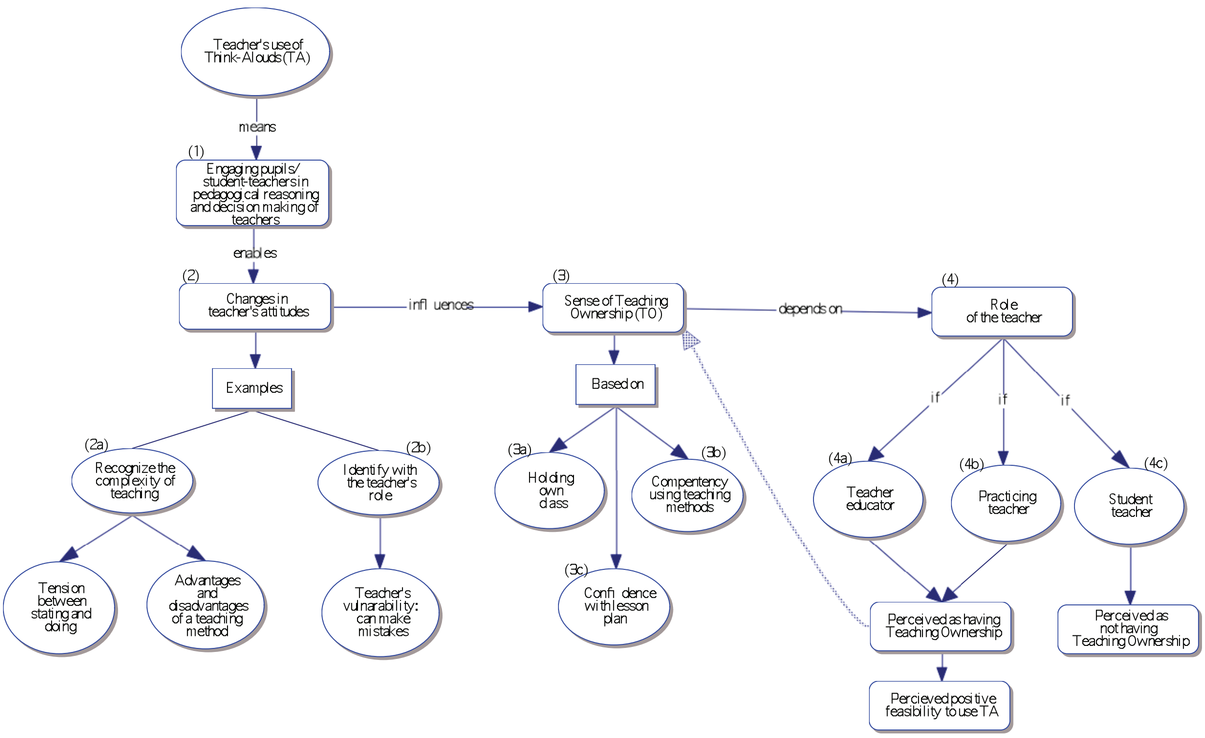

Figure 2. Concept map: The emergent grounded theory about teaching ownership

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USING CONCEPT MAP TO ASSIST THE DEVELOPMENT OF INSTRUCTIONAL MATERIAL FOR EDUCATIONAL HYPERMEDIA SYSTEMS

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Abstract. This paper presents a methodology for using concept map to develop instruction material based on DAPHNE model for modeling educational hypermedia systems. DAPHNE methodology presupposes the use of concept maps in the pre-authoring phase but it is not explicit how to apply it. A complementary approach was proposed in this work, which states how to use concept map to design instructional material and how this proposal is useful in a context of cooperative work among many people. A case study for a course to teach Hypermedia Systems illustrates how to use the proposed methodology.

1 Introduction

Developing educational hypermedia systems has been the target of some research works over the last years. To develop these systems it is necessary to carry carefully out the planning of the content to be included in such systems. A good content stimulates both the process of learning and the acquisition of knowledge. With respect to a hypermedia system, its author usually creates directly and informally without any planning at all a hyperdocument, which is stored in a persistent repository called hyperbase.

In order to help the author to plan previously hyperdocument contents, some models and methodologies were developed. Fernandes and Santibañez (1999a, 199b) propose that the development of hypermedia courses can be seen as a process of three phases: pre-authoring, authoring and presentation.

The pre-authoring phase helps the author to plan and to model the content of the course (hyperbase) according to models and appropriate methodologies. Pre-authoring is the most important phase, because it helps the author of a hypermedia course to capture relevant parts of the content and to structure the information according to educational strategies and objectives. During the authoring phase, the author can create the hyperbase and related guided-tours as planned in the pre-authoring phase, based on the hyperbase designs and guides-tour designs for a given course.

During the presentation phase, the learner can navigate through the hypermedia course trying to attain the instructional objectives of the course. The learner can follow the course in compliance with what was planned and implemented by the authors. The hyperbase allows, if needed, free exploratory navigation, while guided-tours are susceptible of guided navigation (Fernandes and Omar, 2001).

To support the pre-authoring phase of hypermedia courses it was adopted the DAPHNE methodology (Kawasaki, 1996), which combines concept maps (Novak, 1998) and information maps (Horn, 1989; Romiszowski, 1981) to model the hyperbase considering didactics and educational aspects. DAPHNE methodology presupposes the use of concept maps in the pre-authoring phase but it does not provide explicit guidelines on how to develop them.

Concept maps have been broadly and successfully used by students as a learning tool regarding to the process of studying in a constructive way, providing a shorthand design for organizing ideas and assessing the learner's grown of knowledge after instruction. From another perspective, this paper analyses strategies for using concept maps to build instructional material to attend instructional objectives of a certain courseware. Concerning instructional material the challenge is to reach instructional strategies that have a high probability of enhancing student achievement for all involved students in any subject domains.

Thus, the main goal of this paper is to present the methodological experience used in developing educational hypermedia systems using concept maps as a basis to prepare instructional material. The pre-authoring phase for a course to teach Hypermedia Systems was developed and used here as a case study to exhibit the approach proposed for developing the concept maps.

The remainder of this paper is organized as follows. Section 2 presents related work. Section 3 presents the approach proposed for the development of instructional material. Finally, Section 4 presents some conclusions.

2 Related Work

This paper's focus is not concerning models and methodologies for designing educational hypermedia applications as DAPHNE methodology was adopted for the case study. In fact, the focus is concerning concept map literature.

Concept maps are usually applied in classroom for instruction and assessment in order to improve the learner's learning, (Novak et al., 2000; Dempsey and O'Sullivan,, 2005).

Concept maps were also used to assess how well students achieved instructional goals (Ruiz-Primo et al., 1996; McClure et al., 1999; Williams et al., 2004; Rebich et al., 2005).

Clark et al. (2004) describes a related method for designing a structural geology course by using concept mapping. But the course developed is a traditional one, not a hypermedia system, as intended by DAPHNE methodology.

3 An Approach for Developing Instructional Material

Instruction material includes the *contents* for a certain subject domain and related *assessments* to measure intended learning outcomes according to defined instructional objectives.

To develop the instruction material, Daphne pre-authoring phase proposes to start by defining concept maps for the subject domain (Kawasaki, 1996). Based in the instructional objectives and the subject domain concept maps, the pre-author is able to develop hypermediatic guide-tours for the subject domain.

The main contribution of this work is to allow the definition in advance of Instructional Objectives and Course Curriculum to guide carefully the design of Concept Maps. Thus the following sequence is proposed:

1. Definition of Instructional Objectives (IOs)
2. Definition of the Course Curriculum (CC)
3. Development of Concept Maps (CMs)

Defining IOs establishes a direction for the learner's learning. Once understood the set of IOs, the next step is to accomplish a brainstorm to determine the CC based on each stated instructional objective. After the IOs and CC's steps, the concepts involved in a certain subject domain can be established and related in CMs.

3.1 Definition of Instructional Objectives (IOs)

The first step in our approach is to define instructional objectives (IOs). This is important because the set of IOs determines what is to be learned in a specific and observable form and provide measurable learning outcomes.

Defining IOs have a lot of advantages for learners, namely:

- They help them to emphasize important points.
- They assist them when studying significant concepts.
- They aid them to study more efficiently.
- They guide them to what is expected from them.

Besides being a description of expected learners' performance, since objectives tell learners to what is expected of them, OIs help an author to define the content to be seen by learners. Defining what is expected to reach in terms of learning outcome, it is possible to infer from the set of IOs what is necessary to the learner to learn and satisfy the instructional objectives; in other words, the set of IOs indicates all the content to be learned. IOs are also the first effort to define the course curriculum.

Well-developed IOs must use statements that define skills, knowledge and attitudes expected from learners as a result of a learning activity. It is strongly recommended that sentences stating IOs must use action verbs that are observable and measurable, such as in the following examples:

- "Learner will define a Hypermedia System."
- "Learner will list navigational strategies."
- "Learner will differentiate navigational strategies."

Accordingly, it is strongly recommended that sentences stating IOs must avoid using hard to observe and measure verbs, such as in the following examples:):

- "Learners will understand the importance of a Hypermedia System."
- "Learners will be familiar with navigational strategies."

Bloom (1956) categorized verbs by three domains of learning as follows: cognitive domain emphasizing thinking; affective domain highlighting attitudes and feelings; psychomotor domain featuring doing.

This work have taken into account only the cognitive domain, which is further divided into six categories, namely, Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation, as showed in Figure 1. These six categories are grouped into the following three levels (Waller, 2008):

- Level 1. Recall – Knowledge and Comprehension – It is at the basic taxonomic level and involve recall or description of information.
- Level 2. Interpretation – Application and Analysis – It is a higher level of learning and involves application and examination of knowledge.
- Level 3. Problem-Solving – Synthesis and Evaluation – It tests the highest level of learning and involve construction and assessment of knowledge.

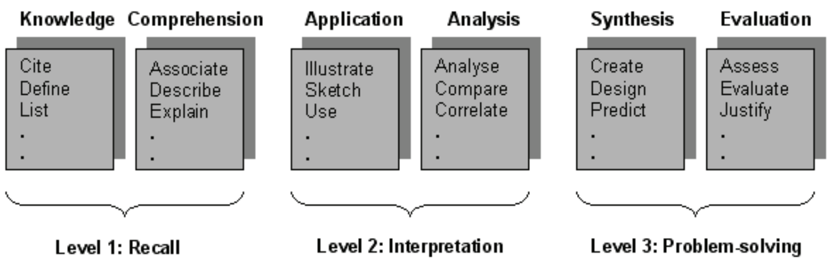

Figure1: The six categories of cognitive domain grouped into three levels.

IOs are a well-arranged pathway that will make it possible to meet the higher-leveled objectives and is mainly the foundation upon which it is possible to build appropriate learning activities and related assessments.

When no set of IOs are defined, there is no basis for the selection or designing of instructional materials, content, or methods. It is difficult to prepare instructional material if it is not available well-defined learning outcomes. Well-defined IOs emphasize important points and reduce non-essential instructional material [Mager, 2003].

3.2 Definition of the Course Curriculum (CC)

Identifying IOs make it easier for assisting the organization of the study program or course curriculum (CC). But how to do that? The idea is creating related concepts for each defined instructional objective.

For clarifying the idea, a case study of a courseware about Hypermedia Systems is used. Table 1 presents some IOs for such a courseware using verbs from Level 1 and 2 and respective contents or concepts in CC.

The set of IOs for Level 1 (Recall) points out simpler and less complex concept maps (CMs) in comparison to the ones for Level 2 (Interpretation). It is almost direct to identify the involved concepts when reading a sentence from the set of IOs. The advantage of using the set of IOs is that from the sentences is possible to infer the relevance of a concept and how deeply it must be focused.

Table 1: Some instructional objectives and study program concerning Hypermedia Systems courseware.

Instructional Objectives (IOs)			Course Curriculum (CC)
Level 1: Recall	Knowledge	Cite types of links. Define node. List media resources. Define hypertext. ….	Node Media resources Link (Simple, Bidirectional, Direct) Anchor Nonlinear reading Hypertext Hypermedia Hyperdocument Hyperbase Semantic Network
	Comprehension	Explain hyperdocument. Describe components of hypertext. Associate hypermedia, hypertext, hyperdocument with links. ….	
Level 2: Interpretation	Application	Sketch a guided-tour. Use backtracking, bookmarks in a browser. Illustrate navigation structures. ….	Structure Sequential, Hierarchical, Network Browser Research, Consult, Navegation Implementation strategies Depth-first, Breadth-first Navigation aids mechanisms Backtracking, Sneak preview Highlighting links, Unique anchors Bread crumbs, History list Bookmarks, Fish-eye views Birds-eye views, Guided tours
	Analysis	Analyse navigation strategies. Compare fish-eye-view and bird eye-view. Correlate hyperdocument and navigation aids mechanisms. ….	

3.3 Defining Concept Maps (CMs)

How to leap from IOs and CC to CMs is the focus of this work. This is reached by answering the two following questions to overcome when creating a CM (Novak, 1998):

1. Getting stuck in the process of creating a concept map, usually at the beginning or after a certain number of concepts were created because of the apparent freedom.

2. Tending to create shallow concept maps that either describes too little or too much and in which the relationships between concepts are rarely named, making it difficult to understand their nature.

A Solution for Question 1

The set of IOs and CC provides a bulk of concepts to be sketched in a CM avoiding the problem of starting the map and the difficult of selecting and organizing the concepts in a certain domain.

The problem of freedom in building a CM is surpassed drawing only concepts stated in the set of IOs. Thus the apparent freedom is controlled by the essential concepts established in IOs' sentences. The set of IOs for Level 1 Recall (Knowledge) indicates some basic concepts, which can be described by some CM like the ones illustrated in Figure 2. Only necessary concepts in a certain moment are drawn. Like a spider weaving its net, nodes in a CM are getting increased and being connected among each other, depending on how deep must the subject be viewed. Figure 3 illustrates a merging among the three concepts presented in Figure 2.

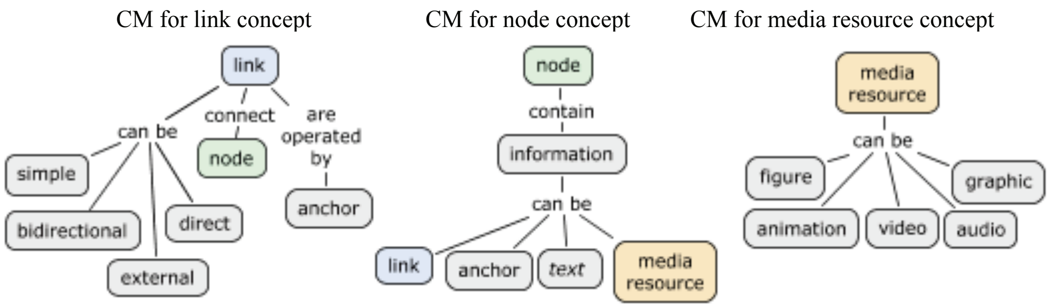

Figure 2: CMs related to Level 1 Recall (Knowledge) for the concepts of link, node and media resource.

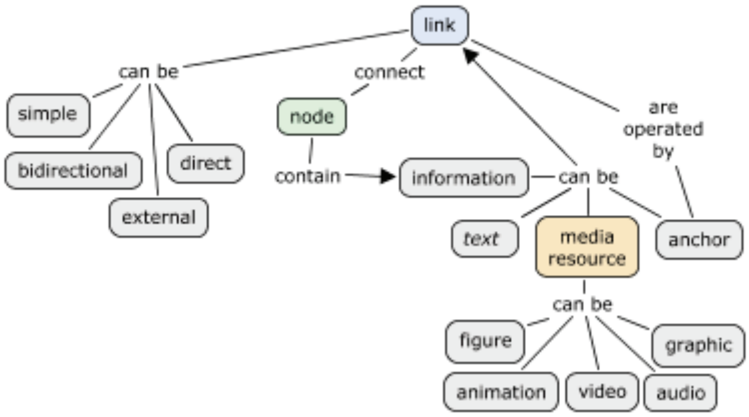

Figure 3: The merging among the three concepts presented in Figure 2.

A Solution for Question 2

Each level of IOs defines the complexity of each CM. So, this may serve as a guide to define how complex the concepts must be in each phase of a course and consequently how they must appear in the set of CMs. Level 1 Recall (Comprehension) has a higher complexity than Level 1 Recall (Knowledge) as it requires more details about concepts to reach the instructional objectives. This behavior appears step by step until the last level of IOs. Figure 4 shows some new concepts from Level 1 Recall (Comprehension) and Figure 5 illustrates these new concepts together with those from Level 1 Recall (Knowledge) presented in figures 2 and 3.

As a solution to the problem of unnamed relationship between concepts, it is strictly necessary to follow the argument mentioned before. This amounts to say that the set of CMs must be build based on the related concepts defined in IOs and CC. As a result, the relationship between concepts can be automatically deduced.

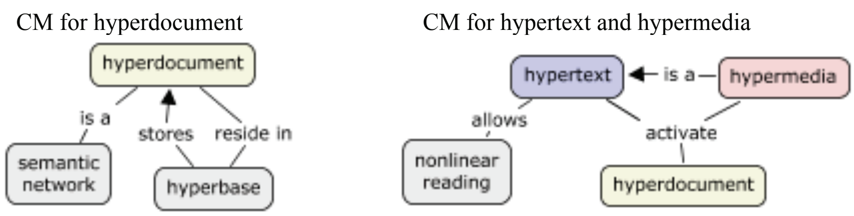

Figure 4: CMs related to Level 1 Recall (Comprehension) for the concepts of hyperdocument, hypertext and hypermedia.

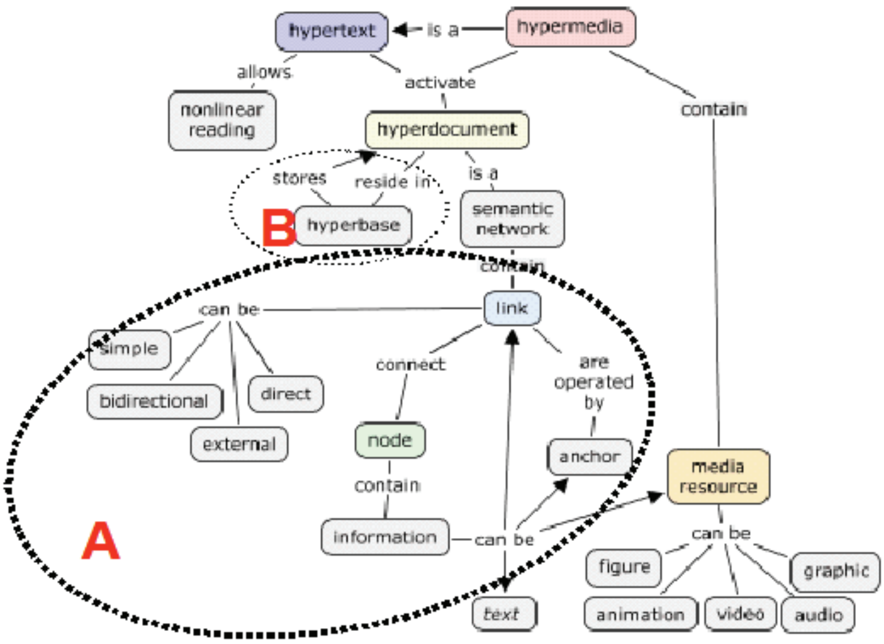

Figure 5: Merge between concepts presented in figure 3 and 4.

3.4 *Meaningful Learning, Advance Organizers and After-the-Fact Organizers*

Our approach also provides useful information to reach meaningful learning. According to Ausubel (1963), learning is based upon the kinds of superordinate, representational, and combinatorial processes that occur during the reception of information. A primary process in learning is subsumption, in which new material is related to relevant ideas in the existing cognitive structure on a substantive, non-verbatim basis. Cognitive structures represent the residue of all learning experiences; forgetting occurs because certain details get integrated and lose their individual identity.

One of the instructional mechanism proposed by Ausubel is the use of advance organizers, which must be introduced in advance of learning itself, and are also presented at a higher level of abstraction, generality, and inclusiveness. Since the substantive content of a given organizer or series of organizers is selected on the basis of its suitability for explaining, integrating, and interrelating the material they precede, this strategy simultaneously satisfies the substantive as well as the programming criteria for enhancing the organization strength of cognitive structure. CMs can be used as advance organizers to improve learning achievement as showed by Willerman et al. (2006) and Kawasaki (1996).

Kawasaki (1996) classifies the concepts in CMs, according to the instructional objectives, in three groups: prerequisite concepts, instructional concepts and complementary note concepts. Instructional concepts are all concepts related to at least one instructional objective. Prerequisite and complementary note concepts are not directly related to any instructional objectives.

For instance, in Figure 5 the region labeled A could constitute a set of prerequisite concepts for learning the concept “semantic network”, which is related to an instructional objective. Due to that, this set of prerequisite concepts could constitute an advance organizer. In this case, it is assumed that all information about the concept of “link” learned in previous course should be known before learning the concept of “semantic network”. If a learner have not attended the previous course or are unable to remember this set of concepts, then the learner can resort to the correspondent advance organizer.

In an analogue way, the region labeled B in Figure 5 could constitutes a set of complementary notes, meaning a set of concepts devised to enrich the learning of instructional concepts. Suppose the learner, after have learned the concept “hyperdocument”, satisfying an instructional objective, want to know more about this concept, then the learner can study the concept “hyperbase” in order to complement the instructional objective, substantially enhancing and supplementing the experience of learning the concept “hyperdocument”. In contrast to the term “advance organizer”, this educational artifact can be named “after-the-fact organizer” or “complementary organizer”.

On the other hand CMs can be indirectly suggested by instructional materials, which were developed with basis on them, and the learner can reach a meaningful learning on the basis of these two principles:

1. The most general ideas of a subject should be presented first and then progressively differentiated in terms of detail and specificity.

