CONCEPT MAPPING AS AN ASSESSMENT TOOL IN SCIENCE EDUCATION

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Abstract. Concept mapping is a method to determine the achievement of knowledge. Concepts are linked with labelled lines to proposition. The concepts create a graphical structured meaningful relationship. The method is also proved to be effective for testing, indicating well students' mentality and its structure. This article describes three case studies using concept maps as assessment tools. Two studies measured the necessity of animations describing abstract topics in chemistry. Memorizing time period, different learning materials, topics, and structure of animation were used as parameters. The third study detected the time when higher taxonomy scored concept maps were created. Could students find concept themselves from the exercise, or should they be given by the instructor? We argue that concept mapping method gives a unique possibility to visualize the structure of students' knowledge.

1 Introduction and theoretical background

The article aims to analyse how to use concept mapping for assessment. Concept mapping was used as data collecting method. Two studies aimed to analyse, how students understand animation and whether it is possible to collect data with that method for analysing such study.

Concept mapping method was developed by Joseph Novak's research team in early 1970s. The method is based on the *meaningful learning* theory of Ausubel (1968). It assumes that learners construct knowledge, being already influenced by previous knowledge. Concept maps consist of concepts (words, things, pictures, symbols), which are linked with labelled lines to proposition (Reiska et al 2008; Novak et al 1983). It is a collection of propositions constructed in a certain way. It expresses graphically structured meaningful relationships existing between different concepts (Ruiz-Primo et al., 1997). Concept maps can prevent rote learning, to summarize already studied knowledge or class discussions, to create presentations etc. They can also be used as assessment tools to detect students' mentality and its' structure (Gouli et al 2003, Novak, 2010). There are some weaknesses of the concept mapping as an assessment tool. Creating acceptable structure of cards could be hard for novice. For instructors, it may be hard to evaluate the result (Chang et al. 2005). Validity and reliability of concept maps has also been questioned (Ruiz-Primo and Shavelson 1996; Ruiz-Primo, 2004).

To evaluate concept maps, we need certain dimensions for measuring. Cañas *et al* (2006) developed a topological taxonomy for evaluating created concept maps. Topological levels were defined by five criteria: 1) recognition and using concepts 2) presence of linking phrases 3) degree of ramification 4) hierarchical depth and 5) presence of cross-links (Reiska et al 2008). The taxonomy consists of 7 levels: from 0 to 6. Maps valued 5 and 6 were considered as satisfying almost all criteria. There are several measures for analysing concept maps: number and quality of propositions, size and hierarchy of the concept map, clusters of maps**.**

Concept maps can be used for formative assessment (Trumpower and Sarwar 2010). This must identify student's strengths and weaknesses.

Cañas, Bunch and Reiska created the software program *CmapAnalysis* to assess concept maps. It enables to analyse various algorithms, rubrics and techniques of concept maps. Parameters can be defined by the researcher. The software helps instructors, researchers and teachers to have automatically routine analytical operations (Cañas et al 2010). *CmapAnalysis* software supports a) taking input Cmaps in the open CXL file format (in addition to the cmap format), allowing the analysis of concept maps developed by concept mapping programs that utilize CXL, b) users are able to add other measures to the program. *CmapAnalysis* enables to measure different categories: size, quality, and structure.

Animations as moving illustrated materials are used at schools to depict dynamic changes over time and location and to illustrate phenomena or concepts that might be difficult to visualise (Nakhleh, 1992; Mayer & Moreno, 2002). New methodologies and visualisation technologies enhance students' understanding of central scientific concepts (Kozma & Russel, 2005; Soika, 2007). The effectiveness of the animation depends on the student's personality (Mayer & Moreno, 2002), structure of the used animation and the method of using the animation in the classroom (Ruiz et al., 2009; Wu & Shah, 2004).

2 Case studies

Three studies were carried out in 2010 and 2011. For every study we had different research questions, but every time one of the data collecting methods was concept mapping. Our previous study (Soika et al 2010) pointed out that concept mapping method allows analyse structure of students' knowledge better than questionnaires.

