Concept Maps: Making Learning Meaningful
Proc. of Fourth Int. Conference on Concept Mapping
J. Sánchez, A.J. Cañas, J.D. Novak, Eds.
Viña del Mar, Chile, 2010

FUTURE CHEMISTRY TEACHERS USE OF KNOWLEDGE DIMENSIONS AND HIGH-ORDER COGNITIVE SKILLS IN PRE-LABORATORY CONCEPT MAPS

Johannes Pernaa & Maija Aksela, University of Helsinki, Finland
johannes.pernaa@helsinki.fi

Abstract. This poster describes a pilot case study, which aim is to study how future chemistry teachers use knowledge dimensions and high-order cognitive skills (HOCS) in their pre-laboratory concept maps to support chemistry laboratory work. The research data consisted of 168 pre-laboratory concept maps that 29 students constructed as a part of their chemistry laboratory studies. Concept maps were analyzed by using a theory based content analysis through Anderson & Krathwohls' learning taxonomy (2001). This study implicates that novice concept mapper students use all knowledge dimensions and applying, analyzing and evaluating HOCS to support the pre-laboratory work.

1 Introduction

Laboratory work is essential in chemistry and a widely studied topic in chemistry education. Laboratory is a diverse learning environment and therefore a challenging space to teach and learn. More research is needed on developing new instruments that promote learning and teaching in laboratory (e.g. Nakhleh, Polles, & Malina, 2002). One solution to promote teaching and student's meaningful learning in laboratory is concept mapping, which is a modeling technique where conceptual frameworks are illustrated with concepts and linking words in order to create concept maps. There is some research of the benefits of concept mapping in chemistry laboratory environment (e.g. Kaya, 2008; Markow & Lonning, 1998; Stensvold & Wilson, 1992; Özmen, Demircioğlu, & Coll, 2009). For example, Stensvold and Wilson (1992) carried out a study which aim was to support students' understanding of concepts and theories related to laboratory activities. In their study, students constructed pre- and post-laboratory concept maps. They found that pre- and post-laboratory concept maps help students to concentrate on working and improve understanding of procedures and concepts. Pre- and post-laboratory concept maps were also used in studies Kaya, 2008; Markow & Lonning, 1998; Özmen et al., 2009. According to these studies, concept maps improve understanding of chemical concepts, help building connections among abstract concepts and work as an alternative conception correcting tool.

2 Theoretical framework

Studies described in introduction, monitored students learning process by measuring statistical differences using pre- and post-laboratory concept achievement tests (e.g. Markow & Lonning, 1998; Özmen et al., 2009) and pre- and post-laboratory interviews (Özmen et al., 2009). In the study performed by Kaya (2008), pre- and post-laboratory concept maps were analyzed using a concept map criteria where the number of valid and invalid concepts, propositions, cross-links, examples and alternative conceptions were scored. After scoring, the value of interconnectedness and total scores were calculated and analyzed for statistically significant differences.

In this study, students' pre-laboratory concept maps were analyzed using major knowledge dimensions and Anderson & Krathwohls' learning taxonomy. Major knowledge dimensions are divided in four categories: factual knowledge (e.g. terminology), conceptual knowledge (e.g. classifications, principles or theories), procedural knowledge (e.g. skills, algorithms or techniques) and metacognitive knowledge (strategic, cognitive or self-knowledge) (Anderson & Krathwohl, 2001).

The learning taxonomy consists of six cognitive skills that are divided in two categories: low-order cognitive skills (LOCS) and high-order cognitive skills (HOCS). LOCS include remembering and understanding and HOCS include applying, analyzing, evaluating and creating (Anderson & Krathwohl, 2001). This poster concentrates on analyzing how students use procedural and metacognitive knowledge dimensions and HOCS in their pre-laboratory concept maps. There is no use to analyze the use of factual and conceptual knowledge dimensions or LOCS, because they are essential elements of concept maps and concept mapping and can be found almost from every map.

3 Methodology of research

This pilot study was executed as a case study (e.g. Cohen, Manion, & Morrison, 2007) during a *Practical chemistry in chemistry education* –course in the University of Helsinki in autumn 2009. The research sample consisted of 29 future chemistry teachers (students) (9 male and 20 female) who participated in the course. 11 students studied chemistry as their major and 18 as their minor. Most students in the course were at the beginning of their university studies. 18 students had done under 100 credits, 7 students under 180 credits and only 4 students over 180 credits (full degree is 300 credits). Before the course, concept map was a rather unknown concept for the students. Majority of the students (N = 23) answered that they have used concept maps before in their studies or their teaching, but at the same time only nine students could explain the difference between concept maps and mind maps.