   For instance, in Figure 2 is stated that “link connect node” and “link are operated by anchor”; on that CM there was no mention about the relation between “node” and “anchor”, as this is a general idea of the concept “link”. The connection between them is presented later in a more detailed map, after the merging of the three CMs, illustrated in Figure 3: “node contain information that can be anchor”.

   The same way, general to specific ideas are presented in the instructional material like they are presented in the levels of CMs.

2. Instructional materials should attempt to integrate new material with previously presented information through comparisons and cross-referencing of new and old ideas.

   For instance, in Figure 4 is presented the concept “hyperdocument is a semantic network”. Further in Figure 5, the concept “semantic network” is connected to the concept “link”, which was previously presented, therefore integrating new material with previously presented ones.

4 Conclusions

This paper presented an approach for creating concept maps to be used in developing instructional material based on DAPHNE model for modeling educational hypermedia systems. DAPHNE methodology presupposes the use of concept maps in the pre-authoring phase but it is not explicit how to create them. Through a case study for a course on Educational Hypermedia Systems the approach was illustrated.

The case study showed that the approach made the efforts of defining concepts maps easier and more complete. But additional work must be done to improve and validate entirely the approach, concerning several aspects: refining concept maps according to instructional objectives, cooperative development of concept maps in this pre-authoring context and a tool for helping the pre-author to define concept maps according to the approach.

5 Acknowledgements

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USING CONCEPT MAPS TO BRIDGE EMPIRICAL AND EXPERT KNOWLEDGE

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Abstract. In their daily complex environment, professional practitioners reason out their actions on the basis of both theoretical models derived from formal research and the model of reality they shape through their own reflective practice. Such is the case in education where the links between theoretical knowledge and reflective practice are not always obvious. An exploratory study seeks to shed light on the relation between the findings of a metasynthesis of results from experiments in the field of IT in pedagogy and the models by professional experts regarding the determinants and conditions of successful IT pedagogical integration. The use of concept maps to convey the complex and dynamic knowledge involved, especially through a refined vocabulary of verbs to help formulate the propositions, facilitates the comparison of the theoretical and experts' models. The qualitative data (concepts and propositions) is submitted to an analysis loosely inspired by the grounded theory in ethnography. The analysis shows an important overlap and convergence in both theoretical and expert knowledge. It also highlights certain original concerns of the experts, suggesting new avenues for research. Action-research seeks to disseminate and validate the heuristics contained in the metasynthesis and the experts' models among the community of professional practitioners engaged in pedagogical integration. Here too, the use of concept maps proves instrumental in supporting effective discussions.

1 Introduction

The daily life of professionals is not best described as routine work, but rather as challenging decision-making in complex situations. Given these conditions, a professional's action is usually based on heuristic reasoning rather than the explicit application of rules in an algorithmic mode. What references orient the reasoning of professionals in a context of highly unpredictable conditions? Through their initial and ongoing education, professional practitioners have access to formalized or theoretical knowledge generated by research that is basically conducted under quasi-experimental conditions. But professionals also call upon their own model of reality, which they shape more or less consciously in their reflective practice. Such is the case in the teaching profession (Schön, 1983) where, at times, these two sources of knowledge, empirical research and reflective practice, are thought of as discrete, or even conflicting. Boutet (2004) argues that theory, which arises out of empirical research, is not opposed to practice, which produces driving constructs, especially in education: "… there is no precise boundary between experience (Aristotle's world of the senses) and thought (Plato's world of reason), but rather a complex interplay that we must dwell on in order to gain a better understanding of human development"[1] (p. 5).

In the application of information technologies (IT) to teaching and learning, it is necessary to establish a dialogue between theory and practice, one of only many such examples. Many principles can be derived from experiments on learning carried out using rigorous protocols and best practices for integrating IT into the classroom. At the same time, in this completely new, rapidly-changing field, expert practitioners are accumulating experiential knowledge which provides them and their colleagues with more and more specific prescriptions for action. The purpose of this paper is to present the first steps of action-research that seeks to create a bridge between empirical and expert knowledge in the field of pedagogical integration of IT.

2 Relevance in view of previous work

Barrette, commissioned by the Association pour la recherche au collégial (ARC), recently conducted a metasynthesis (2004a; 2004b; 2005; 2007) of the results of 32 empirical studies on IT integration into teaching/learning that took place in the college network in Québec, Canada between 1985 and 2005. The reports were assembled, analyzed and synthesized following Miles and Huberman guidelines for cross-case analysis (1994) in order to establish a causal model of the effectiveness of IT integration into teaching/learning. The partial conclusions derived from the small corpus of 32 reports were compared and validated with those proposed by the Center for Applied Research in Educational Technologies (2005). The results help identify theoretical principles that should be considered, if not followed, in any project designed to introduce IT into the teaching/learning process (Barrette, 2007).

Of course, as Cathy Ringstaff and Loretta Kelley (2002) assert: "… measuring the impact of technology use on student achievement is fraught with difficulties. Classrooms are not experimental laboratories where scientists can compare the effectiveness of technology to traditional instructional methods while holding all

[1] Translation

other variables constant." Joy II and Garcia (2000) meticulously examined all the conditions that must be established in order to conduct conclusive experiments on the impact of IT on education. They maintain that it seems practically impossible to ensure that all these conditions are present at once, and even if they could be, this would result in a situation so far removed from students' and teachers' current practices that the conclusions one might draw might not apply.

These methodological, almost epistemological, limitations bring to the fore the importance of confronting theories derived from empirical research with knowledge formalized by experienced practitioners, so that both theoretical models and experts' constructs can generate greater effectiveness in solving complex problems. In the words of Boutet (2004): "In every profession (and, we might add, *especially* in professions in which science still imposes few prescriptions), the practitioner's actions cannot be reduced to applying the results of research that was carried out in experimental conditions to real-life situations. On the contrary, the teaching professional very often grapples with singular, unstable problems and must construct their meaning before even attempting to solve them; the solutions to these problems are multi-pronged and normative rather than unique and objective. That is why Schön (1987) stresses the need for examining the practitioner's actions to discover the knowledge hidden in them"[2] (p. 4-5). It is reassuring that the hidden knowledge of practitioners can be brought to light. Boutet (2004) says that expert experience "manifests itself publicly in the individual's words and behaviour."[3] (p. 5). Concept maps can be seen as valuable tools in the process of eliciting and making explicit the *hidden knowledge* of the expert practitioner.

In 2007, in response to the need to create a bridge between empirical and expert knowledge, Barrette undertook to compile experts' knowledge in the field of IT integration into teaching, and to help formalize representations of the determinants of the effects of this integration on student success. The goal of this exploratory research is to answer the question "How does the model set out in the metasynthesis of empirical research relate to the constructs resulting from the reflective practice of experts on the integration of IT into teaching?" Do these two sources of guidelines for professional heuristics converge? Do they complement one another? Do they contradict one another"?

Initially, four experts were retained: two women and two men who had at least ten years of experience in the Québec college network, either as teachers or as educational advisers, who had participated in projects concerned with the integration of IT into teaching/learning, who had carried out research actions or experimental research, and who had published on the subject.

3 Concept maps used to connect empirical knowledge with expert knowledge

To facilitate the comparison of empirical models with expert models, concept maps have been constructed with the software CmapTools (Cañas et al., 2004) and used according to both the recommendations of researchers at the Institute for Human Machine Cognition and the rules of the Copilot method (Barrette & Regnault, 1992). Concept maps are diagrams that simplify the expression of complex relationships within a field; they therefore serve as knowledge maps. Béatrice Pudelko and Josianne Basque (2005) provide the following generic definition: "A knowledge map is a sphere of knowledge represented in the form of a network of graphic objects, developed according to a pre-established representation convention"[4] (p. 1). Novak and Cañas (2006) specify some of these graphic conventions: "Concept maps … include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts.… Propositions are statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected using linking words or phrases to form a meaningful statement." (p. 1).

Many studies and experiments have already demonstrated that the use of concept maps facilitates the expression of expert knowledge (Coffey *et al.,* 2002), as evidenced by their use in management (Cossette, 2003). The expression of empirical and expert knowledge in the form of concept maps makes it easier to achieve the research objective, which is to connect these two fields of knowledge from different sources, provided that this expression is sufficiently formalized that maps can be compared with each other. With the method used, these requirements are met.

[2] Translation
[3] Translation
[4] Translation

3.1 Method

The conclusions of the metasynthesis of 32 reports on experiments on integrating IT into teaching identify relationships among some of the factors that characterize the integration experiments that were successful in helping students achieve better learning. It is relatively easy to translate these relationships into a concept map, with nodes consisting of factors and effects, and links showing their relationships. This map is constructed in accordance with formalistic principles advanced by Joseph D. Novak and Alberto J. Cañas, and by the Copilot method. The same principles apply to experts' maps, thereby facilitating their comparison.

3.1.1 Formalistic principles followed in the construction of concept maps

3.1.1.1 Constructing a focus question.

Novak and Cañas (2006) maintain that the most useful concept maps are those that express dynamic, complex and contextualized knowledge. For this, they recommend that the map answer a focus question: "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 have to resolve. Every concept map responds to a focus question, and a good focus question can lead to a much richer concept map." (p. 7). This strategy, one of several avenues for creating rich, complex maps, was tested and validated by Derbentseva, Safayeni and Cañas (2006).

It is rather easy to construct the focus question answered by the metasynthesis conclusions expressed in a concept map: "What are the main determinants (causes and conditions) that must be taken into account in order to ensure that the use of IT in the classroom has a positive impact on student outcomes?"

3.1.1.2 Expressing links in the form of phrases

As specified by the above definition by Novak and Cañas, a concept map contains both concepts and links; the combination of two concepts and the link relating them constitute a proposition. This often gives rise to the suggestion that verbs be used as labels for links, and that arrows be used to indicate reading direction: "Concept Maps are a graphical two-dimensional display of knowledge that is comprised of concepts (usually represented within boxes or circles), connected by directed arcs encoding brief relationships (linking phrases) between pairs of concepts." (Cañas et al., 2005. p. 2-3). Here, the proposition takes the form of a simple phrase consisting of a subject, a verb and an object.

It appears this suggestion has been taken up, especially in cases where maps are analyzed and evaluated: "Much of the research on concept maps has scored them by analyzing propositions, that is, by extracting node-link-node combinations. In directed graphs, which are networks in which the link is directional (arrows), the propositions are clearly analogous to the subject-verb-object structure of sentences. Propositions are then typically scored against a template of propositions considered correct. In open-ended domains such as design process, there is no one right answer. In such circumstances, novices' propositions are compared to propositions on which experts agree" (Knight et al. 2004, p. 1). Our study, which is designed specifically to compare concept maps, adopts this recommendation of constructing concept maps that use phrases expressing interrelated ideas.

The Copilot method of constructing concept maps, and its now obsolete software *Copilot* (CCDMD, 1998), is based on the systematic use of verbs to name the links that describe 13 types of relationships, which are grouped into three major classes:

1. Description
    a. Characterization with verbs like "characterizes" or "is typical of"
    b. Example with verbs like "is an example of" or "illustrates"
2. Ordering
    a. Classification with verbs like "comprises" or "groups together"
    b. Composition with verbs like "is composed of" or "consists of"
    c. Sequence with verbs like "precedes" or "is prior to"
    d. Size with verbs like "is smaller than" or "is less than"
3. Explanation
    a. Primary Subject with verbs like "makes" or "performs"
    b. Assisting Subject with verbs like "assists" or "contributes to"
    c. Object with verbs like "focuses on" or "transforms"
    d. Result with verbs like "produces" or "generates"
    e. Instrument with verbs like "uses" or "resorts to"
    f. Goal with verbs like "targets" or "aims to"
    g. Conditions with verbs like "depends on" or "is subject to"

3.1.2 Metasynthesis conclusions in the form of a concept map

When the above formalistic principles are applied, the conclusions of the metasynthesis are translated into a concept map that will serve as a reference point during the analysis of the interviewed experts' maps (figure 1).

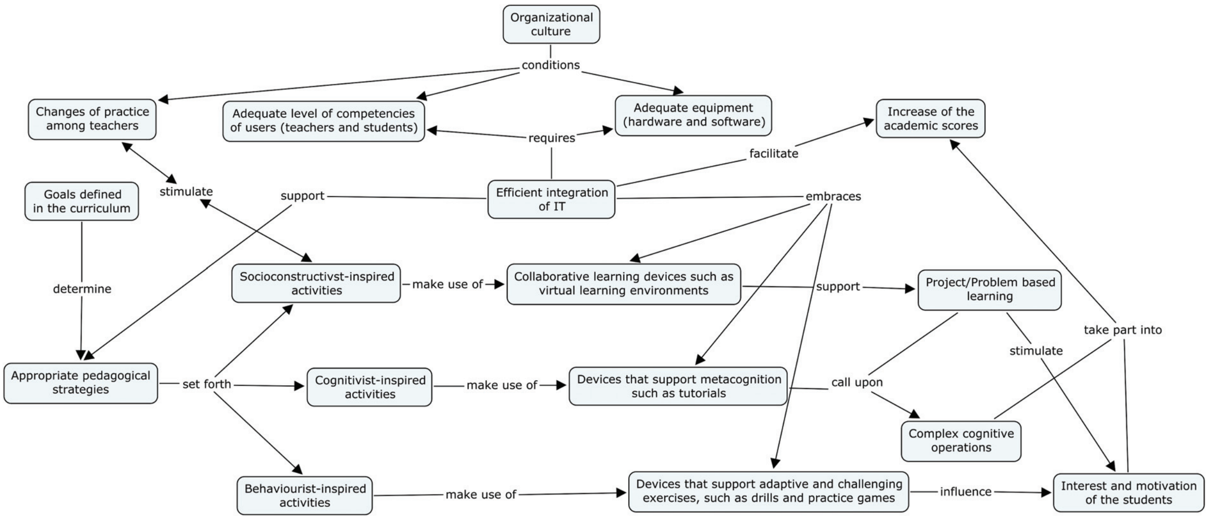

Figure 1. Concept map containing the expression of conclusions of the metasynthesis of the results of experiments on the integration of IT into teaching in Québec colleges.

3.1.3 Compiling expert knowledge

The map based on the conclusions of the metasynthesis contains the knowledge derived from empirical research. Our study is designed to connect this knowledge to the knowledge expressed by experts in a process of reflecting about their practice. Using a knowledge management method designed by Pierre Cossette (2003) that is largely based on the use of dynamic concept maps, this can be achieved in four phases:

1. The material is compiled by means of a semi-open interview of an informant
2. The recorded material is processed so that concepts and links can be extracted
3. The processed material is represented in the form of a concept map, validated by the informant
4. The material represented is analyzed to identify:
    a. The number of concepts and propositions
    b. The concepts considered important because of the number of links with other concepts
    c. The propositions counted and sorted according to the 13 types of relationships
    d. The emphasis on propositions described as strong because they use explanatory verbs that involve primary or assisting subjects, or results, as well as concepts considered important

The semi-open interview starts with the same question as that answered by the concept map from the metasynthesis: "What are the main determinants (causes and conditions) that must be taken into account to ensure that the use of IT in the classroom has a positive impact on student outcomes?" The interview is taped and lasts about two hours. The main researcher listens to the recorded interview and produces a first version of the concept map. The map is drawn with CmapTools; it is then saved on a server so that its author can access it with administrator rights. The main researcher meets with the expert again and together they validate each and every proposition on the first version of the map. After about two hours, they agree on a satisfactory version, which is saved again on the server. The main researcher then analyzes the map produced (phase 4 of the process) and returns the result to its author so that he or she can react and, if necessary, make further changes to the map.

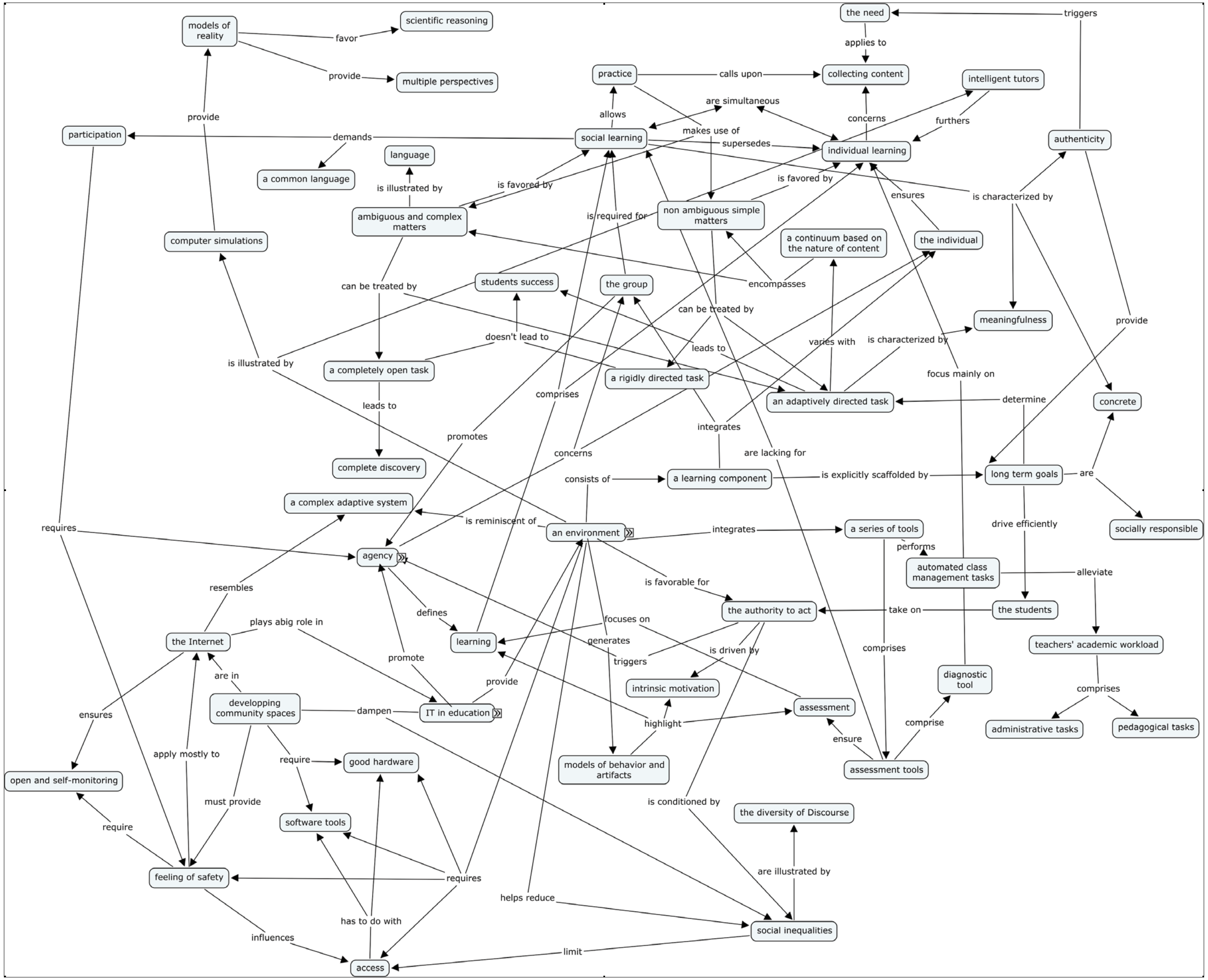

Figure 2. Concept map expressing expert knowledge on IT integration into teaching.

The map in Figure 2 shows a concept map produced on the basis of an interview with an expert and validated by her. The map is constructed according to the formalistic rules established for research. It contains 76 concepts connected by 119 propositions. Based on the number of links transiting them, the most important concepts are:

- Environment (15 links)
- Agency (12 links)
- Social Learning (12 links)
- IT in Education (10 links)

In this expert's discourse, strong propositions can be identified by their use of both explanatory verbs involving causes (primary or assisting subjects) and effects (results), and concepts engaged in several other relationships. The following sequence of ideas, taken from the example, illustrates the richness of this expert's vision: "IT in education provide an environment that is favorable to the authority to act which triggers students' agency and is driven by intrinsic motivation."

Content of the maps provided by each of the four experts ranges from 45 to 76 concepts and from 68 to 136 propositions —many more than the metasynthesis map, which contains 17 concepts and 25 propositions. As evidenced by the example (Figure 2), each expert's map is highly complex and is of little practical use besides serving as a vault storing his or her representation of the knowledge domain. Obviously, the qualitative data these maps contain has to be further analyzed in order to answer our research question.

3.1.4 Analyzing the experts' knowledge

A method of qualitative data analysis, proposed by Pierre Paillé (1994) and adapted from the ethnographic grounded theory approach, is applied to the experts' maps, in order to progressively analyze them against the metasynthesis.

1) Initial codification	Propositions (concept—verb—concept) are considered as units of analysis. The set of propositions formulated by each expert is fashioned into a concept map (as in the example shown in Figure 2) validated by the expert.
2) Categorization	Linking of the ideas expressed in the form of propositions by the experts with each and every proposition (considered a category) of the metasynthesis or with an original category emerging from the expert's material.
3) Ordering	Aggregation of the expert's ideas related to each of the categories. Provides small, manageable concept maps that deal with a circumscribed subject that can be deliberated among practitioners.
4) Integration	Integration of the expert's ideas within a thread of arguments. Provides large and complex concept maps that can be translated into an article or an essay intended for practitioners to discuss.
5) Modelization	Validation by practitioners of the heuristic value of the arguments in the course of long-term consultation and counseling, or congresses, seminars and courses. Serves as theoretical sampling and allows for refinement of the arguments and emergence of new ones.
6) Theorization	Taking hold of the arguments among the community of reflective practitioners. New research projects resulting form this process feeding back new evidence and consolidating the framework of professional decision-making.