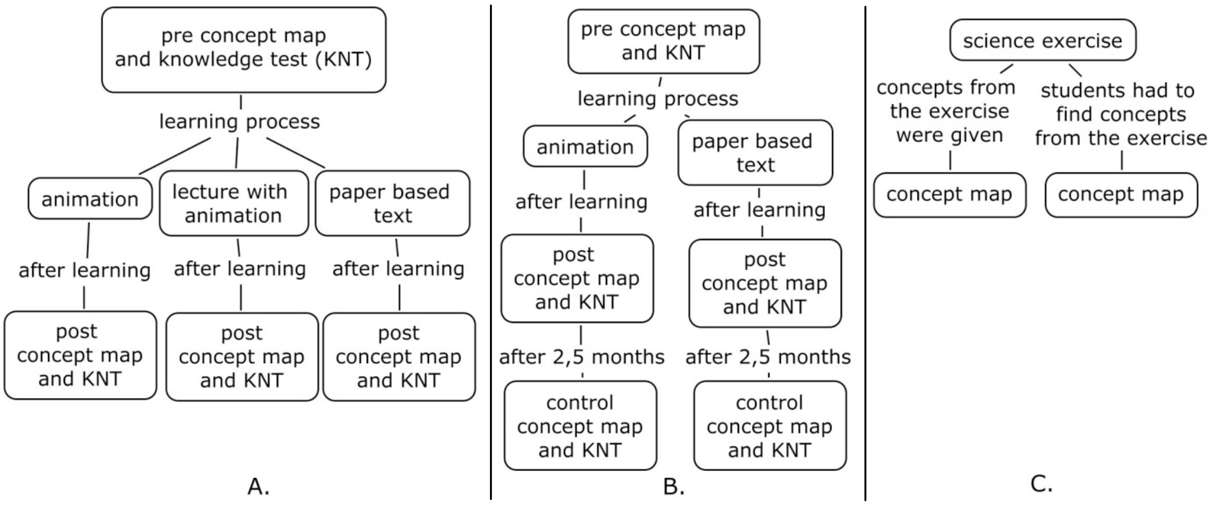

Figure 1. Structure of data collection in three different case studies

2.1 First Study

Aim: to investigate the impact of animation to student knowledge. **Research questions:** 1) what impact animation has to the students' knowledge, if students are studying individually? 2) Are there any differences in students' knowledge if the same animation is explained by a teacher? 3) Are concept maps of different groups of students similar? 4) Which group create more high valued propositions, those, who studied from the animation, or those, who read the paper based text? Our previous study (Soika et al 2010) shows that after concept maps analysis, students from various groups had created absolutely different concept maps. We had to examine these results.

Data collecting and analyzing: 77 students were divided into three groups. One group studied individually from the animation. For the second group, animation was supported by teacher explanation. The third group studied the same topic individually from a paper based text. Studying material was identical and new for students. The main data collecting method is shown in Figure 1. A. Students had to create 2 concept maps from 20 given concepts in appointed time. Pre- and post- concept maps were analysed with software *CmapAnalysis*. Content and correctness of the sentences were assessed manually. Results were compared in MS Excel. Results:

Students group	proposition count [1]	Proposition quality [2]	taxonomy score [3]	knowledge test (KNT)
Animation	2,63	0,19	-0,27	0,21
teacher explained animation	5,56	0,20	1,25	0,31
Paper based text	4,58	0,29	0,97	0,27

Table 1 Average changes in measures per students

The best results are for a group, who studied from an animation, when a teacher was explaining- the results seem to be similar to the group, who studied individually from the paper. The group, who studied individually from the animation, had different results.

[1] Proposition count - the number of propositions (i.e. concept-linking phrase-concept) in the map. Min and max

[2] Proposition quality – proposition „mark", where an expert has decided if the sentence is right or wrong and evaluated the proposition with a number.

[3] Taxonomy score – is calculated by different measures; it includes: average words per concepts, branch point count, concept count, linking phrase count, separated concepts count, proposition count; count of concepts, that has outgoing connections but no incoming connections (root child), sub map count; it is expresses with a number between 0 and 6 where higher scores typically indicate higher quality concept maps.