During the course, students performed six laboratory activities, which from three were given and other three were optional. The students made an advance assignment from each laboratory activity. In the assignment they explained the chemistry, procedures and safety aspects related to the laboratory activity. The students were also asked to include a concept map from the laboratory activity as a part of their advance assignment. They had the liberty to model anything they wanted in their concept maps, as long as it supported their pre-laboratory work. The research data of this study consists of these pre-laboratory concept maps. The total number of maps was 168.

The aim of this research was to examine how students use concepts maps to support their pre-laboratory work. The research was carried out by using a theory-based content analysis where knowledge dimensions and learning taxonomy serve as a theory (Tuomi & Sarajärvi, 2009). Research question of the research was: How do future chemistry teachers use knowledge dimensions and high-order cognitive skills in their pre-laboratory concept maps to support laboratory work?.

4 Preliminary results: The occurrence of major knowledge dimensions and high-order cognitive skills in students' pre-laboratory concept maps

Factual knowledge was present in all 168 maps and conceptual knowledge in 97 % of all maps. Conceptual knowledge was considered absent only if the map illustrated just procedural knowledge (Figure 1). Procedural knowledge occurred by four ways: 1) 77 concept maps contained knowledge about chemistry related to a technique or activity, which explains the criteria of an appropriate procedure, 2) 49 concept maps contained knowledge about the performance of a laboratory technique and 3) 30 maps about the proceeding of a certain activity, which are subject-specific techniques or methods and 4) 18 concept maps contained knowledge of subject-specific skills or algorithms (calculations) (see Anderson & Krathwohl, 2001).

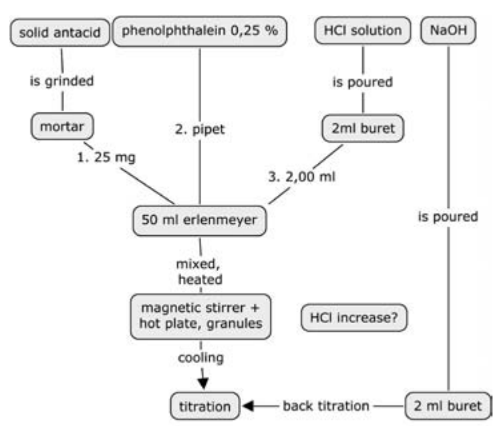

Figure 1. Concept map including only factual and procedural knowledge

Metacognitive knowledge occurred by two ways. Firstly, concept maps contained strategic knowledge, for example the use of colors (f = 62) or styles (f = 22), safety modeling (f =19), sources of error (f = 3) or discussion of the importance of the activity (f = 2). Secondly, concept maps contained cognitive knowledge about the activity, for example relationships between aims and practice (f = 9), things that effect on motivation (f = 4) or learning (f = 2), usability (f = 3) or the difficulty level of the activity (f = 1) (Table 1).

Major types	Subtypes	Examples from concept map	f
Procedural knowledge	a) Knowledge of criteria for determining when to use appropriate procedures	Modeling the chemistry related to laboratory technique or activity	77
	b) Knowledge of subject-specific techniques and methods	Modeling the performance of a laboratory technique	49
		Modeling the proceeding of a laboratory activity	30
	c) Knowledge of subject-specific skills and algorithms	Modeling calculations	18
Metacognitive knowledge	a) Strategic knowledge	Modeling groups or wholeness using colors	62
		Modeling main concepts using colors or styles	22
		Modeling safety aspects	19
		Modeling sources of error	3
		Modeling the importance of the activity	2
	b) Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge	Modeling relationships between aims of the activity and practice	9
		Modeling things that may have an effect on students motivation	4
		Modeling how or where the activity could be used (usability)	3
		Modeling students possible learning	2
		Modeling the difficulty level (students' point of view)	1

Table 1. The occurrence of procedural and metacognitive knowledge dimensions n students' pre-laboratory maps (see Anderson & Krathwohl, 2001)

Students used applying, analyzing and evaluating HOCS in their pre-laboratory concept maps (see Table 2). Applying was used in modeling, how processes from the activities could be used in solving environmental issues (f = 39), relationships between theory and calculations (f = 11) and between the aim and the curriculum (f = 3). In two maps there was also modeled, how to implement a laboratory activity to achieve a certain learning outcome (f = 2).

Analyzing was the most widely used HOCS. The use of colors (f = 49) or styles (f = 22) in order to model chemistry or to raise main concepts up were considered as an act of analyzing. Modeling relationships between different knowledge dimensions or cognitive skills was also interpreted analyzing.

Students used evaluating HOCS on modeling possible error sources (f = 5), things that may effect on motivation (f = 4) or learning (f = 2), usability (f = 3), importance (f = 2) or the difficulty level of the activity. Some examples of the use of applying, analyzing and different knowledge dimensions are presented in example concept map (Figure 2).