3.2 Initial findings and conclusion

At this time, phases 1), 2) and 3) of the analysis have been completed. The initial coding of the experts' material has been easily and successfully conducted, indicating the instrumental value of concept maps, especially when using a formalized scheme for designating the relationships between concepts. Validating a proposition implies that the researcher accompanies the expert in this evaluation procedure:

1. I link these two concepts.
2. The link I establish serves to describe, order or explain the concepts involved.
3. The specific verb and verbal form (negative or antonym) used in the proposition appropriately translates the relationship sub-type I want to express.
4. The specific verb I choose among synonyms refines what I want to convey about the relationship.

Findings: First, the categorization phase showed that 60% to 86% of the propositions expressed by the experts can be linked to categories (propositions) taken from the metasynthesis, indicating that the experts are essentially dealing with the same field as the field covered by the empirical research. Second, none of the 397 propositions from the experts contradicts the metasynthesis conclusions. Third, only rarely are certain propositions derived from metasynthesis conclusions not evoked in expert discourses. Fourth, experts addressed determinants that were not taken into account in the research corpus used for the metasynthesis. Two dimensions of the experts' original contributions thus become evident. The first is related to the role and tasks of teachers. The second involves the social, cultural, ethical and political issues related to IT integration into teaching. Propositions about these topics provide new categories of analysis.

To date, the data-ordering phase has produced all of the concept maps around the categories borrowed from the metasynthsesis (figure 3) and a few around the original categories emerging from the experts' material. The integration phase is still pending. Modelization is well under way: teachers and pedagogical advisors have already participated in workshops held in their own schools or at their professional association's annual congress, where they discussed the appropriateness of some of the aggregations of ideas set forth. Some of the experts participated in these workshops, when their schedules permitted. The quality and intensity of the discussions reveal the efficiency of concept maps in the modeling process, which feeds back into the coding, categorization and relation phases.

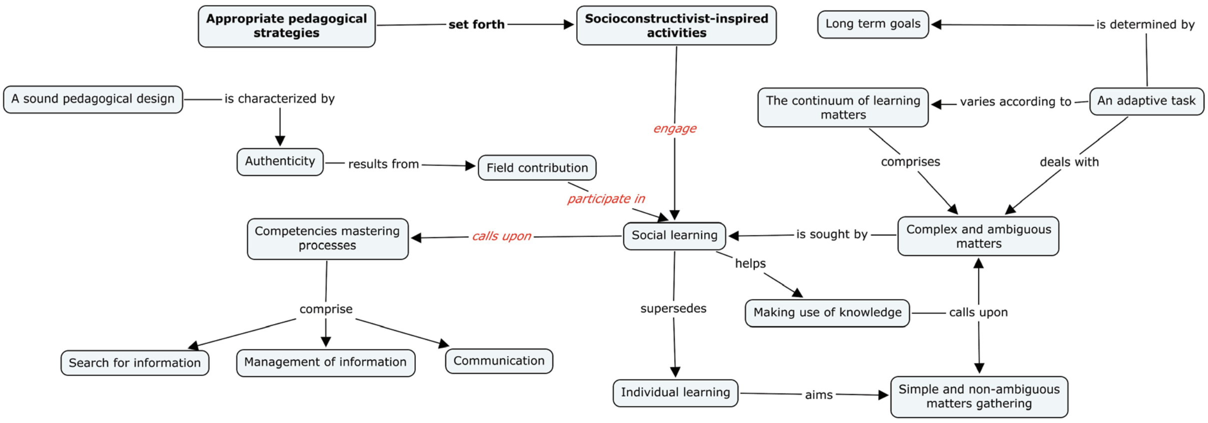

Figure 3. A typical concept map created in the data-ordering phase of the analysis that can be debated by practitioners in a 60 to 90 minute session. Concepts and links are from the interviewed experts, and in bold, from the metasynthesis. Links suggested by the researcher are in italics.

In the next steps, work will focus on the integration phase so it can start to feed the ongoing modeling process. With the help of ARC and its partners, the goal is to mobilize professional associations and networks over the longer term, in order to develop theories among the community of practitioners in the field of IT pedagogical integration. One of the research projects that could arise from this theorizing process relates to the observation and analysis of decision-making by professionals in the field.

In all its stages, our research shows the benefits of using concept maps. It has helped show that the contributions of theoretical and expert models can be distinct yet compatible. It also has been effective in supporting discussion, validation and hopefully theorizing among a community of professional practitioners, simultaneously nurturing empirical knowledge and effective professional practices.

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USING CONCEPT MAPS TO ENHANCE KNOWLEDGE ABOUT SOUND

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Abstract. This presentation is based on research carried out at a junior high school in Portugal. This research intended to assess the potential of the concept map's practical use in acquiring knowledge related to the topic area of Sound, by young learners in the eighth grade. The obtained data points to indicators revealing that using concept maps with learners can indeed, from our point of view exploit their full educational value: the potential in educational innovation which can change the way how students and teachers learn, feel and live their school life.

1 Introduction

Since the beginning of this century various profound social, economic and cultural changes have challenged traditional teaching models, leading to the need for a new educational project which can assist in overcoming the challenges of an online society (Castells, 2004) in which we live. It is in this context that the notion of concept maps emerges (Novak e Gowin, 1999).

Consequently, numerous studies showing the educational role of maps, as well as various advantages of their use for meaningful learning by students, were presented in two international meetings on concept maps that took place in Pamplona (Cañas, Novak & González, 2004) and in Costa Rica (Cañas & Novak, 2006).

Researchers presented several studies, proving their teaching value and full potential when applied as a means of more efficient learning. Moreira and Novak (1988), for example, highlighted studies with students who, in that model, were divided into a group subjected to a curriculum organized for meaningful learning and another group exposed exclusively to so-called more traditional teaching methods. The obtained data revealed that the first group not only got the best results in problem-solving tasks, but also improved their results in the overall course, as opposed to the second group subjected to the more conventional learning process. Furthermore, according to the same authors, the teaching and learning process can be improved if we know the way human beings create and value knowledge, as well as the psychological processes which enable them to understand knowledge.

This knowledge, theoretically based on constructivism and meaningful learning, may be reached by using the tools that teachers have at hand, especially the above mentioned concept maps.

2 Concept maps and their role

The idea of the concept map was developed in the 1970s in the Department of Education at Cornell University, being one of the main work approaches in the Program of Education in Science and Mathematics of this department (Galagovsky, 1993). Although Ausubel does not speak of concept maps, these derive from his theory. In fact, the concept maps appeared as instructional resource from the ausubelian model for meaningful learning, according to which science is based on concepts that range from the most general (supracommanded concepts) to the most specific ones (little inclusive concepts), passing one or more intermediate hierarchies (subordinated concepts). The concepts are related to each other through propositions, using connecting words in order to show the conceptual organization of a given topic, as well as the knowledge of the pupils concerning the same one (Novak & Gowin, 1999). At the top of this diagram there are the supracommanded concepts and, as one goes down vertically, the concepts of lesser hierarchy are displayed.

Among several others uses, concept maps "allow the assessment of previous knowledge and the diagnosis of alternative concepts" (Trowbridge & Wandersee, 1998, p.116). Apart from this aim, concept maps have other functions. On one hand, they are a way of illustrating the hierarchical, conceptual e proportional aspects of knowledge and, on the other hand, they are a metacognitive way of helping learners to reorganize their cognitive structures into stronger integrated patterns (idem). After finishing off a learning task, concept maps show a schematic summary of what was learned (Novak & Gowin, 1999). Further important aspects could be considered in relation to the usage of concept maps, such as generating enthusiasm; arousing curiosity about learning; improving interpersonal relationships; and stimulating playfulness.

3 Using ICT in school context

Regarding the demands of the society based on information and knowledge (Drucker, 2000), educational issues begin truly to be viewed in a completely different light. Today's society understands the limits of the traditional school and, opposing it, demands a school to be a place where you learn how to like learning, where you find meaning for what you are doing, where you begin the discovery of knowledge, where you explore paths, get encouragement, motivation and each other's rhythms and feelings are respected. That is, a culture which is not based on a merely passive, reproductive knowledge, but one of active thinking, capable of keeping alive the constructed knowledge.

In this regard, ICT can be an important supporting tool, capable of helping change the teaching experience, abandoning traditional methods inducing routine learning, in favour of more dynamic and meaningful learning. The computer gets an important role as a teaching aid to help teachers move away from the world of blackboard and chalk (Gates, 1999).

4 Methodology

4.1 Sample

The case study of this research took place in a junior high school in Portugal, during the school year 2007/2008, in two classes of the eighth grade taught by the same Physics teacher. Characterizing both classes comprised collecting data referring to age, gender, family members and their qualifications, as well as other data about school life, including possible failure in the previous year leading to the repetition of the eighth grade presently. Further data was added, namely the one obtained from qualitative analysis of student-constructed concept maps before teaching the topic Sound.

After analyzing the characterization data of both classes, the control class (N=28) and the experimental class (N=28) were chosen, being the necessary procedure for the methodology used in this research: *semi-experimental plan*. Another important factor to be stressed is that the obtained data was similar in both classes, as required by this research technique. As the obtained data was similar in both groups, the experimental class was chosen randomly.

Preparing the students in both classes for the process of constructing concept maps was similar. Before teaching the topic Sound, learners had been taught the technique of constructing concept maps, having later conceived several maps in relation to subject of Physics, namely the topic area of Optics taught before in class. After having constructed the maps, students discussed them in depth with the teacher during class, reorganising them afterwards.

4.2 Obtaining data

Obtaining data from this research was based on combining a qualitative method, by direct and detached observation, with a quantitative one, on a *semi-experimental plan*. During the final stage of research, data was also obtained through a questionnaire on usage of concept maps and a test paper on knowledge about main areas of Sound.

While observing, the researcher took down information in a custom-made table. Verbal interactions between students and teacher were noted in this table as they were constructing the maps. The main purpose was to assess the level of satisfaction/dissatisfaction with the map-constructing strategy, the main difficulties felt during the construction, the type of learning taking place in relation to the subject of Physics, and more specifically the topic of Sound, and whether the concept map was indeed constructed with the cooperation of all group members. This way the teaching and learning process was assessed.

Although the researcher made notes in the same way in both classes, the teacher adopted different teaching methods while going through the topic of Sound in the two classes. Thus, in the control class lessons on the topic Sound were fundamentally conveying information, without any concept maps, while in the experimental class lessons took place in a constructivist environment for learning, during which the students conceived progressive concept maps at the same rate at which the concepts of Sound were being taught with the prevailing principles of authors like Savery & Duffy (1995) and Brooks & Brooks (1999): (1) learning is an active and involving process; (2) learning is a process of constructing knowledge; (3) learners should have access to a metacognitive level; and (4) learning should include "social negotiation".

In the experimental class, students constructed progressive concept maps while the topic area Sound was being taught. These maps were progressively self-corrected and enlarged so as to include new concepts as they were being taught. The maps revealed the process of structuring and restructuring of knowledge as a result of discussion among students and, naturally, between students and teacher.

The table below characterizes the moments of constructing the concept maps and the methodology used in both classes for this research.

Moments of constructing the concept maps	**Methodology**	**Recording material / device**	**Class**	
Before teaching Sound	Individual	ICT	Experimental	Control
While teaching Sound	In groups	Paper	Experimental	Experimental
After teaching Sound	Individual	ICT	Experimental	Control

Table 1: Concept maps constructed by the students

The analysis of the concept maps constructed by the students was essentially qualitative (a scale of three rates was used: weak, acceptable, good) and it was based on suggested characteristics by several researchers, namely Novak & Gowin (1999) and Mintzes, Wandersee & Novak (2000). The characteristics were the following: *hierarchical organisation of concepts (that is, considering the context in which a concept map is constructed, is each subordinate concept more specific and less general than the concept above it?)* ; *linear structure versus ramified*; *number of concepts adequately connected; linking words; and cross links.*

The research showed that, before the topic area Sound was taught, the hierarchical organisation of concepts, the linear structure versus *branch structure*, the number of concepts adequately connected, the linking words and the cross links in both classes were considered weak. On the other hand, the linear versus ramified structure was considered acceptable in both classes.

After the topic area Sound was taught, the maps constructed by the students of the experimental class (EC) revealed a cognitive evolution when compared with the ones by the control class (CC), as shown on Table 2.

Features / **Avaliation**	**Weak**		**Acceptable**		**Good**	
	Control class	Experimental class	Control class	Experimental class	Control class	Experimental class
Hierarchical organization of concepts	X			X		
Linear structure versus ramified			X			X
Number of concepts adequately connected	X					X
Linking words	X					X
Cross links	X	X				

Table 2: Evaluation of the concept maps organized by the students in individual work, after teaching Sound

Concerning the elaboration of the progressive concept maps by the experimental class, these were constructed after the subtopics of the topic area Sound were taught, such as sound production, sound travel, sound phenomena, sound characteristics, the sound perception and sound pollution. As a mere example, two maps constructed by the same group after the first three subtopics were taught, are presented below (Figure 1):

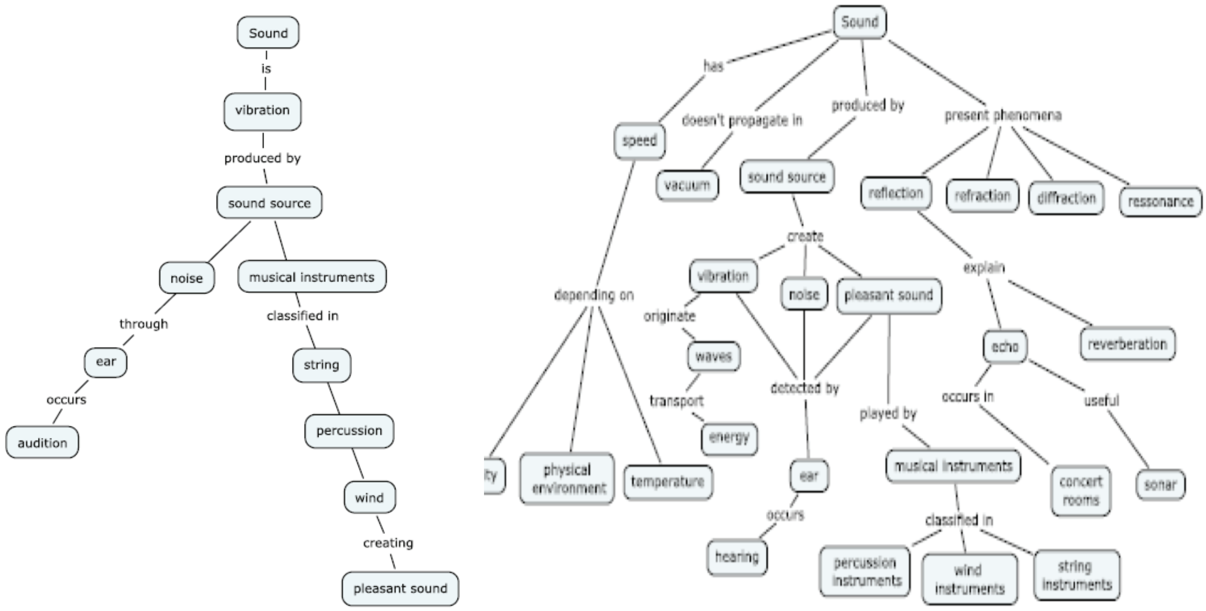

Figure 1. First and third map designed by the same work group.

After comparing them, we can see that the second map shows a reorganisation of the concepts involved in the first map as a result of the discussion by the group members, as well as the introduction to new concepts during the lesson.

The main difficulties detected by the teacher when analyzing the maps constructed by the students of the experimental class (EC) were, above all, the hierarchical organisation of some concepts, as well as the establishment of cross links among them. These aspects were confirmed in the answers given by the students of the experimental class (EC), when they were questioned about the difficulties they had while constructing the maps.

These students were also asked about two other aspects. The first one was concerning their perspectives on the advantages of using the maps. In case of a positive answer, they were asked to order the the following items of a list given in the questionnaire, according to a degree of importance:

A – they make it easier for the student to learn;
B – they are a good means of representing the relationships between concepts through propositions;
C – they help organising ideas and information;
D - they enable information summarizing;
E – they enable students to construct their own knowledge;
F – they help the discussion of several concepts;
G – they are a resource for self-learning available to the student;
H – they are tools that allow a cooperative activity;
I – they show the concepts and the fundamental propositions in an explicit and concise language;
J – they help develop the awareness that knowledge is constructed by mankind and evolves with time;
L – they help the relationship between teacher and student in their elaboration;
M – they help the relationship among students in their elaboration;
N- they increase students' self-confidence in their skills.

The obtained results showed that 80% of the students considered the use of concept maps to be advantageous. The characterization of those advantages can be found in Figure 2:

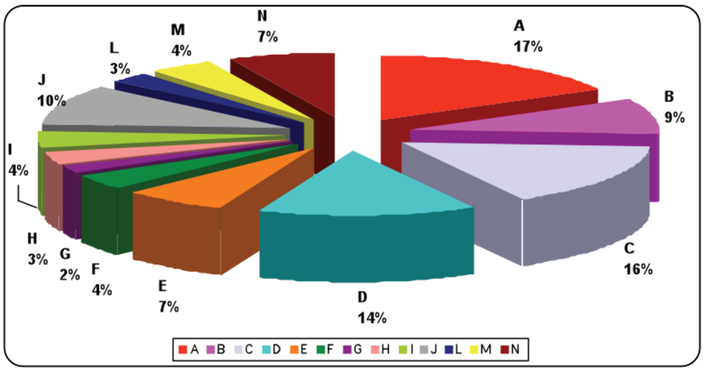

Figure 2. Advantages of using concept maps

As we observe in the Figure 2, the students tend to select often the following four items: A – they make it easier for the student to learn (17%); C – they help organising ideas and information (16%); D - they enable information summarizing (14%); and J – they help develop the awareness that knowledge is constructed by mankind and evolves with time (10%).

The second aspect that we intended to analyse in this research was to find out what the pupils thought about using Information and Communication Technologies (ICT) for making concept maps.

By asking the question "Which method did you enjoy using the most for making maps?, " we obtained the multiple-choice answers as shown in the following figure:

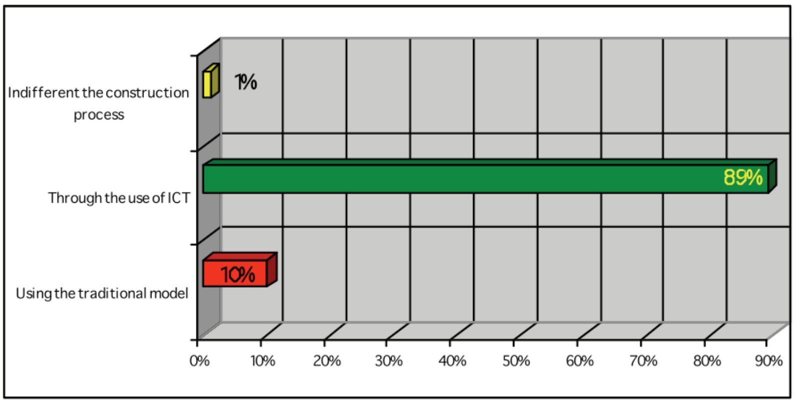

Figure 3. Tools used by the students for the construction of the concept maps

As we can see in Figure 3, the results show clearly that the pupils express their significant support for constructing progressive maps using ICT (89%). Adding to this, they assumed a much more moderate answer in relation to the possibility of using the traditional method (written by hand), considering that only 10% of them openly confessed to prefer it. Agreeing with this clear answer of the pupils supporting ICT, we should emphasize the very low percentage of pupils who answered that it indifferent to them which method the teacher should adopt to make the above maps (1%).

The pupils' eagerness for using the technological tools can be explained by the fact that they adapt themselves to the user's interests and speed (Drucker, 2000). In addition, the skills, which the teaching institution develops, play an important role in this particular aspect. It is precisely because of the evolution of the present-day society that Charlot (2007) advises, "school must take into account the new logical issues in its own organisation" (p. 131). The truth is that in a global economy and in a network society the main challenge for the contemporary society nowadays must be, as Magalhães (2007) reminds us, "the one of a truly widespread ICT use, especially of computers" (p.281).

Thus, using ICT for constructing concept maps, the teacher can motivate his/her pupils to construct their own learning in a meaningful way. With this strategy, in a certain way an innovative one, we think we are helping to change teaching in Portugal.

After having taught the main syllabus topics concerning Sound, we compared the marks of the classes (both experimental and control) in a knowledge test. The obtained data enabled putting together a global assessment matrix, gathering information answer by answer of the above pupils. The results are shown in the figure below:

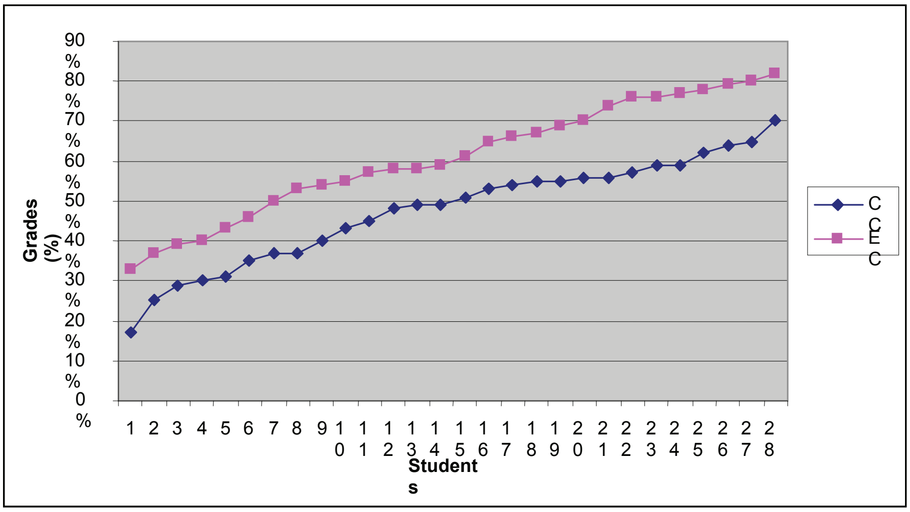

Figure 4. Global assessment by answer, concerning pupil's knowledge test on Sound

As Figure 4 shows, we can see a significant positive performance of the pupils in the experimental class (EC), concerning the topic Sound.