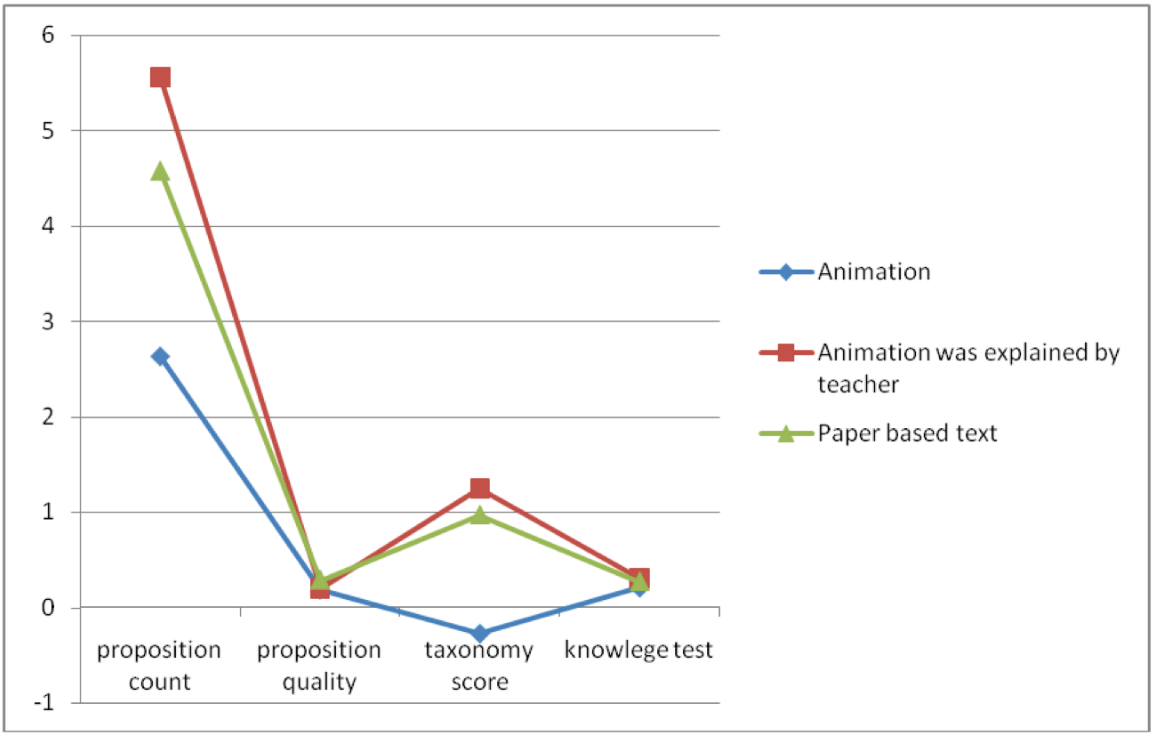

Figure 2. Changes in values of different measures

Results: The structure of created concept maps depends on the studying method, but we can’t see such difference in the results change of knowledge test. If students are studying individually from the paper based text, the results are better than when they have been studying individually from the animation. The taxonomy score of the group, who studied from the animation fell. Concept maps of that group also didn’t have so many new propositions.

2.2 Second Study

Research questions: 1) What impact do the long time period has to knowledge based concept maps? 2) Are there any differences in knowledge of various groups of students? 3) What kind of similarities are in concept maps of various groups?

Data collection and analysis: 62 students were divided into two groups. One group studied individually from an animation. The second group studied the same topic individually from a paper based text. Studying material was identical. The main data collection method is shown in Figure 1. B.
Students had to create 3 concept maps in appointed time from 22 concepts given to them. Pre concept maps (were made before learning), post concept maps (were made in the same day after learning) and control concept maps (were created 2, 5 months after learning), were analysed with CmapAnalysis software. The content and correctness of the sentences were assessed manually. Results were compared in MSExcel. Most important results of the study were:

	group of students	proposition count [4]	proposition quality [4]	taxonomy score[4]	knowledge test (KNT)
Before and after learning	Animation:	-0,83	1,03	0,084	0,95
	Paper based text	5,7	0,47	0,54	0,87