Cognitive skill	Subcategories	Examples from concept maps		f
Apply	1) Executing 2) Implementing	Modeling, how a process can be used in solving environmental issues		39
		Modeling relationships between theory and calculations		11
		Modeling relationship between the aim and the curriculum		3
		Modeling possible learning outcome		2
Analyze	1) Differentiating 2) Organizing 3) Attributing	Modeling chemistry through colors or by dividing concepts into groups		49
		Modeling main concepts using colors or styles		22
		Modeling relationships between	procedural and factual or conceptual knowledge	50
			conceptual knowledge and applying	14
			metacognitive and conceptual knowledge	13
			metacognitive knowledge and applying	8
			procedural knowledge and applying	7
			metacognitive and procedural knowledge	2
Evaluate	1) Checking 2) Critiquing	Modeling possible error sources		5
		Modeling pupils possible motivation		4
		Modeling usability		3
		Modeling the importance of a certain type of activity		2
		Modeling students possible learning		2
		Modeling difficulty level		1

Table 2. The occurrence of procedural and metacognitive knowledge dimensions n students' pre-laboratory maps (see Anderson & Krathwohl, 2001)

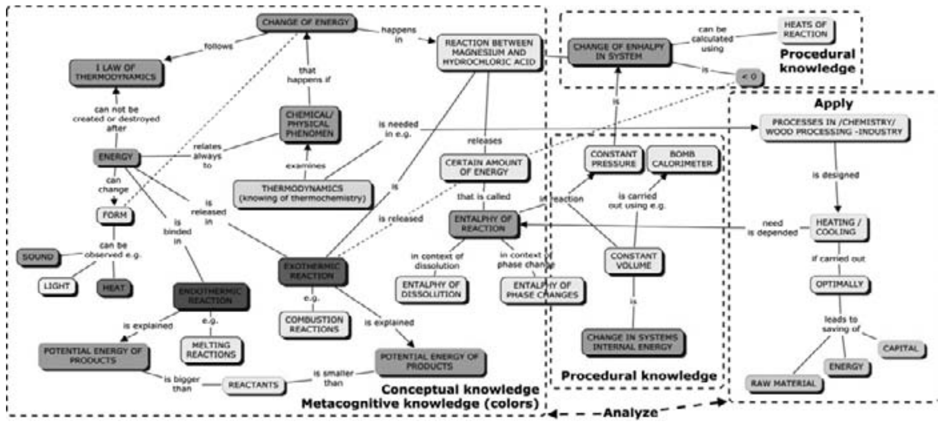

Figure 2. Examples of applying HOCS, analyzing HOCS and different knowledge levels

5 Summary and discussion

Students used procedural knowledge and metacognitive knowledge in several different ways in their pre-laboratory concept maps to support laboratory work. The most widely used way to use procedural knowledge was to model relationships between theory and practice and metacognitive knowledge to include strategic knowledge from the activity to the concept map. According to studied concept maps, students used applying, analyzing and evaluating in their pre-laboratory work. They did not create new ideas in a pre-laboratory phase, but synthesizing new is more typical to post-laboratory work. Analyzing was the most widely used HOCS. Students used analyzing in eight different ways, which from the most common was the use of colors to model chemistry related to practice.

In the future, the reliability of the content analysis will be analyzed using *inter-rater reliability.* There is also more data to analyze in this same context. At the course exam, students were asked to critically analyze, how concept mapping supports pre-laboratory work from knowledge dimensions and cognitive skills point of view. This gives information about the students' perceptions of the benefits of the concept mapping to aid pre-laboratory work. After this analyze, a summary will be prepared and presented for the students of the next course. This helps us in advicing students to a more meaningful direction in their pre-labratory concept mapping. This study also demonstrated that concept maps can be analyzed using a criteria based on knowledge dimensions and cognitive skills and it gives useful information about students metacognitive skill level.

References

Anderson, L. W., & Krathwohl, D. R. (Eds.) (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. New York: Routledge.

Kaya, O. N. (2008). A student-centred approach: Assessing the changes in prospective science teachers' conceptual understanding by concept mapping in a general chemistry laboratory. *Research in Science Education, 38*(1), 91-110.

Markow, P. G., & Lonning, R. A. (1998). Usefulness of concept maps in college chemistry laboratories: Students' perceptions and effects on achievement. *Journal of Research in Science Teaching, 35*(9), 1015-1029.

Stensvold, M., & Wilson, J. T. (1992). Using concept maps as a tool to apply chemistry concepts to laboratory activities. *Journal of Chemical Education, 69*(3), 230-232.

Tuomi, J., & Sarajärvi, A. (2009). *Laadullinen tutkimus ja sisällönanalyysi*. Jyväskylä: Tammi.

Özmen, H., Demircioğlu, G., & Coll, R. K. (2009). A comparative study of the effects of a concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base chemistry. *International Journal of Science and Mathematics Education*, 7(1), 1-24.