5 Conclusions

Generally speaking, concept maps are hierarchic diagrams that aim at showing the conceptual organization of a source of knowledge, being an important variable in learning. Using then means giving a new sense to teaching, a new meaning to teaching concepts, learning and even the assessment of the learning process. The analysis of the conceptual structure of the source of knowledge and the use of this analysis for the learning and teaching process as a means of enabling meaningful learning is obvious nowadays. Meaningful learning is a key concept that the teacher should bear in mind when teaching. This learning is opposed to learning by heart, unfortunately preferred in our classrooms during more traditionally taught lessons.

Even if our obtained data cannot be generalised due to their limited scope, they clearly show the contribution of concept mapping in the classroom, when the maps are made in a constructivist environment, helping pupils in their meaningful learning. In the light of the evidence gathered in this research, which was briefly presented before, we can conclude from emerging indicators that pupils would clearly tend to support the integration of concept maps into the school environment.

Therefore, we think it is legitimate to conclude from this research that using concept maps can indeed exploit its full pedagogical value: the potential for educational innovation that can transform the way pupils and teachers learn, feel and live their school life in the 21st century.

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USING CONCEPT MAPS TRANSCRIBED FROM INTERVIEWS TO QUANTIFY THE STRUCTURE OF PRESCHOOL CHILDREN'S KNOWLEDGE ABOUT PLANTS

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Abstract. This paper reports the results of an investigation into the usefulness of concept maps to evaluate the structure of preschool children's knowledge about plants. The children, mostly low-SES African-American children, experienced an inquiry-based hands-on science curriculum, the *Young Florida Naturalists*. As part of the evaluation, researchers interviewed the children to ascertain their knowledge about plants. The children's responses were transcribed and used to form concept maps. The researchers developed a scoring system for the concept maps, determined a measure of interrater reliability, and investigated relationships between concept map scores and fall and spring measures of the children's achievement. The estimated interrater reliability for scoring the maps was .98. When the prekindergarten class, gender, and age are controlled, no relationship was found between the children's initial status on measures of school readiness and early literacy achievement and their ability to express complexity in the structure of their knowledge about plants. However, a relationship was found between the children's spring scores on the BBCS-3:R Self-/Social Awareness and Texture/Material scales and their concept map scores.

1 Introduction

Concept mapping has been widely used to assess the structure of children's knowledge especially in science. However, concept mapping is used across many subject domains and across a considerable age span of learners. The purpose of this study was to investigate the reliability and validity of the use of concept maps to assess the concept development of preschool children participating in the *Young Florida Naturalists* project. The project was implemented during the 2006-2007 academic year at an urban, professional learning demonstration preschool center that primarily serves low-SES, African American children. The curriculum was implemented in two classes of 4-year-old prekindergarteners and one class of 3-year-old preschoolers. One or two of the project researchers were on site most of the time during the project's implementation.

Novak and Cañas (2006) stated that a concept map is a graphical tool for representing knowledge. Concept maps include concepts shown by ovals in our study, by the relationship between concepts shown by a linking line with a directional arrow, and by words on the linking lines representing the relationship between the linked concepts. Two linked concepts are called a proposition, and propositions form meaningful statements when read. Concept maps generally represent concepts in a hierarchical fashion with the most general concepts at the top. Concept maps can also have cross-links which connect concepts in different segments (branches, domains, or strings) of the map. Novak and Cañas contended that the two features of concept maps that indicate *leaps of creative thinking* are the hierarchal structure of the map and the use of cross-links.

Novak and Cañas (2006) also advocated concrete experiences and hands-on learning with young children.

> After age 3, new concept and propositional learning is mediated heavily by language, and takes place primarily by a *reception learning* process where new meanings are obtained by asking questions and getting clarification of relationships between old concepts and propositions and new concepts and propositions. This acquisition is mediated in a very important way when concrete experiences or props are available; hence the importance of "hands-on" activity for science learning with young children, but this is also true with learners of any age and in any subject matter domain. (page 3)

The *Young Florida Naturalists* project was based on the same tenets posited by Novak and Cañas and focused on three goals to increase the background knowledge and concept development of preschool children. The first goal was to increase young children's knowledge of plants and their role in the environment. The second was to introduce scientific learning through hands-on instructional experiences. The third was to examine the utility of concept mapping as a tool to track concept development in young preschool children.

2 The Intervention: *Young Florida Naturalists*

The *Young Florida Naturalists* project builds on the work of Hirsch (2006), Neuman and Celano (2006), Novak and Gowin (1984), and Zimmerman (2005) regarding concept mapping, elementary science learning, and the knowledge gap of at-risk, young children. Learning experiences involved plants and their role in the environment. Instructional activities included advance organizers to guide the children's investigations which included activities that demonstrate the effects of water, sunlight, air and soil on plant growth. Building background knowledge was emphasized as the children engaged in concrete experiences with plants in a butterfly garden developed on the center's grounds. Vocabulary development was emphasized through read aloud activities based on environmental books. Concept mapping was used to document the hierarchical relationships described by the children before, during, and after learning experiences had been initiated.

2.1 Assessment and Scoring of Young Florida Naturalists Project Concept Maps

One formative assessment of the children's achievement consisted of an individual interview which began with the question—*What do we know about plants?* Children were assessed individually by research staff and their responses were transcribed. Concept maps were constructed to reflect their statements about plants.

Ruiz-Prima and Shavelson (1996) developed a framework for using concept maps for assessment in science. The framework describes concept map production as the interrelationship of three facets of the map: task for the child, format of the response, and a scoring system that produces accurate and consistent results. The evaluation of the concept maps in this study builds on their framework. Moreover, we assumed the concept maps would be hierarchical in structure and describe the children's classification and sorting systems; however, Hall, Dansereau, and Skaggs (1992) suggested that the structure of concept maps actually depends on the nature of the knowledge being mapped. Safayeni, Derbentseva, and Cañas (2005) suggested that different structures of maps make useful distinctions between process and content. The relationships between concepts can be static or dynamic with static relationships serving to define, describe, and organize knowledge and dynamic statements serving to describe processes.

The task format our children experienced was low-directed. Ruiz-Prima, Schultz, Li, and Shavelson (2001) found that high- and low-directed maps provide different information about the structure of the student's connected knowledge, and that low-directed maps better reflect the students' knowledge structures. However, our children's task was not completely low-directed as the interview protocol provided some structure. The structured interview, conducted May 2-3, 2007, began with the researcher saying to the child; *Tell me what you know about plants*. During the interview, the researchers also used these prompts: *What makes you say that*, *Tell me more about…*, *What else have you learned about…, Do you have anything else to add about…, Can you think of something else to add?* and redirecting with *We want to know what you know about plants*. The children were not provided links, and their responses were not constrained by any structure other than the interview protocol.

The format for the children's response was oral explanation. A researcher, knowledgeable about the curriculum but with no direct contact with the children, transformed the children's responses into concept maps. Thus, the mapper relied only on the children's responses to form the concept maps. Figure 1 provides examples showing two of the children's oral and mapped responses. The concept map on the left shows connected, unconnected, and partially correct knowledge. The concept map has no cross-links, but does have two levels beyond the focal concept. The concept map on the right is simpler and introduces irrelevant knowledge.

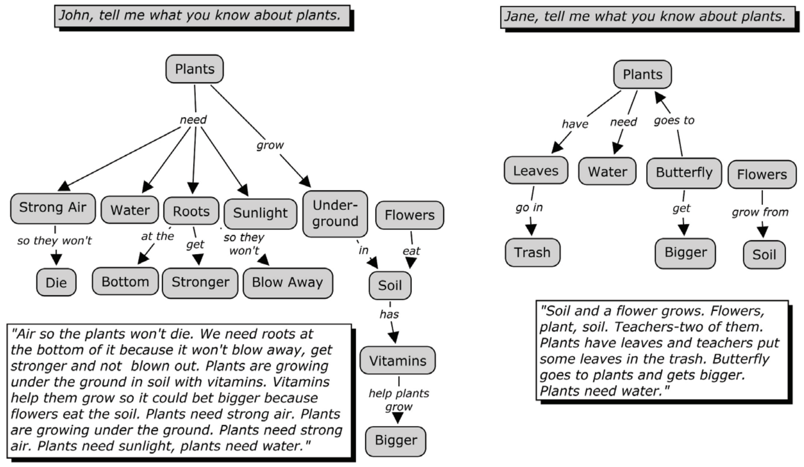

Figure 1. Two examples the children's responses to the interview focal question and the corresponding concept maps.

We expected most of the concept maps would indicate attributes as suggested in the two examples provided in Figure 1. However, because the children had observed and conducted several experiments as part of the inquiry-based curriculum their responses were influenced by these experiences, and they described processes as well as content. For example, the children observed various colors added to water containing white carnations and learned that *stems suck up water like a straw* and that the flower changes color (a dynamic statement). The children also planted seeds in styrofoam cups and watched them become plants, and they sometimes described the planting process in their responses. Furthermore, prior to this assessment, the children planted a butterfly garden and watched the butterfly metamorphous during the school year. Their responses frequently included irrelevant and not fully connected concepts from the butterfly garden and other hands-on experiences. The use of dynamic and somewhat irrelevant but true propositions presented mapping challenges.

3 Scoring the Children's Concept Maps

The scoring system used to assess the concepts maps was an adaptation of a system developed by Novak and Gowin (1984). The quality of the propositions were scored in a manner similar to that proposed by Kinchin (2000), McClure and Bell (1990), and Yin, Vanides, Ruiz-Prima, Ayala, and Shavelson (2005). The system provides scores for three components of the map: propositions, cross-links, and hierarchy.

3.1 The Scoring System

The concept map score is the sum of the scores for the three components. First, the propositions are scored. Propositions receive 0 points if the proposition is incorrect or is totally irrelevant, 1 point if the proposition is correct but is somewhat relevant or if the proposition provides an example of the concept (e.g., flowers can be pink), 2 points if the proposition describes an attribute of the concept, and 3 points if the proposition states a purpose of the attribute. Propositions receiving 2 or 3 points are considered quality propositions. Second, cross-links are scored. Cross-links connect concepts in different strings (branches or segments) of the concept map and receive 5 points. Cross-links connect concepts at different or at the same levels in the map's hierarchy but to receive points they must link concepts that are part of a quality propositions. Each sufficient cross-link receives 5 points and receives no proposition points. Figure 2 provides examples of cross-links that are sufficient and insufficient. The focal concept in each example is *plants*. Numbers in parentheses represent the points awarded for the propositions or cross-links.

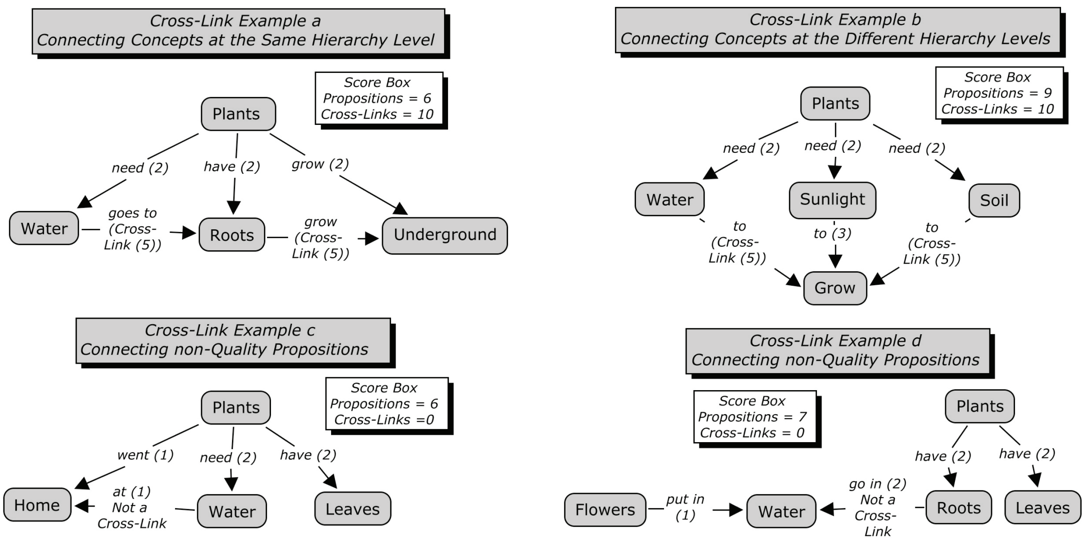

Figure 2. Examples of cross-links sufficient or insufficient to receive points.

Example a shows three quality propositions and two sufficient cross-links. Each cross-link receives 5 points. *Example b* shows three quality propositions involving the focal concept, *plants*. These three concepts all connect to a fourth concept, *grow*. One of the resulting three connections receives 3 points because it is in the same branch of the map and describes a purpose of the concept, *sunlight*. The other two connections are sufficient cross-links and each receives 5 points. *Example c* shows a proposition connecting *home* with the focal concept, *plants*, that receives 1 point because it is true but somewhat irrelevant and a proposition connecting *home* to *water*. This cross-link is insufficient to receive points because *home* is not connected to *plants* with a quality proposition. *Example d* shows a proposition between *flowers* and *water* that receives 1 point as it is somewhat irrelevant (it also does not include the focal concept); therefore, *water* cannot form a cross-link that is sufficient to receive points. However, the r*oots-water* proposition is a quality proposition and receives 2 points.

Last, hierarchy levels are scored. Level one, the focal concept, receives no points. A scored level two is established when three or more concepts form quality propositions with the focal concept. A specified number of branches was chosen to avoid rewarding string maps with hierarchy points. Level two receives 5 points. Examples of level two are presented in the Figure 3.

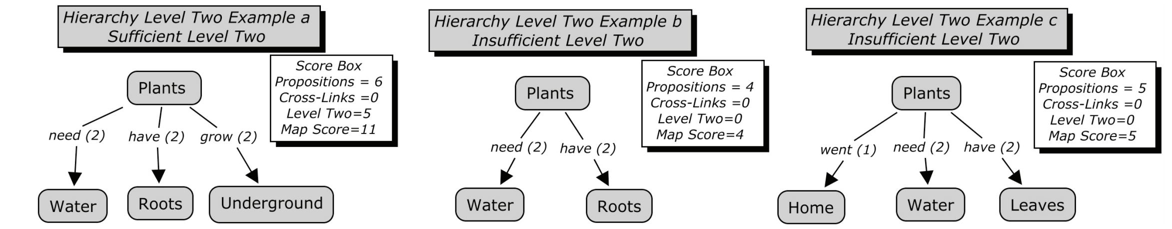

Figure 3. Examples of hierarchy level two concepts sufficient or insufficient to receive points.

Example a shows three concepts, *water*, *roots*, and *underground*, connected with quality propositions to the focal concept. This example of hierarchy level two is sufficient to receive 5 points. *Example b* shows only two quality propositions with the focal concept; therefore, this level two is insufficient to receive 5 points. *Example c* shows only two quality propositions with the focal concept; therefore, the level two is insufficient to receive 5 points.

A scored level three is established when new concepts are connected with quality propositions or scored cross-links to three or more level two concepts involved in quality propositions with the focal concept. Examples of level three are presented in the Figure 4.

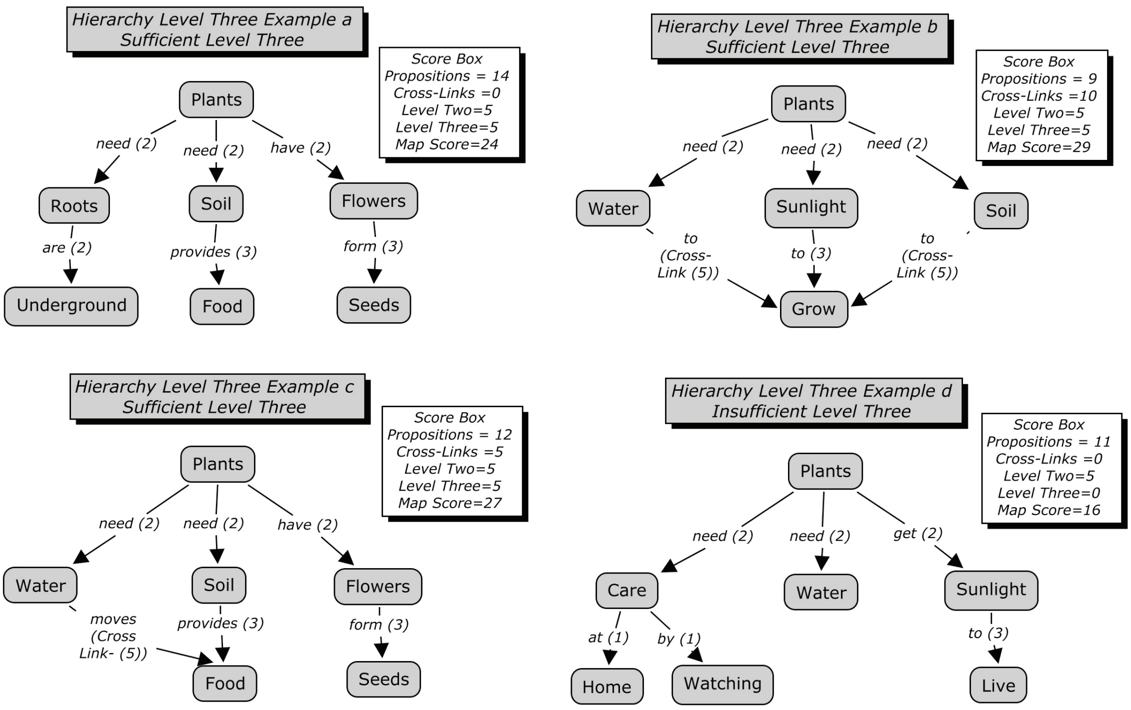

Figure 4. Examples of hierarchy level three concepts sufficient or insufficient to receive points.

Example a shows three level two concepts that form quality propositions with the focal concept (5 points awarded for level two) and each level two concept is involved in a quality proposition with a level three concept. This is sufficient for awarding 5 points for level three. *Example b* shows three level two concepts that form quality propositions with the focal concept (5 points awarded for level two) and all level two concepts are involved in quality propositions or scored cross-links with a single level three concept, *grow*. Because there are three scored quality connections, this is an example of a level three that is sufficient to receive 5 points. *Example c* shows three level two concepts that form quality propositions with the focal concept (5 points awarded for level two) and that have three quality connections (two quality propositions and one scored cross-link) with two level three concepts. Because there are three quality connections, this is an example of a level three that is sufficient to receive 5 points. *Example d* shows three level two concepts that form quality propositions with the focal concept (5 points awarded for level two); however, two of the three connections with level three concepts are propositions receiving 1 point and are, therefore, not of quality. This is an example of a level three that is insufficient to receive 5 points.

4 Results

4.1 Interrater Reliability

Training in the use of the scoring system was provided to three researchers who then independently scored 48 concepts maps constructed from the transcribed interviews of children in two prekindergarten classes and one preschool class of 3 year olds. To examine the generalizibility of scores across raters, four map (p) by rater (r) G studies were conducted for three components of the concept map score and the total score. The results of the G studies are presented in Table 1.

The G studies indicated the interrater reliability is .96, .90, .94, and .98 for the propositions, cross-link, hierarchy, and total score, respectively. Raters contributed little to the total variance of the concept map scores. The researchers' concept map scores were averaged across raters and the resulting concept map score was used in the remaining analyses

	Concept Map Score Types							
	Proposition Score		Cross-Link Scores		Hierarchy Score		Total Score	
Source of Variation	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability	Estimated Variance Component	Percent of Total Variability
Maps (p)	40.56	86.15	23.81	70.84	14.20	82.79	200.24	94.53
Raters (r)	0.95	2.01	1.55	4.61	0.22	1.27	0.10	0.05
pr,e	5.57	11.84	8.25	24.54	2.73	15.95	11.50	5.43
$\hat{\rho}^2$ relative	.96		.90		.94		.98	
$\hat{\phi}$ absolute	.95		.88		.94		.98	

Table 1: Generalizibility Study Results

4.2 Concept Map Scores Differences by Population Subclasses

Ethnicity, gender, and date of birth information were available for 30 of the prekindergarteners. Date of birth was used to calculate the children's age in months on September 1, 2006. All but one child was African American, 53% were boys, and 57% were no more than 54 months old on September 1. The gender and age variables were tested in a regression that controlled for class. Results of the regression are presented in Table 2.

Source of Variance	*df*	Mean Square	F ratio	*p*-value
Class	1	714.24	4.13	.0530
Gender	1	643.96	3.72	.0622
Age	1	244.52	1.41	.2457
Class*Age	1	785.16	4.54	.0432

Table 2: Regression Results

The children's concept map scores were differentiated by gender and there was a statistically significant class by age interaction. The adjusted mean score for girls was 27.48 and for boys was 18.17 indicating that the structure of the girls' knowledge represented on the concept maps was more complex than the boys. In one class, older children had higher concept map scores and, in the other class, age did not predict the children's scores.