[4] See footnotes behind Table 1

Before and after 2,5 months learning	Animation	-0,5	0,365	0,41	0,31
	Paper based text	-0,6	0,475	0,44	0,30

Table 2. Average changes in measures per students

Results: After learning from animation, concept maps of students were similar to each other and had less propositions than maps made after learning from the paper based text. The studying method impacted connections between concepts. We also had a question based knowledge test before and after learning process. There were no significant differences of changes between different groups. After 2, 5 months control maps of both groups were similar again. There had been an influence in students' knowledge.

2.3 Third Study

Aim: to understand how to collect data from students who have to connect concepts from a science exercise.

Research questions: 1) what kind of concepts are students going to find out from the narrative science exercise? Are these concepts similar/ same for concepts found out from the same exercise by teacher? 2) Do different conditions measure same results of learning? Conditions were: a) students had to create a concept map in appointed time from given 20 different level exercise based concepts, b) students had to find 20 concepts from the exercise and to create a concept map in appointed time.

Data collection and analysing: 54 students were divided into 2 groups having the same exercise. Students had to read the text, to find answers to different level multiplied questions. Thereafter they created a concept map, which had to describe natural science and everyday life connected purport of the exercise. They had 20 minutes to read and solve the exercise and 20 minutes to create a concept map about the exercise. We analysed these maps manually and with the software.

Results: Students, who had got certain concepts created higher taxonomy scored maps and more propositions per students than other group (average taxonomy score 3,75/ 3,03; average propositions per students 18,5 /16,6 (illustrated in Figure 3.)). Looking at maps, we notice visual difference (Figure 5, Figure 6.). Of course the result depends on the given concepts. In our study 14 concepts of 16 most represented self found concepts were given also from the instructor to the other group. In appointed time students are going to create higher taxonomy scored concept maps (which also point out more their visual background), when certain concepts are given to them.

Calculation differences in connections for three most central concepts offer opportunity to analyse the structure of the whole map. When we didn't give concepts, the map of concepts was as a "star". When we gave concepts, the connections between concepts created network (diagram in Figure 4 Illustrative concept maps are in Figure 5 and Figure 6.).

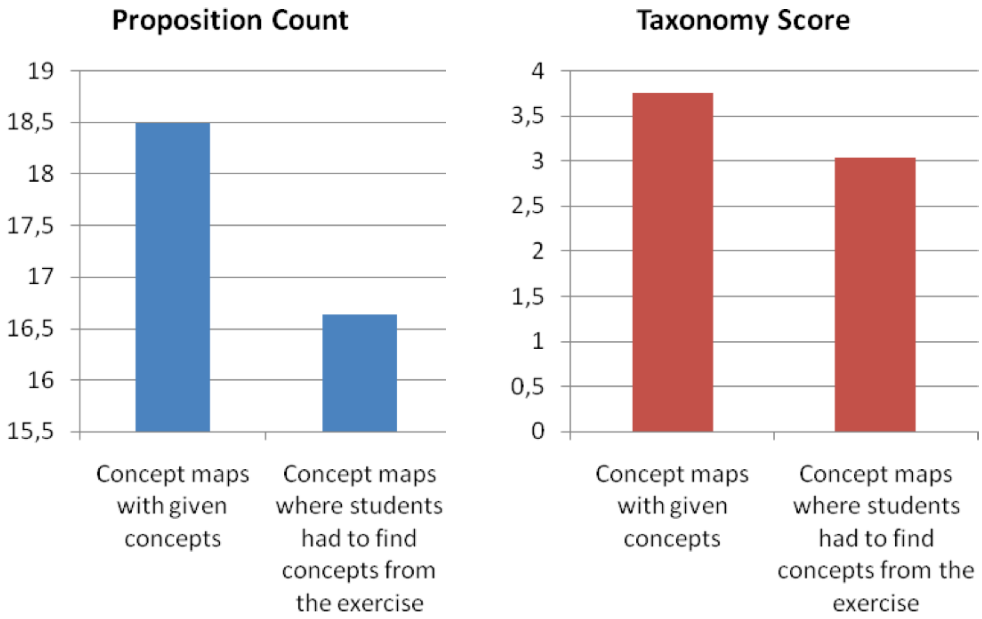

Figure 3. Differences in proposition count and taxonomy score of various groups of students.