4.3 Correlations of Concept Map and Achievement Scores

Prekindergarteners participating in the *Young Florida Naturalists* project were assessed as part of the evaluation of a community initiative which provided support to preschool centers serving low-income neighborhoods. The evaluation consisted of fall and spring assessments of the children using the Test of Early Reading Ability-Third Edition (TERA-3; Reid, Hresko, & Hammil, 2001) and the Bracken Concept Scale-Third Edition: Receptive (BBCS-3:R; Bracken, 2006). TERA-3 assesses components of early reading skills, including familiarity with the letters of the alphabet and numerals, discovery of the arbitrary conventions used in reading and writing English, and recognition that print conveys information, ideas, and thoughts. TERA-3 is composed of three scales: Alphabet, Conventions, and Meaning, each measuring one of the three components. Coefficient alphas for the TERA-3 when used with children between 4 and 5 years old range from .82 to .95. The BBCS-3:R is a receptive measure of children's basic concept development and includes ten scales: Colors, Letters, Numbers/Counting, Sizes/Comparisons, Shapes, Direction/Position, Self-/Social Awareness, Texture/Material, Quantity, and Time/Sequence. The first five scales form the School Readiness Composite (SRC). Internal consistency coefficients for the BBCS-3:R when used with children between 3 and 5 years old range from .94 to .98.

The concept map scores of the prekindergarteners were used in conjunction with the available fall and spring TERA-3 and BBCS-3:R scores to investigate associations between concept map and achievement scores. Children's raw achievement scores were used as concept map scores were not standardized. The interest was in achievement scores relative to the children in the *Young Florida Naturalists* classes. Table 3 shows the estimated correlations between the children's concept map and achievement scores.

Test	Subtest	Fall			Spring		
		Mean	Correlation	*p*-value	Mean	Correlation	*p*-value
TERA-3	Alphabet	10.47	.14	.49	12.07	**.42**	**.03**
	Conventions	8.37	.08	.71	9.14	.27	.19
	Meaning	5.37	**.39**	**.04**	7.72	.21	.30
BBCS-3:R	SRC	45.48	.12	.56	62.00	**.36**	**.07**
	Direction/Position	25.55	.13	.52	37.79	.30	.14
	Self-/Social Awareness	22.21	.19	.36	27.29	**.40**	**.05**
	Texture/Material	12.59	.01	.97	15.86	**.36**	**.08**
	Quantity	15.21	.25	.21	19.57	.17	.40
	Time/Sequence	10.69	.05	.81	16.82	.12	.56

Note: In the fall, 27 children had both TERA-3 and concept map scores and 26 had both BBCS-3:R and concept map scores. In the spring, 26 children had both TERA-3 and concept map scores and 25 had both BBCS-3:R and concept map scores.

Table 3: Correlations of Achievement Test Means and Concept Map Scores

Bold-faced correlations were statistically significant at alpha=.10. Four of these five correlations were with spring achievement scores. Because gender and an interaction between class and age predicted the children's concept map scores, we wanted to control for these variables in studying the relationship between the spring achievement and concept map scores. A regression was conducted for each spring variable significantly correlated with concept map scores. For the one fall achievement score, we wanted to know if fall achievement predicted the concept map score over and above class, gender, age, and a class by age interaction. Results of the analyses are reported in Table 4.

Bold-faced *p*-values indicate the concept map scores were statistically significant (alpha=.05) predictors of the achievement measured by the BBCS-3:R Texture/Materials and Self-/Social Awareness scales. The Self-/Social Awareness scale assesses person-oriented knowledge. Inspection of the scale items shows that children were asked to select pictures that correspond to named attributes of people and/or relationships among people. The Texture/Material scale assesses children's knowledge about the attributes of objects in their environment. Children learn of these attributes by using their sight, touch, and hearing to identify, name, and discriminate between various object attributes, characteristics, and qualities. These two findings are particularly rewarding as associations with these measures correspond with the quality propositions that are the building blocks used to quantify concept map structure.

Model	Time	Source of Variance	F-Ratio	*p*-value
CMap Score on TERA-3 Meaning	Fall	Class	2.97	.0987
		Age	0.13	.7207
		Class*Age	2.72	.0890
		TERA-3 Meaning	2.33	.1411
TERA-3 Alphabet on CMap Score	Spring	Class	4.13	.0543
		Gender	4.91	.0373
		CMap Score	0.94	.3422
BBCS-3:R School Readiness Composite on CMap Score	Spring	Gender	3.93	.0600
		CMap Score	1.41	.2474
BBCS-3:R Texture/Materials on CMap Score	Spring	Class	3.03	.0954
		CMap Score	4.92	**.0371**
BBCS-3:R Self-/Social Awareness on CMap Score	Spring	Class	7.33	.0132
		Age	3.20	.0881
		CMap Score	6.61	**.0178**

Table 4: Achievement Score Regression Results

5 Conclusions

This small study indicated that it is possible to quantify the structure of preschool children's concept maps constructed from interviews. Concept maps can be scored reliably by university researchers, and the complexity of the maps predicted children's achievement scores measuring the development of person-oriented knowledge and knowledge about the attributes of common objects in their environment. However, there are limitations to these findings. Specifically, the results cannot be generalized beyond the *Young Florida Naturalists* curriculum and the three preschool classes at this one center. Additionally, at this point, the formation and scoring of the concept maps cannot be generalized beyond university researchers to practitioners in preschool settings. The results are further confounded by the age and low-SES status of the children. According to Novak and Cañas (2006), language and concrete experiences mediate propositional learning. The children's interview responses are only as good as their ability to use language to communicate their knowledge. This study did not investigate the relationship between the children's language development and the complexity of their concept maps.

5.1 Implication for Practice

Novak and Musonda (1991), in a study that constructed concept maps from young children's transcribed interviews, found that rating the interviews did not provide clarity when determining the structure of the children's knowledge relative to the entire domain. However, construction of concept maps allowed the respondent's propositions to be arranged in a hierarchical form and cross-links illustrated. Our experiences with preschool children's concept maps similarly showed that their maps could be useful as formative assessments. We suggest that concept maps can and should be used to assess children's knowledge structure during the implementation of the curriculum. For example, the two concept maps shown in Figure 1 provide examples of children's propositions that show areas where teachers could clarify the children's knowledge structures. Neither John nor Jane could connect *flowers* with the focal concept, *plants*. It is not clear whether they viewed *flowers* as a synonym for *plants* as suggested in everyday language such as "Let's plant some flowers along the border of the walk," whether John and Jane viewed *flowers* as an attribute of plants, or whether they viewed flowers as something entirely different. John's map also presents a dilemma to the raters with the proposition *flowers eat soil*. The map rater must determine whether John uses *eat* generically to mean *takes in food* or whether John means a more literal use of *eat*. Jane's knowledge is much more fragmented and is tied closely to classroom experiences with plants. These examples of knowledge structures derived from the children's maps could be helpful in clarifying children's knowledge as well as to refining the curriculum before further implementation.

5.1 Further Research

Several avenues for future research are evident from this study. First, the concept maps in this study were constructed by one researcher. A mapping protocol for constructing concept maps from the children's transcribed interviews needs to be developed and tested for intermapper reliability. Second, both the scoring system and mapping protocol need to be adapted for use by practitioners. The relationship between the practitioner and the researcher's concept map scores should be investigated. Finally, a purpose of the *Young Florida Naturalists* project was to enhance the vocabulary development of the preschool children. The TERA-3 and BBCS-3:R assess important school readiness skills, but do not directly assess vocabulary. An investigation of the association between the scores of concept map and vocabulary measures such as the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4; Dunn & Dunn, 2007) should be conducted.

6 Acknowledgment

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WHAT CONCEPT MAPS TELL US ABOUT CHANGES IN PEDAGOGICAL CONTENT KNOWLEDGE OF PROSPECTIVE CHEMISTRY TEACHERS PARTICIPATING IN AN INQUIRY-BASED WORKSHOP?

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Abstract. In this study, we aimed to investigate if prospective chemistry teachers' participation in a professional development workshop changed their knowledge of inquiry-based teaching as a subject-specific instructional strategy. For this aim, as part of a project that intends to enhance science teachers' knowledge of inquiry pedagogy, we firstly developed an inquiry-based professional development workshop for supporting chemistry teachers in their effort to implement inquiry-based approach in their chemistry classrooms. Twenty pre-service chemistry teachers were selected as participants of the study. The concept maps which were constructed at the beginning and at the end of the workshop were used to expose the changes in the participants' knowledge of inquiry-based teaching. The result of the Paired Samples T-Test indicated significant difference between the mean of pre- and post-concept map scores. Furthermore, when the structures of the concept maps were classified as linear, spokes, tree and network, it was determined that after the professional development workshop more improved knowledge about inquiry-based teaching were constructed in their minds. Based on all data from concept maps, there is support for assertion that the professional development workshop provided considerable improvement in participants' knowledge of inquiry-based teaching as a type of pedagogical content knowledge.

1 Introduction

In science education, knowing *how* to teach science concepts to students and to make science concepts understandable for them is one of the most important issues. Therefore, science teachers should not only know what to teach, but also they should know how to teach. For science teachers, the issue of "how to teach" requires specialized knowledge that distinguishes them from subject matter specialists. For this reason, it is not sufficient for teachers to have knowledge about content and pedagogy separately. It is important to have sufficient knowledge about combination of content and pedagogy.

In this respect, Shulman (1987) argued what knowledge teachers need to have for teaching, and proposed pedagogical content knowledge (PCK) as a form of teachers' special knowledge needed to help students understand specific content. Shulman described pedagogical content knowledge as "special amalgam of content and pedagogy that is uniquely the providence of teachers ...... Pedagogical content knowledge …. identifies the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to diverse interests and abilities of learners, and presenting for instruction." (Shulman, 1987). According to Tamir (1988), PCK involves knowledge about students' common difficulties in a topic, curriculum knowledge, instructional strategies knowledge and methods of assessment knowledge. These definitions are putting forward that PCK constitutes the intersection between content knowledge and pedagogical knowledge, and it is a critical concept for effective science teaching.

According to Magnusson et al. (1999) PCK for science teaching consists of five components: (a) orientation toward science teaching, (b) knowledge and belief about science curriculum, (c) knowledge and belief about students' understanding of specific science topics, (d) knowledge and belief about assessment in science, and (e) knowledge and belief about instructional strategies. They describe these components and their relationships through a concept map as in shown Figure-1. Since the instructional strategies have a robust impact on students' success, and teachers' understandings related to components of PCK determine how the components are utilized in classroom teaching, "knowledge about instructional strategies" component of PCK appears to have a considerable importance. Also, Van Driel et al. (1998) emphasize that teachers' knowledge about teaching strategies is one of two key elements of PCK. Therefore, for science teachers it is essential to have sufficient knowledge and understandings with respect to instructional strategies.

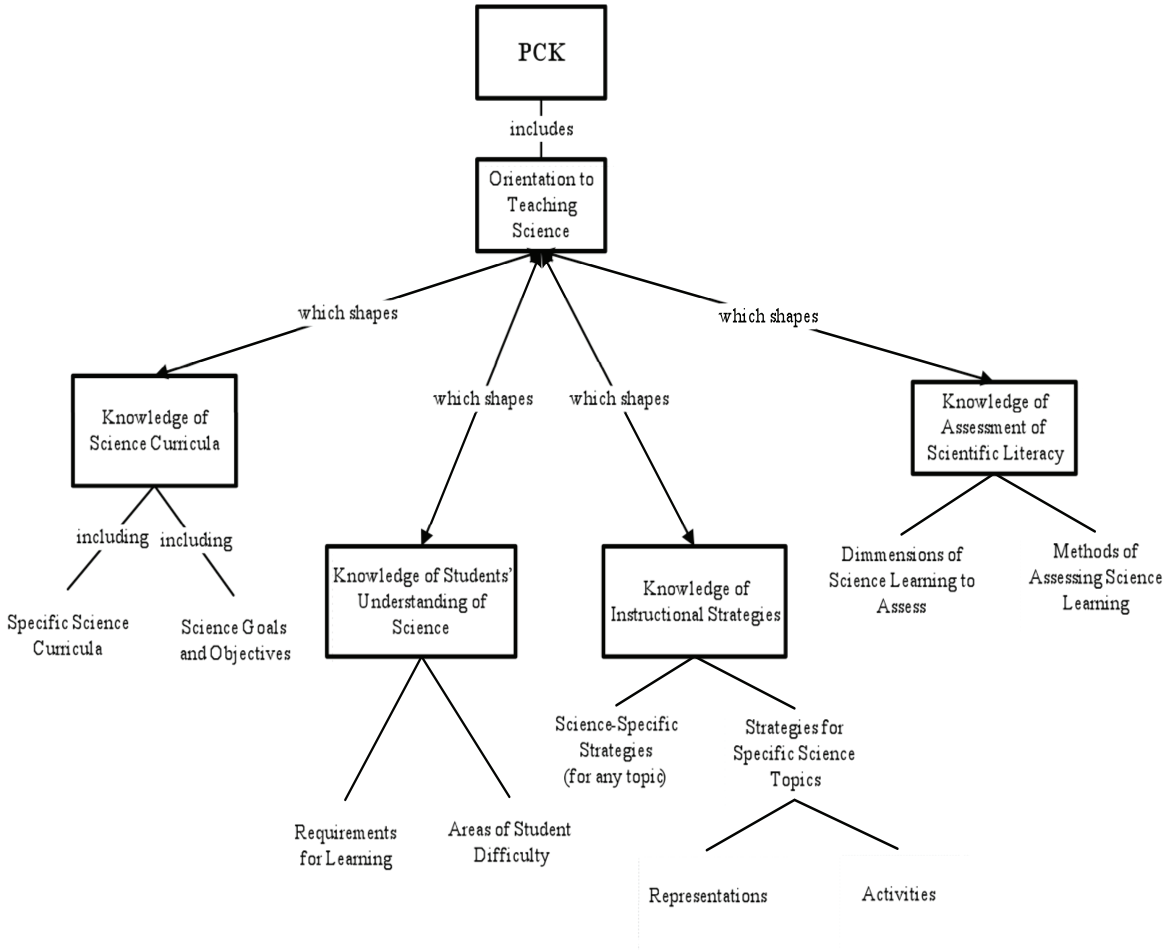

Figure-1. Components of pedagogical content knowledge for science teaching (Magnusson et al., 1999)

Knowledge of instructional strategies which is one of the components of PCK is consists of two categories: knowledge of subject-specific strategies and knowledge of topic-specific strategies. Subject-specific strategies are more comprehensive than topic-specific strategies and represent general approaches to science instructions. They are specific to teaching science as opposed to other subjects (Magnusson et al., 1999). When the science education literature is examined, it is seen that a number of subject-specific strategies have been developed. We assert that the most appropriate and promising one for science teaching is inquiry-based teaching. For this reason, we focus on is inquiry-based teaching in our studies (e.g. Budak & Köseoğlu, 2007a, 2007b).

Inquiry-based teaching focuses on actively searching for knowledge to satisfy curiosity and it is supported by the constructivist approach. It includes practices that promote learning of scientific concepts and processes as well as "how scientists study the natural world" (NRC, 1996). In many studies it is found that inquiry-based science teaching had positive effects on students' science achievement, cognitive development, laboratory skills, science process skills, and understanding of science knowledge (Budak & Köseoğlu, 2007c; Chang & Mao, 1998; Mattheis & Nakayama, 1988; Padilla, Okey, & Garrand, 1984; Saunders & Shepardson, 1987). For this reason, inquiry is a word that has been used by science educators for many years to describe good science teaching and learning. Also recent science education reform documents in many countries emphasize the importance of inquiry-based science teaching. This implies that both pre-service and in-service teachers must be prepared with the knowledge of inquiry-based teaching which is a type of subject-specific strategy.

However, the studies indicate that science teachers' knowledge of inquiry-based teaching has not been sufficiently developed (Keys and Bryans, 2001). As it can be anticipated, planning and enacting an inquiry-based science lesson is difficult for teachers who have inadequate knowledge of inquiry teaching. For inquiry to be effective in providing students with a conceptual understanding of science, science teachers must first understand what inquiry is and then apply this knowledge in science lessons as a pedagogical tool. Therefore, through the professional development courses which were developed in the light of researches about effective professional development programs, knowledge and skills needed to carry out inquiry-based learning should be provided for science teachers. Thus, teachers can transport this knowledge from the professional development programs into their classrooms.

Although many researches about professional development programs focusing on inquiry-based science teaching are already available, there is little research on what knowledge teachers learn in these programs. More research should be devoted to examining how such programs affect teachers' knowledge of inquiry-based teaching. Teachers' knowledge of subject-specific strategies for science teaching contains the ability to describe a strategy (Magnusson et al., 1999). By using an instrument such as concept map which allows teachers to describe inquiry-based teaching, their knowledge can be explored in professional development programs. Concept mapping is one of the primarily useful research tools used for examining teachers' knowledge base (Baxter & Lederman, 1999; Wee et al., 2007). Morine-Dershimer (1989) suggests that concept maps can provide valuable feedback on teachers' knowledge. Concept maps have been used by cognitive researchers to measure knowledge structures which are represented by key terms and the relationships among them (Baxter & Lederman, 1999). According to Novak & Gowin (1984) concept maps are schematic devices for representing a set of concept meanings embedded in a framework of propositions. They provide a "picture" of how key concepts in a domain are mentally organized/structured (Ruiz-Pimo et al., 2001). For these reasons, in our pre-service and in-service teacher education workshops about inquiry-based teaching we used concept mapping as the main assessment method for probing the development of science teachers from various aspects.

2 Purpose

Concept maps are thought to be reliable indicators of knowledge structures constructed in mind. In this study we utilized this feature of concept maps and aimed to investigate if prospective chemistry teachers' participation in a professional development workshop enhanced their knowledge of inquiry-based teaching as a subject-specific instructional strategy which is a component of PCK.

3 Methodology

As part of a project, funded by Gazi University, that intends to enhance science teachers' knowledge of inquiry pedagogy, we firstly developed an inquiry-based professional development workshop for supporting chemistry teachers in their efforts to implement inquiry-based approaches in their chemistry classrooms. The workshop was structured in such a form that could be used in both pre-service and in-service teacher education (extracts from video recordings of the workshop with English subtitle will be displayed in the presentation). It is organized in six sessions. Each session focuses on a different aspect of inquiry-based teaching. The six sessions are as follows:

Session-I: Activities Based-on Inquiry:
Session-II: What is Inquiry?
Session-III: Scientific Process Skills in Inquiry
Session-IV: Asking Question in Inquiry
Session-V: Models and Strategies Which Support Inquiry
Session-VI: Opinion Sharing About Inquiry

The focus of the sessions and the way they were delivered are described via a concept map in Figure-2. As it is seen, in the sessions participants are engaged in a number of activities; the video recordings which involve some examples of the implementations of inquiry in high school science classrooms were displayed; knowledge about inquiry-based science teaching was introduced through a power point presentation and involving teachers to participate by discussing their ideas. The topic of how the concept maps can be used in inquiry-based science instructions was given a special emphasis in Session-V.

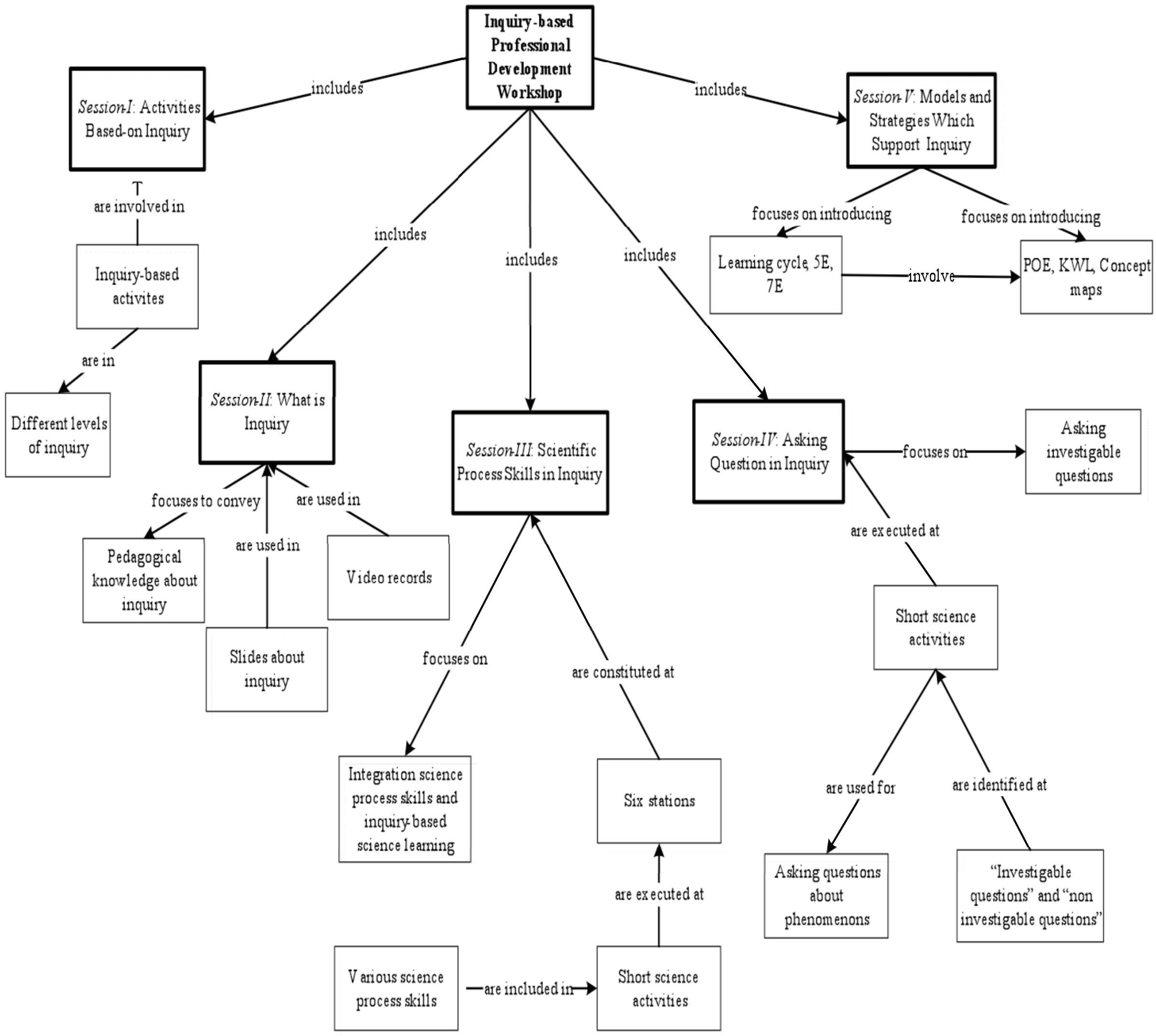

Figure-2. Structure of the sessions of inquiry-based professional development workshop

Since students are deemed to learn best when they are actively involved during the learning process, teachers probably will learn inquiry-based teaching when they are engaged in this methodology personally. In order to both engage participants in inquiry-based teaching and modeling the methodology, sessions were designed in the learning cycle format. In this way, through the variety of activities it is allowed that participants firstly experience one of the aspects of inquiry-based teaching that we expect them to use in their science lessons (*exploration phase for one of the aspects of inquiry-based teaching*). Secondly, participants are expected to construct knowledge and understanding by discussing and using their experiences (*concept development phase*). Lastly, participants are provided opportunities such as in-workshop activities or in-class activities to apply what they learned about different aspects of inquiry-based teaching (*concept application phase*). Throughout the workshop, participants sometimes act as a teacher and sometimes as a student.