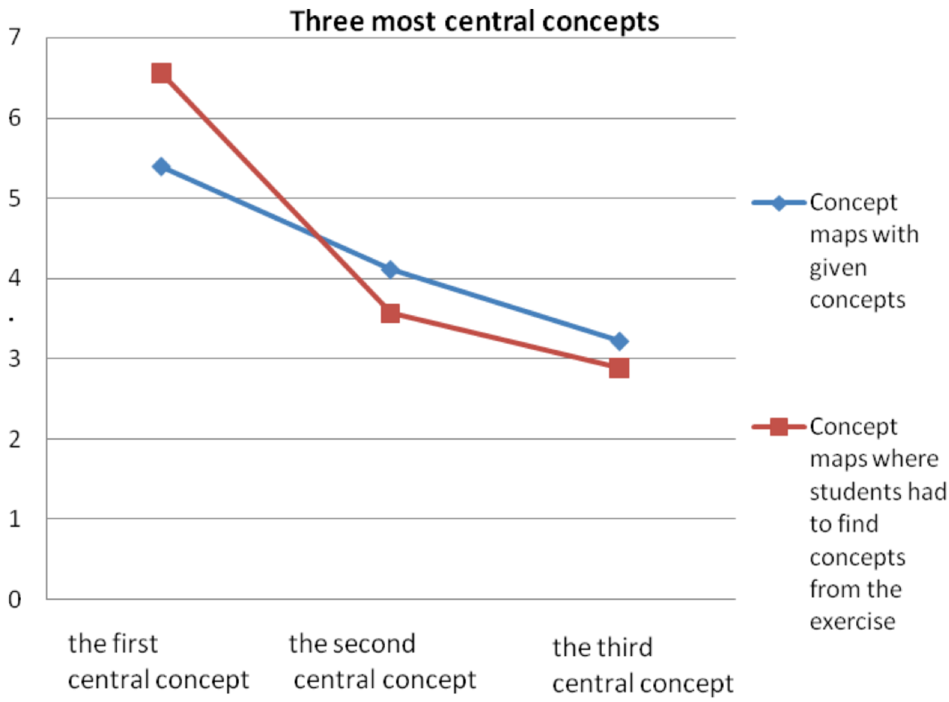

Figure 4. Differences in links of three most central concepts in various groups of students.