In order to investigate the effect of the professional development workshop on knowledge of inquiry-based teaching 20 pre-service chemistry teachers at Gazi University in Ankara, the capital of Turkey, were selected as participants of the study. The workshop was conducted in a chemistry teaching laboratory during 10 weeks and 3 hours in a week. During the workshop participants were directed for learning to apply inquiry-based pedagogy within various chemistry themes. Before the workshop, participants were provided a specific training by the researchers on constructing concept maps. In this training, it is focused on chemistry themes in constructing concept maps. Both at the beginning and end of the workshop, participants were asked to construct a concept map that reflects their knowledge of inquiry-based teaching. The reason for us to prefer the "construct-a-map from scratch" technique was that this technique better reveals the differences between the knowledge structures than "fill-in-the-map" technique (Ruiz-Primo et al., 2001).

4 Results and Discussion

For the purpose of identifying the effect of our inquiry-based professional development workshop on the participants' knowledge of inquiry-based teaching, pre- and postconcept maps of participants were analyzed by utilizing the approach used by Novak & Gowin (1984), whose primary basis is Ausubel's cognitive learning theory. This is a popular approach for analyzing concept maps and getting quantitative measures. By taking this approach into account, concept maps of the participants were analyzed and scored according to the following factors: a) number concepts: 2 points for every concept relevant to the subject, b) overall hierarchical structure: maximum 10 points for arranging concepts according to the degree of relevancy to each other, c) number of meaningful proposition: 1 point for every valid proposition and 1 points for every clear proposition.

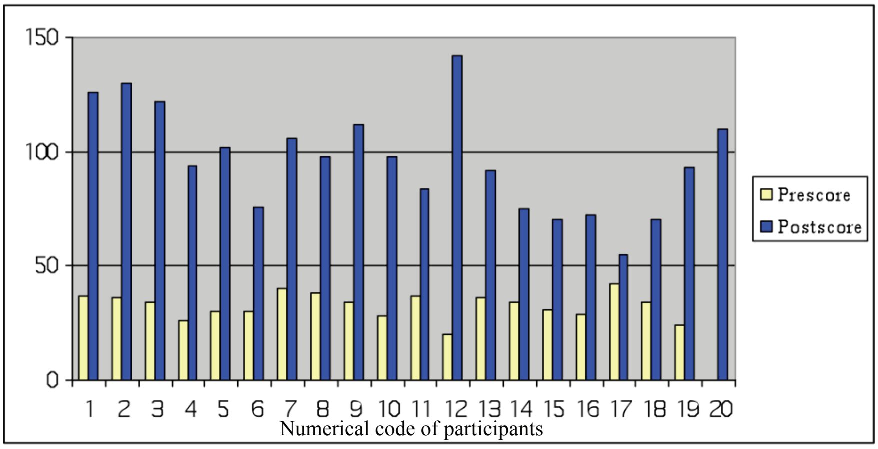

Figure-3. Distribution of the scores

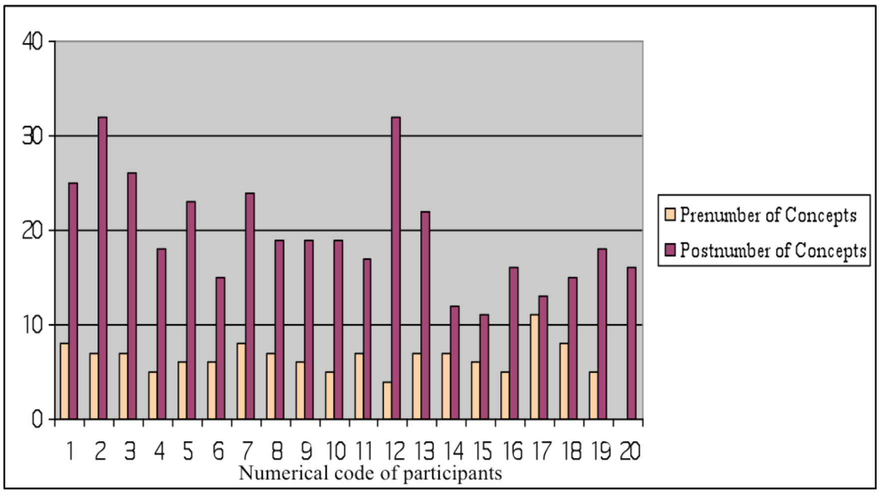

Figure-4. Distribution of the number of concepts

Each concept map was scored by the two of us jointly. It is determined that the scores obtained from the concept maps are distributed normally (for both pre- and post-concept map scores p>0.05) by using Kolmogorov-Smirnov Test in SPSS software. A paired samples t-test was used to investigate if prospective chemistry teachers' participation in professional development workshop changed their knowledge of inquiry-based teaching as a subject-specific instructional strategy. The result indicates a significant difference between the mean of pre- and post-concept map scores ($t_{(19)}$=-10,94; p<.05). It means that knowledge of the pre-service chemistry teachers about inquiry-based teaching had an important progress. Also the distribution graphs, belonging to the pre- and post-scores, and pre- and post-number of concepts, in Figure-3 and Figure-4 show this improvement.

Structures of all of concept maps were classified as linear, spokes, tree and network by us. We classified the concept maps into the structures by discussing and reaching an agreement. Pre-concept maps exhibited linear or spokes structure. But post-concept maps exhibited tree or network structure. According to Yin et al. (2005) among them, network structure is considered to be the most complex, while the linear structure is considered to be the simplest. Therefore, structures of the concept maps indicate that after the professional development workshop much more improved knowledge about inquiry-based teaching were constructed in pre-service teachers' minds. The concept maps of one of the participants as shown in Figure-5 and Figure-6 illustrate vividly how great this development is from pre- to post-concept maps. Despite the fact that participants had already participated in a science methods course in which they learned science teaching strategies before the workshop, pre-concept maps demonstrate that they did not have enough knowledge about inquiry-based teaching. The reason may be that in the science methods course science teaching strategies are introduced to them roughly, and opportunities for experiencing the strategies are not given. On the other hand, it was seen from the post-concept maps that participants had many concepts concerning and connected to inquiry pedagogy as it can also be seen from Figure-6. Furthermore, post-concept maps such as in Figure-6 indicated that the key concepts focused in each session were learned by connecting the key concepts in other sessions.

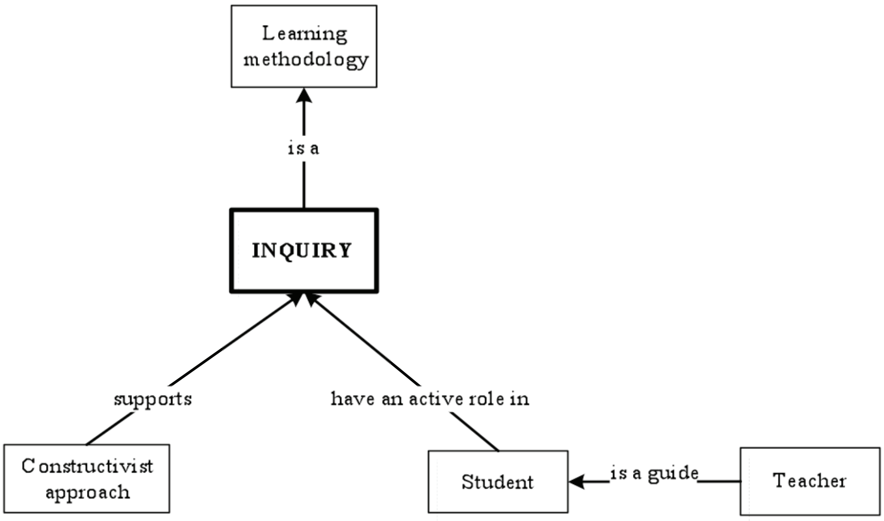

Figure-5. Pre-concept map of one of the participants

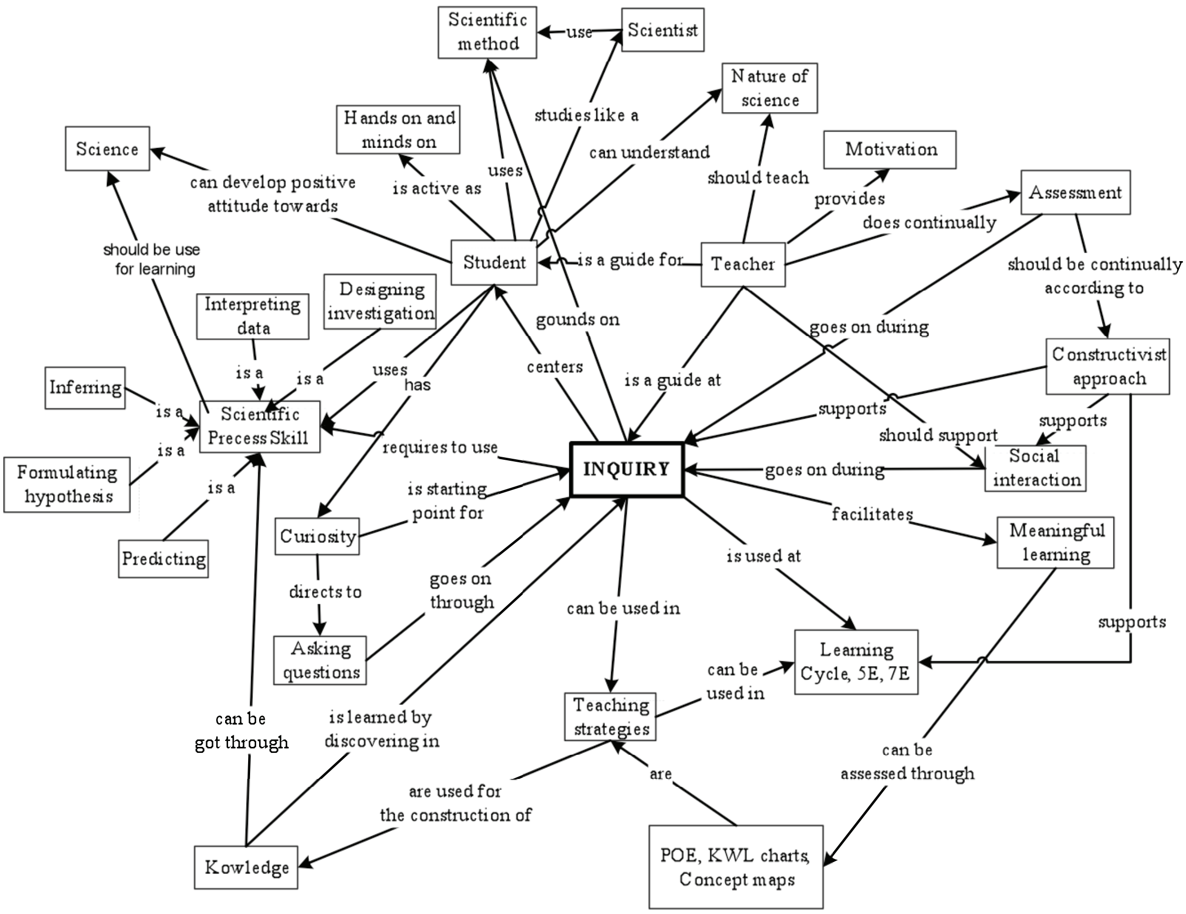

Figure-6: Post-concept map of one of the participants

Based on all the data from concept maps, there is support for assertion that the professional development workshop provided considerable improvement in participants' knowledge of inquiry-based teaching as a kind of PCK. The results of this study run in parallel with the results of our previous studies, which indicate that the inquiry-based professional development workshops contribute participants' improvement from various aspects (Budak & Köseoğlu, 2007a, 2007b). If the participants strive to use this new knowledge in designing inquiry lessons, they can implement inquiry-based teaching more readily.

Moreover, based on the results of this study, it was concluded from the dialogues with participants during the workshops that having the concept map which describes the structure of workshop as a hand-out before the workshop motivated them for participating to the workshop, and this concept map served as a roadmap for them through the workshop sessions. Therefore, we plan to distribute the concept map (Figure-2) to teachers in the future to provoke their participation to the workshops.

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WHO AM I? BUILDING A SENSE OF PRIDE AND BELONGING IN A COLLABORATIVE NETWORK

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Abstract. The *Conéctate al Conocimiento* project in Panamá has among its aims to establish a community of students and teachers that covers all public schools in the country. With this in mind, a network of schools has been implemented that supports and fosters collaboration, publishing and sharing, and that provides each participant with his/her own space and identity. During their training workshops, teachers started preparing concept maps on the focus question "Who am I?" and publishing them on the project's servers (as Web pages). This lead to creating "Who am I?" Cmaps of the schools, which have become the schools' 'portals' and to student's creating their own "Who am I?" Cmaps. In this paper we report how this effort has become a source of pride and belonging, resulting in a huge number of linked concept maps that encompass schools, students, teachers and school projects, and which allow users to navigate through the entire *Conéctate* project.

1 Introduction

As part of the *Conéctate al Conocimiento* project (Connect to Knowledge; Tarté, 2006) in Panamá, hundreds of schools are being introduced to meaningful learning and concept mapping through the use of technology in a collaborative network. The project is clear in its objective of transforming the way learning takes place in the classroom, moving away from a traditional rote-learning setting towards a constructivist environment emphasizing collaboration and project based learning. To achieve this goal, classroom teachers participate in two-week long full-time workshops. It is clear that transforming the environment in the classroom is not an easy task, and therefore making sure the teachers return to their classroom with a high degree of motivation improves the chances that the transformation will take place. Asking teachers to build a concept map about themselves and about their school has resulted in a high level of pride and a sense of belonging to the project. In this paper we begin presenting a summary of the *Conéctate* project, and later introduce the "Who Am I?" maps and explain how it resulted in a huge mesh of linked maps involving thousands of teachers and students throughout the country, as summarized in Figure 1.

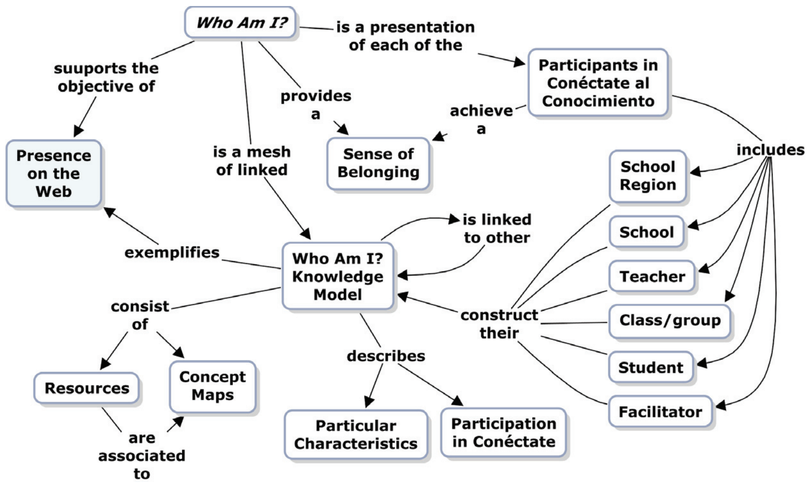

Figure 1. Through the "Who Am I" concept maps, teachers in the *Conéctate al Conocimiento* project achieve a sense of pride and belonging.

2 Background Information: Proyecto Conéctate al Conocimiento

In 2004, under the leadership of the then recently elected President Martín Torrijos, Panama adopted a national strategy based on meaningful learning for the public elementary school system through *Conéctate al Conocimiento*. The objective was to create a computer network that interconnects the schools creating, with the aid of technology, a space that allows the construction, sharing, and publishing of knowledge, the development of new learning skills individually and in groups, and the preparation of the national capacity for the country's development as a knowledge-based society. This implies aiding in the transformation of elementary public education, from a traditional rote-learning system to one emphasizing knowledge construction and the development of skills according to the needs of the 21st century. The project's goal is to include teachers and students from 1000 schools from all regions of the country over a 5-year period, with particular emphasis on reaching remote, rural schools. At the heart of the *Conéctate* project is the implementation of a concept map-centered learning environment in the classroom (Cañas & Novak, 2005; Novak & Cañas, 2004, 2006).

2.1 An Interconnected Community of Schools Facilitating Publishing, Sharing, and Collaboration

Conéctate was designed to be a network of schools that facilitates collaboration, publishing, and sharing. To achieve this goal, the whole set of participating schools is seen as being part of the same community, as a single organization, with all schools interconnected and connected to the Internet. Within each school, a CmapServer (Cañas, Hill, Granados, Pérez, & Pérez, 2003) is installed in a LAN with a public IP address, which means that every school's server can be reached from other schools and from anywhere on the Internet. This allows the school to have a 'presence' on the Web, not only access to it. *Conéctate* emphasizes students as knowledge builders, and facilitates and encourages students and teachers publishing their work on the Web, not limiting their use of the Internet to information consumption through copying and pasting. Students and teachers publish, share and collaborate, and students can access their concept maps and resources from home or an Internet Cafe (CmapServers and resources in the *Conéctate* schools can be reached through the Places View in CmapTools (Cañas et al., 2004) or through a Web browser). Within the CmapServer, each student and teacher has his/her own area for files, concept maps, and resources. The project is also deploying *Nicho* (Lott et al., 2008), a software tool designed at IHMC that simplifies assigning each student and teacher a project-wide unique userid and automatically sets things up so it is as an email address managed by Google, for a chat service, for CmapTools, and for Web browsing; additionally Nicho provides each student their own personal space in the school's file server. Through Nicho, students can use any of the computers in the school to access their resources and personally tailored environment. The userid and personal 'space' is valid for as many years the students stay in the school system, and their 'space' with its resources migrates with them if they switch schools. The goal is for the technology to fully support and facilitate the sharing and collaborating environment needed to implement a concept map-centered learning environment.

Even though Panama is a small country, rural villages are often very hard to reach, requiring many hours of travel over bad or nonexistent roads. In many cases, the schools to be included in the project did not have electricity, or the electricity distribution was such that using computers in the school would leave the rest of the village without electricity. As a result, there are schools in *Conéctate* with electricity from a local power plant, a satellite connection to the Internet, yet they are fully part of the school network and have presence on the Web.

2.2 Teacher Training

Given the physical infrastructure of schools and the scale of the project, it was determined when *Conéctate* started in 2004 that it would be impossible to install computers (i.e., desktops) in each of the classrooms, and so they have been installed in a special room that is referred to as the *Innovation Classroom*. The advent of lower cost laptops, however, has allowed *Conéctate* teachers and students to recently begin using laptops that can be taken to the classroom providing a more flexible usage of the technology. Our experience has taught us that in most technology-in-education projects that have a computer lab, what takes place in the lab is usually not reflected in what takes place in the classroom. That is, training teachers on how to use new technologies, particularly if the computers are not in the classroom, does not achieve changing the way learning takes place in the classroom. In other words, training teachers on how to construct concept maps using CmapTools would not lead to the concept map-centered learning environment where the diverse activities that occur in the classroom take advantage of concept mapping. It was therefore determined that, to the extent possible, all classroom teachers involved in the project would participate in an initial workshop that would encompass methodologies to implement a meaningful learning (Ausubel, 1968) environment in the classroom, based on concept mapping, project-based learning and collaborative projects within the classroom, in addition to the use of new technologies.

The teacher training workshops consist of 2 weeks of full time, intensive work. Training is also provided to the school principal (a principal that supports and understands the project is one of the key factors needed for success) and Ministry of Education supervisors. Approximately 47% of the teachers have never used a computer before attending the workshop, and many have never used a keyboard (Miller, Cañas, & Novak, 2006). The decision was made, however, to have the teachers learn to use the computer through CmapTools as opposed to using Windows and/or Office as is often done. Within a few minutes, teachers are constructing their own concept maps, maybe with some difficulty in manipulating the mouse, but are engaged in representing their understanding of some topic, an effort that they can immediately identify with, and that they perceive will be useful for their students. Suárez & Villareal-Bermúdez (2006) report that after a few days into the workshop, there is no distinction in the quality of the concept maps constructed by teachers who had or had not used a computer previously.[1] That is, the use of the computer has become, to a certain extent, transparent. The workshops aim to be completely constructivist in nature. Given that most teachers will not have computers in their classrooms, it is important that they feel comfortable with the idea of working with concept maps, both with and without computers. Overall, the objective of the workshop is to provide a basic understanding of constructivist environments, meaningful learning, concept mapping, and proper use of the technology so that teachers can take advantage in a constructivist way of any resource that they have available, whether it is technology-based (e.g., software, sensors, etc.) or not.

2.3 Conéctate's Status

Conéctate now encompasses more than 700 schools with computers and Internet connection, with over 5,000 fourth-, fifth-, and sixth-grade teachers trained in the 2-week workshops, reaching approximately 100,000 students.

3 Who Am I?

Conéctate was designed to facilitate and promote collaboration and sharing among students and teachers from participating schools. Going from a rote-learning setting to collaborating using concept maps in a meaningful learning environment is a long leap for many teachers, who, as was stated earlier, had never used a computer and/or had never browsed through the Web. An important aspect that the project pursues is providing a sense of belonging: that teachers –and schools– are not alone, that they are part of a larger community, and we believe that technology can be instrumental in achieving it.

Among the activities that take place during the teacher training workshop, there is one in particular that demonstrates how different components of the project fit together, and how the activities during the workshop continue when the teachers return to their schools. During a workshop in August 2006, teachers were asked to construct a concept map about themselves as a means to introduce them to concept mapping through a familiar topic, and were given the focus question "Who Am I?" We were aware of the use of "Who Am I?" concept maps in the WWMaps collaborative project (Tifi & Lombardi, 2006) in which schools from *Conéctate* had been involved. The concept map was extremely popular with the teachers, who really enjoyed working on the Cmap. As a result, the "Who Am I?" concept map was introduced as a standard activity during the workshop. Teachers began to bring pictures (family pictures, for example) that they wished to scan and link to the map, or borrow a digital camera to take pictures of their school and family when they return home for the weekend in between the two weeks of training. We began to notice that when they returned to their communities, teachers would "Google" themselves – that is, search for themselves on the Web. (When a concept map created with CmapTools is saved to CmapServer, a Web page is automatically generated which preserves any links to images or other resources. CmapServers that are part of the CmapTools network are automatically crawled by Google, and so the teachers' "Who Am I?" are searchable on Google soon after the workshop.) For teachers who had never previously used the Web to go back to their community and show colleagues, students, family and friends that they were *on* the Web gave them a sense of pride and belonging to *Conéctate* that surprised us. Figure 2 is an example of a concept map made by a teacher during the workshop.

3.1 The School's "Who Am I?" Concept Map

Further along during the series of workshops, teachers from the same school together with their Principal began to prepare a "Who Am I?" concept map for their school, a collaborative effort that involved constructing maps that uniquely describe the characteristics of their own school, the region in which it is located, and what distinguish them from other schools. The resulting concept maps are interesting, as teachers get quite personal in both their own concept maps and their school's map, particularly when trying to describe what is important to them in their school (e.g., a remote rural school emphasizes that it has a boat with a motor, another emphasizes that children receive free lunch, and yet another may list the names of the employees that clean the school). The

[1] Miller (2008) reports that by the end of the workshop teachers with previous computer experience do construct better maps, but there are other parameters involved, such as age (teachers with previous experience tend to be younger).

teacher's concept maps are then linked to the school's map, and when they are saved on the school's CmapServer, together they become the 'Web page' or 'portal' for the school. The school's map is then linked to a geographical map of Panama.

When they return from the workshop, their school has a 'presence' on the Web. They now have "Webpages" that they constructed by themselves, and more importantly, that they can modify at any time without the need of any webmaster or technician. This is a source of pride. Since each school has a CmapServer, their "Who Am I?" maps are housed at their school's server, not at a central server.

Figure 3 shows a Web browser with three windows.[2] The top left window is the main concept map for *Conéctate*, its Web page (www.conectate.edu.pa). This map has a link to a geographical map of Panama, shown in the lower left window. For each province or indigenous region (equivalent in Panama to a reserve), there are links to each of the schools' "Who Am I?" maps, as is shown in a partial display of the schools of the province of Chiriquí. The top right window displays the concept map for the school "El Limón," which describes details about this school. This school consists of only a computer aid and two teachers, one covering first, third and fifth grade, and the second covering second, fourth and sixth. The map shows the icons that link to the teachers' "Who Am I?" maps.

It is very common to see in the CmapServer's logs the result of searches by teacher name --most likely teachers searching for themselves (or for a colleague). Having their maps linked to the *Conéctate* concept map provides a sense of belonging -- their school is now *part* of *Conéctate*.

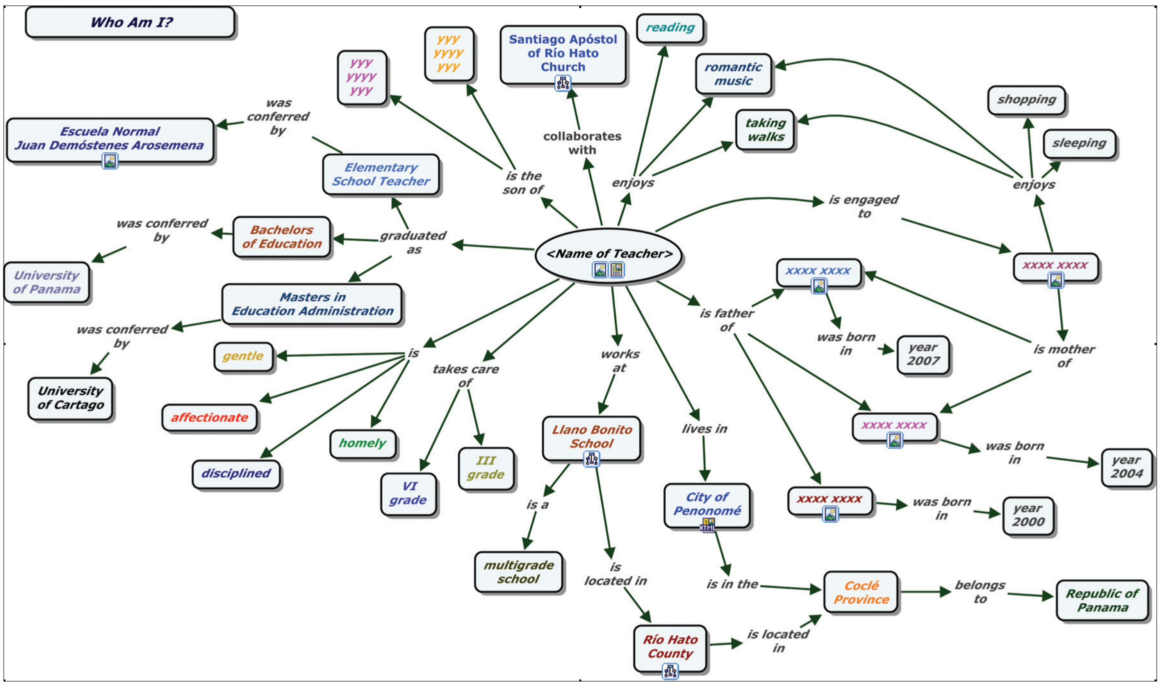

Figure 2. A "Who Am I?" concept map prepared by a teacher (proper names have been removed). It includes a link to the "Who Am I?" map of his school, links to maps the teacher prepared on his Church and on his County, links to pictures of himself, his children, and his fiancé, and links to Web pages of his city. The school is small, in a rural community, so he is responsible for two grades (III and VI), but the "Who Am I?" maps of his grades are not yet linked to his map.

3.2 A Mesh of "Who Am I?" Concept Maps

As the teachers returned to their schools from the workshops, they began asking the students in their classrooms to make their own "Who Am I?" concept map. The students would also collaborate in preparing a "Who Am I?" of their classroom. The maps of the students could now be linked to the map of the classroom, and the map of the classroom to the teacher's map and to the school's map. Soon it became obvious that "Who Am I?", which

[2] These maps were not translated to emphasize the authenticity of the Web pages.

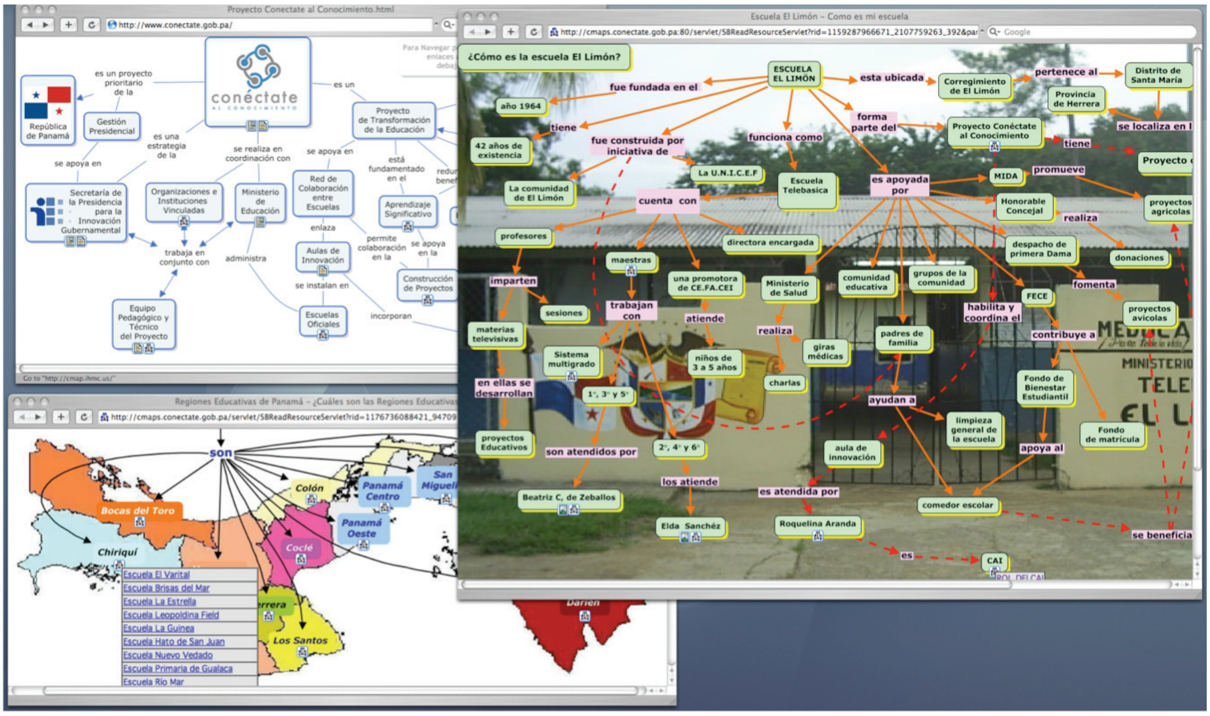

Figure 3. From the *Conéctate* concept map Web page in the top left window, a link opens a map with all regions of Panama shown in the lower left window, from which links lead to the "Who Am I?" concept map of each school in the Project, as is exemplified by the map for the Escuela La Unión, displayed in the window at the right.

was introduced as a focus question for the first map in the teachers' workshops had become a collaborative effort on its own that was resulting in linking all participants in *Conéctate*. Figure 4 depicts the "mesh" of "Who Am I?" concept maps that has resulted. Starting from *Conéctate's* Web page concept map, links lead to a map of Panama divided in regions and to maps describing collaborative project between schools in *Conéctate*. The regions map has links to each of the school's "Who Am I?" concept map, which, as explained earlier, is housed in the CmapServer physically at the school (unless an Internet link has not yet been established at the school). Each school's "Who Am I?" map reflects the idiosyncrasies of the school, with different content and images. We recommend that the map should have at least links to the "Who Am I?" map of the Principal, each teacher and, directly or indirectly through another map, each class, and to the projects in which the school is involved. Additionally, some schools have created concept maps about other activities or organizations they are collaborating with and linked them to the school's map. Each teacher's map, as shown in Figure 2, is very personal, showing in part the teacher's degrees, but often describing the family with links to pictures. The map in Figure 2 has links to a concept map about the Church the teacher belongs to, and of the County where he lives. We propose that each class build their own "Who Am I?" concept map and link it to their school and to their teacher's maps. From the class's map, a link leads to each of the student's "Who Am I?" concept map. Students enjoy creating this map, and teachers are starting to take advantage of a unit on biographies that is part of the Panamanian curriculum to introduce the construction of the map. As all concept maps that a student saves on the school's CmapServer (in their own personal space as assigned by Nicho) are automatically published and available to everybody on Internet, we are proposing that students begin selecting from the knowledge models that they have constructed and create a portfolio of their best work to link to their "Who Am I?" concept map.

As the *Conéctate* progresses, students will be able to navigate to the concept maps of any other student in the country, thereby contributing to a sense of community. As students start collaborating with other students, they can easily search for their peers' concept maps and learn who they are and what their interests are,. As the mesh grows, eventually all participants in *Conéctate* will be linked together.

3.3 Status of "Who Am I?"

The "Who Am I?" effort began way into the second year of *Conéctate*, when thousands of teachers had already participated in the workshop, and hundreds of schools were already part of the project. An effort is in place to incorporate all these participants into the mesh. To get a feeling for the current level of participation, 356 schools were surveyed early 2008, out of 573 that were at that point part of the project. Out of these, 218 (61%)

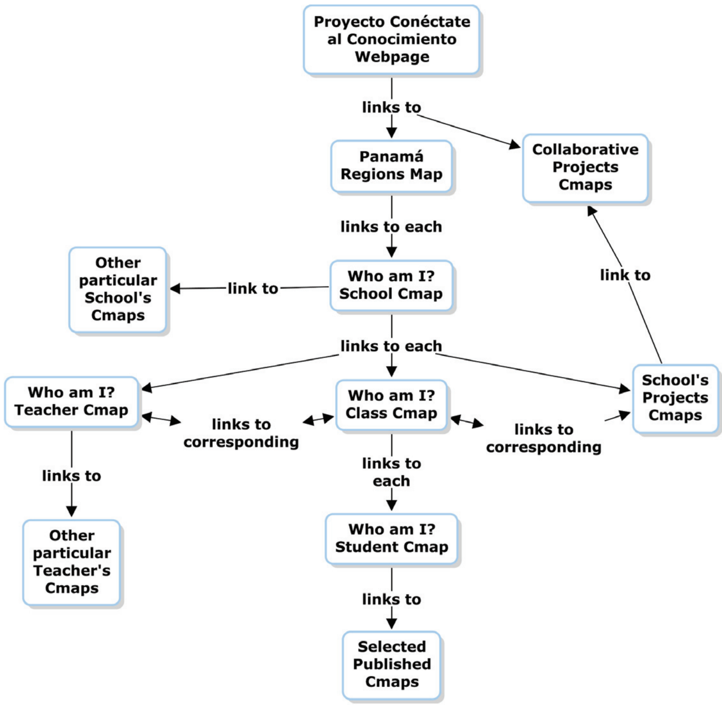

Figure 4. Starting from *Conéctate's* Web page concept map, links lead to the "Who Am I?" map of each school in the Project, from which links lead to the principal's, teachers', classes' and students' "Who Am I?" concept map. Participants link to their personal map other concept maps or resources that they select.

had a school "Who Am I?" concept map. There were 1248 teachers' "Who Am I?" maps, and 3968 students' maps. However, we are aware that a lot of the students construct their map and never link them to the school or class map, and so an extra effort is required to make sure the maps are linked into the mesh. "Who Am I?" has become a popular first map to ask of students when introducing them to concept mapping, but being an initial map the students don't yet know how to link them to the schools' other concept map.

4 Discussion and Summary

The construction and publishing of the "Who Am I?" map generates motivation and a sense of pride of belonging to *Conéctate* in teachers and students. Principals and teachers return from the training workshop with their 'school portal' already on the Web and linked to the *Conéctate's* Website's maps. They can "show off" their achievement upon their return to their community. Building the "Who Am I?" map for the School has also served as a means to get the teachers and Principals to collaborate, in many cases learning how to use features like synchronous collaboration in CmapTools while jointly building the maps. This has taken place during the workshops, or, in the case of schools that joined *Conéctate* before this effort got underway, by meeting at the school to elaborate their personal and schools' maps.

The "Who Am I" project makes the teachers and students aware of the power of "publishing" their knowledge on the Web, of sharing and making it available to others. In *Conéctate* we emphasize the power of the Internet as a publishing and sharing platform, not limited to an information consumption tool. By publishing their "Who Am I?" map during the workshop and then "Googling" themselves and colleagues, teachers became much more aware of the power of being able to easily publish their concept maps on the Web than teachers in previous workshops. They then became more interested in publishing other maps. For example, during a workshop, Vielka Gálvez, a teacher from a rural region, made a Google search about the community she lives in (Remedios, Chiriquí), and found only one Web page. Concerned that there was nothing about her community, she constructed a concept map describing it and linked it to her "Who Am I?" map so that the world will know "who we are, what we do, what we have, etc." The teacher was responsible for "putting her community on the Web". This was the first time she had ever been in touch with Internet.

"Who Am I?" also serves as a good first map to ask from teachers or students who are learning concept mapping. Through interviews we found many students who proudly told us that they "learned to use the computer by making the 'Who Am I?' map"; that they "learned how to add photos, backgrounds and color the map"; that they are "happy to share their map with children around the world through the Internet"; that they "talked about things that I like and I dislike"; and that "my 'Who Am I?' map is different from that of my classmates." Thus, constructing the "Who Am I? concept map allows the student to think about themselves, it represents a platform on which to build and publish their knowledge based on their personal experience, helping reinforce their self-image by having to make public a description of their attributes, features, personality, place where they live, family, opinions, ideas, thoughts, friends, etc. Exteriorizing or making public a students' knowledge and feelings is a key characteristic of concept mapping. Teachers report finding out about problems in students' lives throught their "Who Am I?" maps.

The "Who Am I?" map is being incorporated into many places of the Panamanian curriculum. The English teacher at the Toribio Berrío Sosa School has her students do their "Who Am I?" concept map in English. In the Antonio José de Sucre School, the teacher Vielka Valdés uses the "Who Am I?" concept map in her Religion classes. It has been used as part of the Biographies unit of the school's curriculum, and as part of the "Names" collaborative project between schools.

Finally, navigating through the "Who Am I?" maps is becoming an effective way of understanding and getting a pulse of the *Conéctate al Conocimiento* project.

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YOUNG FLORIDA NATURALISTS: CONCEPT MAPPING AND SCIENCE LEARNING OF PRESCHOOL CHILDREN

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Abstract. The *Young Florida Naturalists* project focused on increasing the background knowledge and concept development of 3- and 4-year-old children (n = 53) enrolled in three classes at an early learning center. This study built on the work of Hirsch (2006), Neuman & Celano (2006), Novak & Gowin (1984), and Zimmerman (2005) regarding concept mapping, elementary science learning, and the knowledge gap of at-risk, young children. Learning experiences involved plants and their role in the environment. Instructional activities included advance organizers or statements of scientific beliefs to guide the children's investigations. Investigations included activities such as determining the effects of sunlight on plant growth. Building background knowledge was emphasized as the children engaged in concrete experiences with plants in a butterfly garden developed on the center's grounds. Vocabulary development was emphasized through read-aloud activities based on environmental books purchased with grant funds. Concept mapping was used to document the hierarchical relationships described by the children before, during, and after learning experiences were initiated.

1 Introduction

Several areas have been highlighted in research on literacy development, development of scientific thinking, and cognitive development. In the area of literacy development, it has been found that vocabulary growth and language expansion occur through reading aloud to children (Lyon, 2001). In the area of development of scientific thinking, Zimmerman (2005) conducted an extensive review of research. She reported that young children tend to ignore evidence that conflicts with prior beliefs and that advance organizers are essential to effective science teaching with young children. Concept mapping has been documented (Novak & Gowin, 1984) as a strategy for examining children's understanding of relationships among concepts. Through concept mapping children are able to make visible their thinking about the relationships among the concepts being studied. With these findings in mind, the *Young Florida Naturalists* project focused on the following: a) using read aloud strategies to reinforce vocabulary and concept development, b) providing advance organizers to frame experiments involving plants, and c) initiating concept mapping to capture children's thinking about the relationships among the concepts. Hirsch (2006) and Neuman & Celano (2006) indicated that for children to become proficient readers, they must possess broad knowledge that enhances comprehension. Many at-risk, young children enroll in kindergarten with what has been described as a knowledge gap. They have not been exposed to experiences that have enabled them to develop broad background knowledge across content areas when compared to middle-class peers. This project was designed to enable young children to build core knowledge essential to becoming proficient readers.

2 Method

The *Young Florida Naturalists* project focused on three goals. The first goal was *to increase young children's knowledge of plants and their role in the environment*. The second goal was *to introduce scientific learning through hands-on instructional experiences*. The third goal was *to examine the utility of concept mapping as a tool to track concept development in at-risk young children (3- and 4-year-olds)* and is, therefore, focused on how young children learn. Through these goals the proposed project addressed a city-wide goal to have all children enroll in kindergarten, "ready to read, ready to learn, and ready to succeed."

2.1 Objectives

The objectives of the *Young Florida Naturalists* curriculum were the following:

- Enable young children to correctly identify concepts and their hierarchical relationships by providing environmental experiences with plants.
- Enhance vocabulary development and language expansion of young children by reading selected books to them.
- Help children develop concept maps based on their statements about plants and the environment.
- Help scaffold children's thinking about plants and their relationship to the environment by using advance organizers as an instructional tool.
- Help young children develop conceptual thinking by providing opportunities to construct concept maps using word/picture cards.

2.2 Hypotheses

The hypotheses were as follows:

Young children will not be able to articulate the hierarchical relationships among the concepts related to plants and their role in the environment.

Young children will not be able to construct a concept map that includes second or third level concepts, related to plants in the environment.

2.2 Participants and Context

The *Young Florida Naturalists* project focused on increasing the background knowledge and concept development of 3- and 4-year-old children (n = 53) enrolled in three classes at an early learning center located in a high-need, urban neighborhood. This study built on the work of Hirsch (2006), Neuman & Celano (2006), Novak & Gowin (1984), and Zimmerman (2005) regarding concept mapping, elementary science learning, and the knowledge gap of at-risk, young children. Learning experiences involved plants and their role in the environment. Instructional activities included advance organizers or statements of scientific beliefs to guide the children's investigations. Investigations included activities such as determining the effects of water, sunlight, air and soil on plant growth. Building background knowledge was emphasized as the children engaged in concrete experiences with plants in a butterfly garden developed on the center's grounds. Vocabulary development was emphasized through read aloud activities based on environmental books purchased with grant funds. Concept mapping was used to document the hierarchical relationships described by the children before, during, and after learning experiences had been initiated.