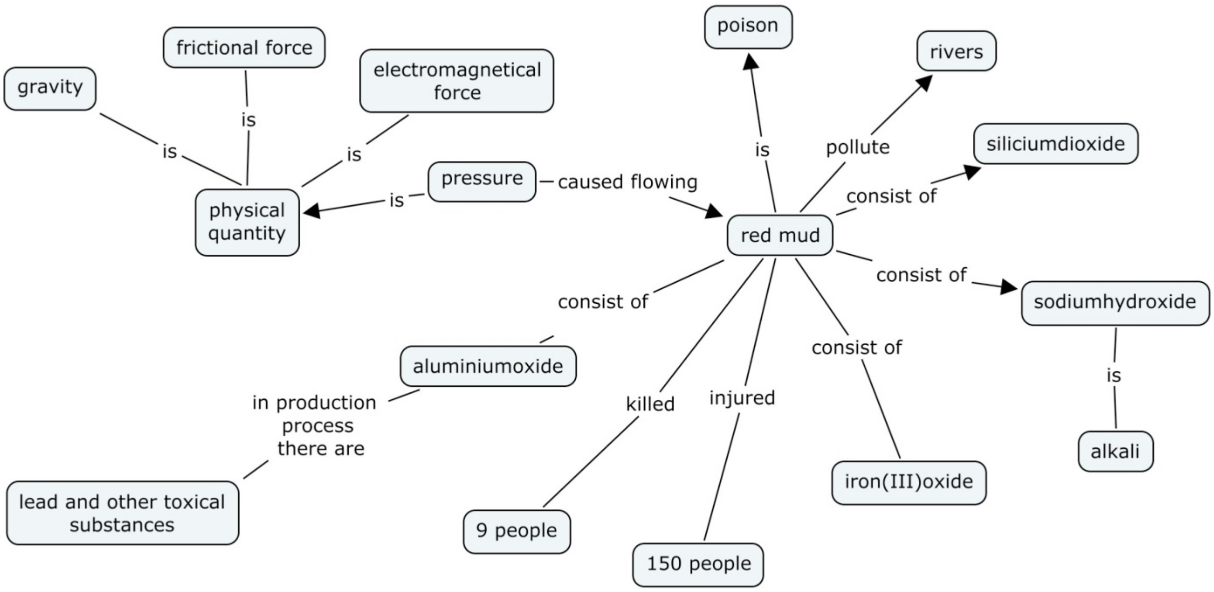

Figure 5. A concept map, made by a student, who had solved a science exercise and had to find concepts by herself from the exercise.

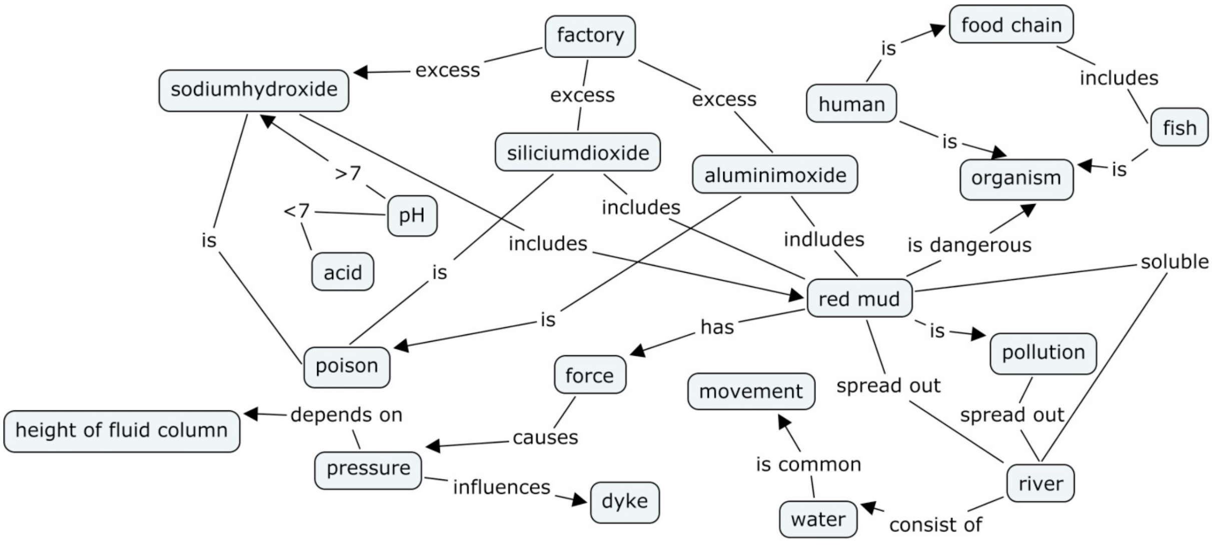

Figure 6. A concept map, made by a student, who had solved a science exercise and had got certain concepts about the exercise from the instructor.

3 Discussion

Concept mapping method could be used as an assessment tool. We couldn't see such differences in students' knowledge with any questionnaires as we noticed in our two studies about the animations. The new national curricula for basic and secondary school (2010) set new purposes and competences developed at school. New assessment tools are needed to assess these competences. Teachers must use more formative than summative assessment.

Our studies revealed the potentiality of concept mapping method. It is easier to understand the knowledge of students with concept maps than with ordinary tests. Concept mapping is not the only "right" assessing tool, but this is an opportunity for evaluating students. Our third study revealed that while using concept mapping to assess students, we must remind the purpose of the work. The result depends deeply on that.

4 Acknowledgements

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