This project was conceived as a foundational study in the development of young children's knowledge about plants and their role in the environment. Concept mapping has primarily been conducted with students at the upper elementary level through college levels (Novak & Gowin, 1984). There has been some seminal work in Spain and Italy (Figueiredo, Lopes, Firmino & de Sousa, 2004). In the Spanish study (Figueiredo et al., 2004), 13 children aged 3-6 years were engaged in an instructional unit about cows for a period of four weeks. Our project, lasting eight weeks, focused on the study of plants and their role in the environment.

Teachers provided instruction based on a unit of lessons they developed for the *Young Florida Naturalists* curriculum. The teachers used the *Understanding by Design* (Wiggins & McTighe, 1998) framework to construct lessons focused on big ideas and essential questions related to the science concepts incorporated in the unit plan. Instructional strategies involved the use of advance organizers or scientific beliefs about the nature of plants and the environment and the use concept mapping. Advance organizers (i.e., information presented to students prior to learning that provides general rules and examples) were identified in research as an essential strategy for use with young children. It has been documented that young children will hold on to beliefs that have been refuted by evidence/data (Zimmerman, 2005). Additionally, project teachers were trained in basic concept mapping. Read alouds continued to be a predominant instructional strategy for vocabulary and concept development; therefore, the curriculum was an extension of the school's literacy curriculum. Reinforcement of concepts occurred through hands-on experiences in the butterfly garden.

The first lesson for each class involved development of a group concept map, based on a series of 20-25 pictures. This concept map was a point of reference throughout the eight-week instructional period (March-April 2007). Modifications were made as the children learned new information (concepts) that needed to be added or as they chose to correct errors that they detected in their first attempt.

Following the first lesson, the teachers and children worked with volunteers and parents to plant a butterfly garden. Various experiments were conducted to determine the effects on the plants, e.g., effect of too much water on plants. All lessons were provided in the packet/unit developed for instruction.

2.3 Assessments

A series of three assessments was conducted to document the changes in the children's concept development and the connections made among the concepts. The assessments mirror those conducted in the study about cows that was conducted in Spain (Figueiredo et al., 2004). The assessments were as follows:

- *Assessment 1*: Task of sorting and organizing around pictures about the cow; in this project, the task involved sorting and organizing a 20-25 pictures about plants.
- *Assessment 2*: Individual talk—"What do we know about the cow?" In this project, the question was, "What do you know about plants?"
- *Assessment 3*: To assess the understanding of the concept map itself, each child was asked, "What do these images here represent? What is this scheme for?" In this project, the questions were similar and children were able to reference the class concept map about plants.

2.4 Family Involvement

At the conclusion of the instructional period, a family event was conducted. Parents were provided with a packet of materials and books, along with plants/cuttings to start a garden at home. This event was a celebration of what the children had learned. Additionally, families were invited to participate in a city-wide butterfly release and festival at a local nature preserve. Grant funds were used to pay for admissions for the families.

3 Results Related to Objectives

3.1 Objective 1: Enable young children to correctly identify concepts and their hierarchical relationships by providing environmental experiences with plants.

Objective 1 was addressed through the following purchases of materials and activities: a) classroom manipulative materials related to plants and butterflies; b) children's nonfiction books about plants and butterflies; c) experiments with live plants; d) planting a butterfly garden; and e) observing the butterfly life cycle/butterfly release.

Using the advice of an Associate Professor of Biology at the local state university, we purchased classroom plant- and butterfly-related manipulative materials and nonfiction books, experimented with live plants, planted a butterfly garden, and the children observed the butterfly life cycle, and participated in a butterfly release. To prepare children for the actual experience of planting and caring for a butterfly garden, the classroom teachers conducted demonstrations showing that plants need water, air (CO_2), soil (nutrients), and sunlight. The children also planted beans (seeds) in cups so they could learn about roots, stems, and leaves. Another activity focused on the stem and its function to transport water and nutrients to the leaves and flowers. Carnations and colored water were used to illustrate the function of the stem.

3.2 Objective 2: Enhance vocabulary development and language expansion of young children by reading aloud selected children's books to them.

The teachers collaborated with project researchers to select nonfiction books developmentally appropriate for the children. Each classroom received 26 books related to plants and butterflies. The books were used to implement the lessons as detailed in the unit plan. Vocabulary and concept cards were provided for the weekly lessons. The transcripts of the children's statements during each assessment reflected the new vocabulary the children learned, such as soil, stem, nutrients, chrysalis, tap root, and fibrous root.

At the conclusion of the *Young Florida Naturalists* lessons, a family event was conducted. Families were invited to see children demonstrating activities that were included in a take-home packet, as well as view a PowerPoint© presentation of pictures taken during the project's implementation. The demonstrations were held twice, during the morning drop-off time and during the afternoon pick-up time to accommodate parents' work schedules. Parents were provided with a packet of materials, books, and activity suggestions, along with plants to start a garden at home. The purpose of the take-home packet was to enable parents to read to their children thereby reinforcing the vocabulary and science concepts the children learned.

3.3 Objective 3: Help children develop concept maps based on their statements about plants and the environment.

The three teachers constructed initial concept maps with the children in their respective classes. The teachers read two books, *The Butterfly Life Cycle* and *Green and Growing*, to stimulate the children's thinking. The concept maps were posted in the classrooms. Final concept maps were constructed with the children's input prior to *Assessment 3*.

The final class concept map was used with the children for *Assessment 3*. The *Assessment 3* Prompt was: *What do these pictures represent? This is the concept map you did with Ms._______. What do the pictures tell you about plants?*

Project researchers videotaped each child's response to *Assessment 3*, transcribed the responses, and developed individual concept maps for each child's portfolio. Each portfolio provides documentation of the responses to assessments and shows each child's growth over the *Young Florida Naturalists* curriculum implementation period.

3.4 Objective 4: Help scaffold children's thinking about plants and their relationship to the environment by providing advance organizers as an instructional tool.

The nonfiction books purchased for the classrooms served to provide factual information about plants and butterflies for the lessons. Reading the books to the children served as a form of advance organizer for lesson content. The books included titles such as, *We Need Sunlight, Water, and Soil, From Seed to Plant,* and *How a Plant Grows.* Also, the teachers used the *Understanding by Design* (Wiggins & McTighe, 1998) process to develop the unit. Through this "backward design" process, the big ideas and essential questions were identified before the learning activities were planned. The big ideas and essential questions also served as advance organizers for lesson discussions and activities. Some of the big ideas and essential questions were the following:

- The world is made up of living and non-living things.
- Certain plants attract butterflies.
- What do living things need from the environment to survive?
- What are the basic characteristics of living things?

3.5 Objective 5: Help young children develop conceptual thinking by providing opportunities to develop concept maps using word/picture cards.

Each class constructed an initial concept map to illustrate the children's understandings about butterflies and plants. Pictures and word cards were provided by project researchers. As part of their literacy instruction, the children had been engaged in activities related to Eric Carle's book, *The Very Hungry Caterpillar.* The concept maps reflected their understandings of the life cycle of the butterfly. One vocabulary word had to be addressed through explicit instruction. Children had learned the word *cocoon* instead of *chrysalis* for the pupa stage of the butterfly. Most students had limited knowledge of plant parts and their functions.

The final concept map was constructed using pictures and word cards of plants and parts of plants provided by project researchers. Teachers led the discussions in each class. The final concept maps reflected that children could make propositions connecting second- and third-level concepts, e.g., a plant (first level) can have a flower (second level) that can provide fruit (third level).

4 Assessment Results

4.1 Assessment 1: Task of sorting and organizing around pictures about plants and butterflies.

The following picture, Figure 1, illustrates the organization of the pictures by Student # 1. The student used 10 of the pictures and stated the following: *Trees and roots need sunlight. (Leaf) goes on a tree and needs sun. Plant the seeds with the flower. Stem goes with flower. Caterpillar turns into chrysalis. Chrysalis turns into butterfly. Butterfly goes with eggs.*

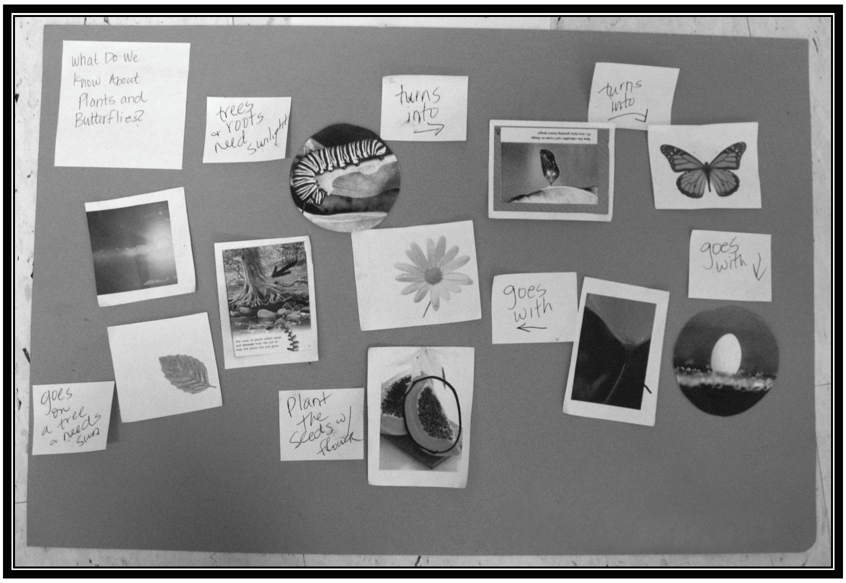

Figure 1. Assessment 1 child's map

Children were assessed individually by project staff. Pictures of the children's concept maps were reviewed. Two-thirds (67%) of the 4-year-old children were able to make at least one, second level concept proposition about plants. Their propositions were basic, such as, "*plants* (first level) need *sunlight* (second level)." Only 35% of the 3-year-old children were able to make at least one, second level concept proposition. The 3-year-olds tended to name the pictures without making propositions. These results appear in Figure 2.

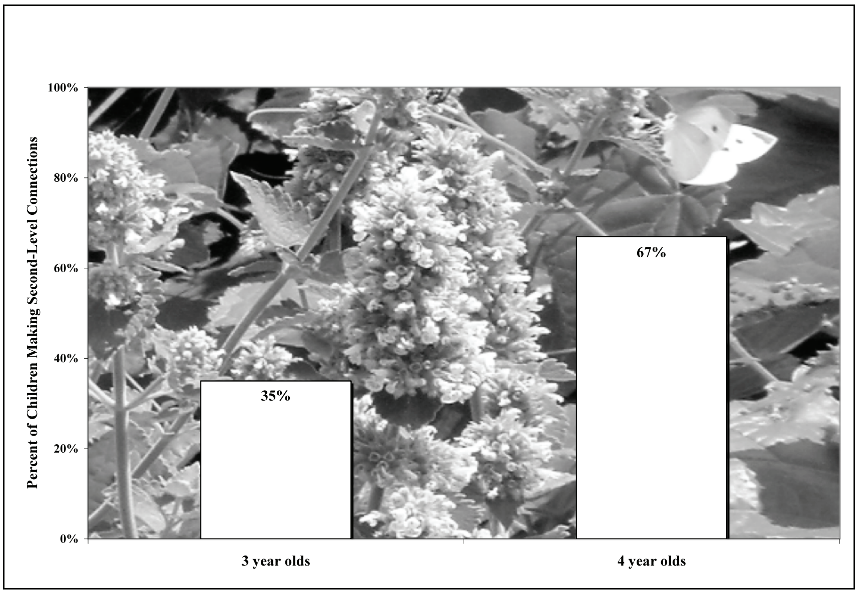

Figure 2. Assessment 1 results

4.2 Assessment 2: Individual talk—"What do we know about plants?"

As shown in Figure 3, Student # 1 was able to recall from memory three parts of a plant—stem, petals, and leaves. The student was also able to recall the process of planting seeds to grow flowers

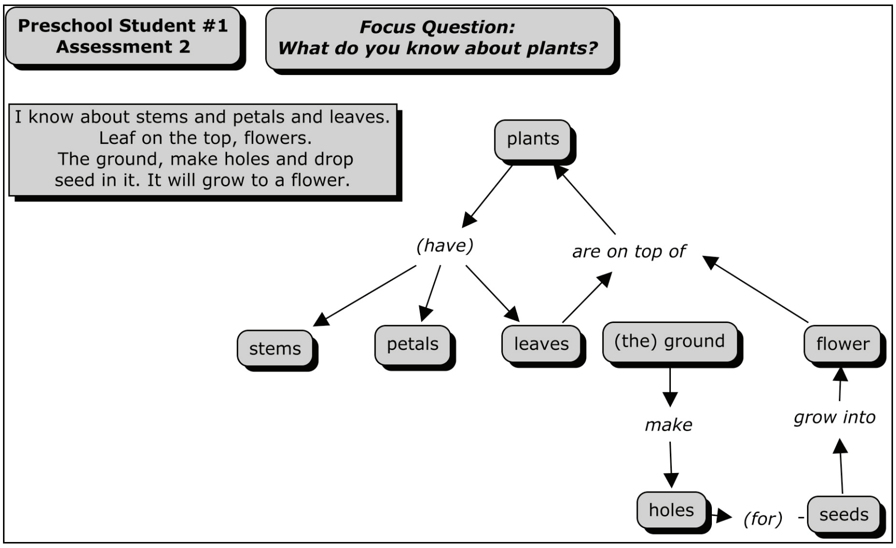

Figure 3. Assessment 2 child's map

Children were assessed individually by project researchers and their responses were transcribed. Responses ranged from 3 words to 136 words. Concept maps were constructed to reflect their statements about plants. A review of the concept maps revealed that 18 (64%) four-year-old children and 7 (41%) three-year-old children were able to make second and third level concept propositions. Results appear in Figure 2.

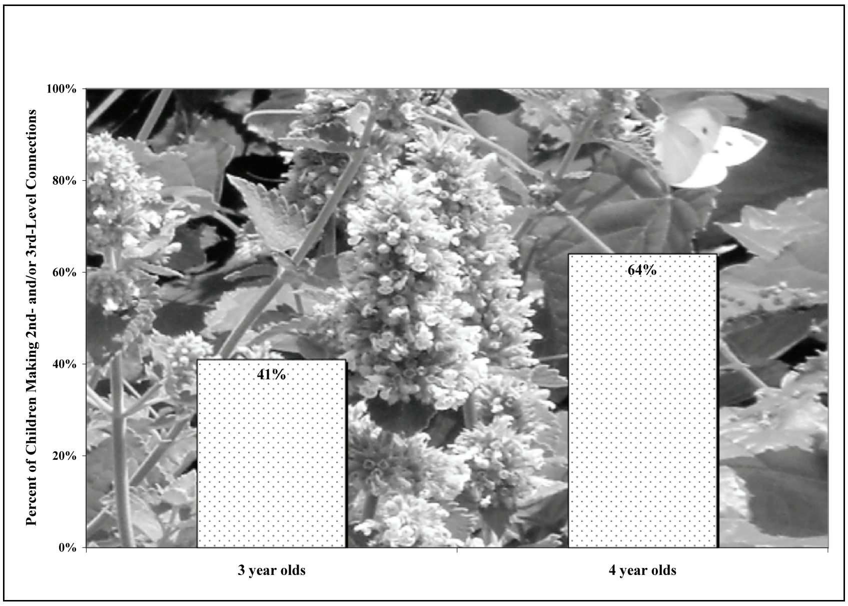

Figure 4. Assessment 2 results

4.3 Assessment 3: To assess the understanding of the final concept map itself, each child was asked, "What do these pictures represent? This is the concept map you did with Ms. ____. What do the pictures tell you about plants?"

The transcript of Student # 1 and the accompanying map, shown in Figure 5, illustrates the increased complexity of the three year old's conceptual development.

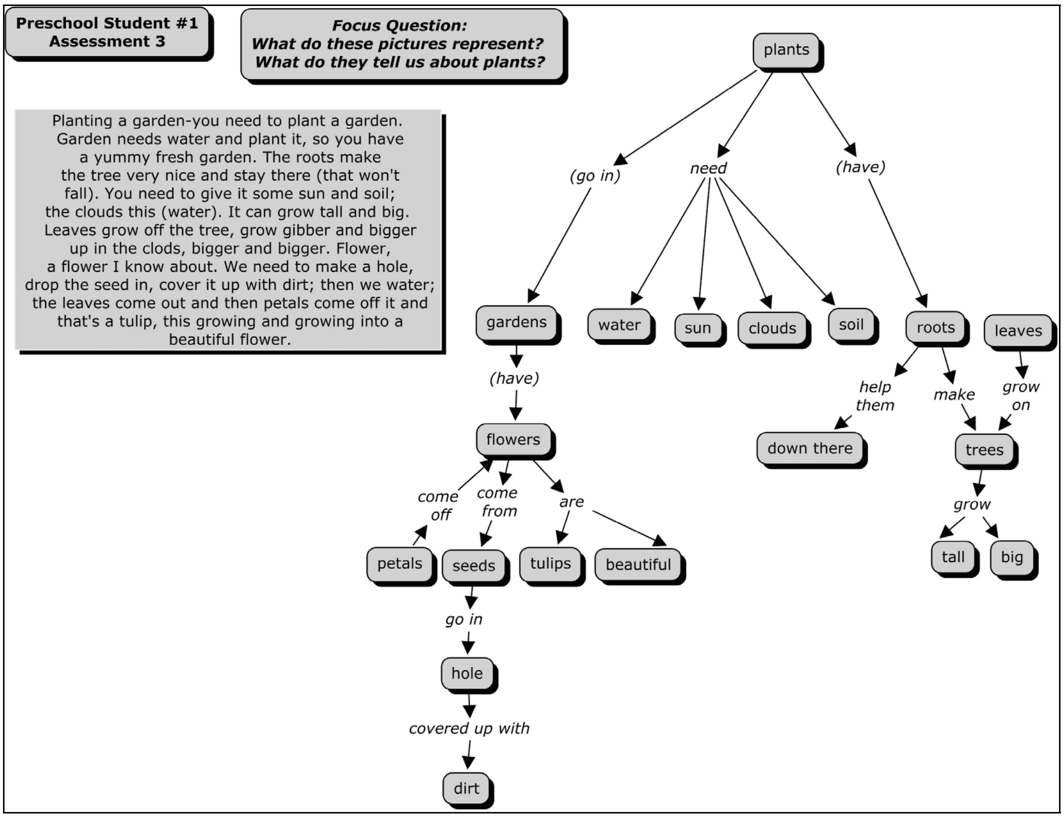

Figure 5. Assessment 3 child's map

Children were assessed individually and videotaped by project researchers. Their responses, ranging from 7 to 117 words, were transcribed, and concept maps constructed based on their statements. A review of the concept maps revealed that 28 (93%) 4-year-old children and 11 (85%) 3-year-old children were able to make second and third level concept propositions. See Figure 6. Based on the results of the three assessments, both hypotheses were rejected.

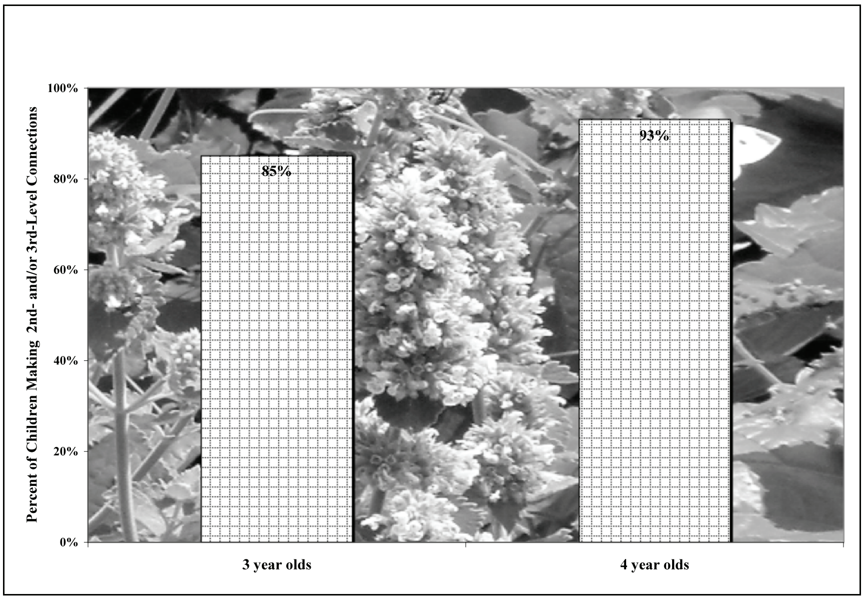

Figure 6. Assessment 3 results

5 Discussion

This project was designed to be ongoing. The teachers and children have continued to take care of the garden. (See Figures 7 & 8 below.) Plants that suffered some cold damage are sprouting again and others, like the passion flower vine, are blooming. Butterflies are being attracted to the garden once again. The garden has provided essential, hands-on learning experiences for the children.

Additionally, the teachers have expressed their excitement about how much the children have learned and have retained. The enhancement of both vocabulary and conceptual development has been validated through the children's oral responses to the assessment questions.

The learning protocols from the *Young Florida Naturalists* curriculum will be made available to other child care centers through a partnership with the local early learning coalition and to the public school district prekindergarten office. Also, a policy brief and the instructional plan will be posted on the project sponsor's Web site in an effort to disseminate the learning protocols.

Figure 7. Preschool children in garden

Figure 8. Butterfly host and nectar plants

5 Acknowledgment

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