Concept Maps: Making Learning Meaningful
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THE IMPORTANCE OF ANIMATION AS A VISUAL METHOD IN LEARNING CHEMISTRY

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Abstract. We examined differences in students' motivation and learning outcomes as resulting from two different teaching methods. For the first group visual material was presented in a traditional paper form. For the second group the material was presented via the computer animation. We examined what kind of concept maps were created by the students before and after studying process and what kind of differences were between the knowledge tests before and after the learning.
The results were assessed by the changes between the results of the knowledge tests and concept maps. While we were looking at the concept maps, created after animation, we saw a visual similarity (which did not exist before the learning process). Comparing the concept maps, which were made after studying from the paper or the animation, we could see changes in the structures. By their structure, concept maps of the animation- learned students had become more similar to each other. After analyzing individually made concept maps, we created concept maps of the groups. We could notice change of centralities and structures of the maps after the studying process.
This study confirmed that teachers should use visualisation tools – such as animations- purposefully during the learning process.

1 Introduction and theoretical background

Over the last decades, studies from many countries have pointed out the decreasing interest of basic and secondary school students towards science (Nakhleh, 1992; De Vos & Reiding, 1999; Mullis et al., 2004; Van Driel et al., 2007; 2008, Elliott & Paige, 2010). Many reasons have been observed as causes of this. Respectively, the proposed resolution strategies to make science more attractive to students also vary. Some researchers primarily focus on methodological innovation and diversification. Investigations have indicated the necessity to apply innovative methodology and technology – such as videos and animations – to promote better learning outcomes, motivation and application skills (e.g. Moreno & Ortegano- Layne, 2008; Cardoso et al., 2009). Others, while recognising the importance of methodological considerations, attempt to go deeper and focus primarily on the teachers' general attitudes and beliefs. Differences in teaching practice in this case are not reducible to methodological issues, but rather to the differences in teachers' aims at some more general science learning goals, that lie beyond the subject itself (Van Driel et al., 2008). Working within and elaborating the theoretical model of Roberts (1995), Van Driel and others, for example, have distinguished science teachers' attitudes towards the aims of science teaching. These aims, or 'curriculum emphases', may vary from stressing science as cumulative, reliable and valid knowledge (a traditional science curricula) to using science as a way to understand and to explain both technology and everyday occurrences (Van Driel et al., 2008). On that basis, large-scale curricular reforms in science education are proposed and discussed (ibid).

In Estonia also, the low popularity of science among students is a pressing problem (Mullis et al., 2004; Teppo & Rannikmäe, 2005). While the knowledge level of Estonian students in science, as compared with that of students from other countries, has shown relatively satisfactory, the most pressing problem is the students' motivation and attitudes towards science (Martin et al., 2004). The situation compels to seek for new ways to motivate students, thereby without turning the attention away from the importance of good learning outcomes. The research has also referred to the necessary changes in Estonian science teachers' understanding of science and teaching (Rannikmäe et al., 2008). Also it is discussed the necessary changes in Estonian teacher education in preparation of science teachers (Kask et al., 2008).

The current investigation has examined the differences in motivation and learning outcomes as resulting from two different teaching methods used in chemistry lessons for final-grade students in an Estonian gymnasium. It was studied the differences provided by learning via animation one hand and via the traditional paper text on the other hand.

Our research questions are:

1. How is the knowledge of students influenced from the animation and the paper based instruction? (How do students link concepts before and after the learning process? What kind of new relationships between concepts they create after learning process?)
2. That kind of different learning outcomes (facts, knowledge, linking concepts) are acquired in different groups of students?
3. Are the familiar (learnt and used for years) and new concepts connected similarly in different groups? Are there any differences in group concept maps comparing the animation and paper group?

It is acknowledged that no method alone, apart form the context and teacher's general attitude towards science and teaching, can be seen as a proper solution. However, a competency in using new technological media as well as knowing their limitations is a promising way to enhance the students' motivation and better learning outcomes in science studies.

Animation

Several studies have demonstrated positive impact of animations on understanding abstract processes. In general educational terms, animations can be viewed as a technique of visualisation. According to Mayer and Moreno, animation refers to a simulated motion picture depicting movement of drawn (or simulated) objects (Mayer & Moreno, 2002). Together with other techniques elaborated as a result of rapidly developing information and communication technologies, use of animations has been strongly encouraged as an innovative, constructivist and students-centred alternative to the traditional learning approaches in many countries (e.g. Moreno et al., 2001; Neo & Neo, 2009). Studies from many countries have demonstrated positive effects which the use of different and innovative methodologies and visualisation technologies may have to students' understanding of central scientific concepts (Wu & Shah, 2004; Kozma & Russel, 2005; Nakhleh, 1992). The visual illustration makes it possible to prevent the formation of students' misconceptions and to guide them to the new knowledge. Animations as moving illustrated materials are used more often at schools to depict dynamic changes over time and location, and illustrate phenomena or concepts that might be difficult to visualise (Nakhleh, 1992; Mayer & Moreno, 2002; Ruiz, Cook, & Levinson, 2009). Usually these are processes, which are too slow or fast, in the nano- or microstages (Lowe, 2004; Kozma & Russell, 2005). When acquisition concepts is episodic, it could become an inhibitory factor, which is hindering the personal development of a student. (Tamm & Tuulmets, 2005; Henno et al., 2007).

Also in Estonia animations have been shown to be beneficial in science lessons (Soika, 2007). The use of activating and innovative learning technologies in Estonia is also encouraged by the new national curricula for basic school and gymnasium (Põhikooli... 2010; Gümnaasiumi... 2010). In these official documents, learning is emphasised as a process during which a student actively constructs personal knowledge in continuous interaction with his/her social environment (Põhikooli... 2010, § 5, p.1, Gümnaasiumi… 2010, § 6, p.2). Accordingly, in establishing the requirements for the social, cognitive and physical environment of learning, the usage of strategies based on new information and communication technologies is also highly emphasised (Põhikooli...2010, § 6, p.4; Gümnaasiumi… § 7, p.5). Together with the general ethos of constructivism, it may be argued that the application of animations in science lessons in Estonia is, theoretically at least, relatively well- prepared.

However, besides the acknowledged positive effects, there are also some dangers involving the use of animations in the learning process. The most important benefits of animations are: 1) they assist to understand abstract and invisible processes (Sanger, Brecheisen & Hyneki, 2001) 2) they can improve students' learning motivation- it is easier to understand abstract and difficult themes (Rieber, 1991).

The disadvantages of animations are: 1) in some situations animations may decrease the effectiveness of studying process (Ruiz et al., 2009) 2) the impact to students' mind is not determined, thus understanding the information of the animation, may differ, it also depends on the sex and the spatial visualisation understanding ability (Wu & Shah, 2004).

Concept mapping

There are several opportunities to determine the achievement of knowledge: tests, interviews etc. Concept mapping method was used in this study. By this method concepts are linked with labelled lines to proposition. Thus the concepts create a graphical structured meaningful relationship (Ruiz-Primo, Schultz & Shavelson, 1997). Usually phrases are composed of concepts that could be words, phrases, or symbols. Structure of the map expresses the knowledge of student; it reflects how the concepts, ideas and rules are connected in students' mind (Reiska, Cañas, Novak & Miller, 2008; Ruiz-Primo et al., 1997; Novak, Gowin & Johansen, 1983; Chang, Sung, Chang & Lin, 2005). The method is based on the theory of Ausubel (1968), which assumes, that learners construct their knowledge, and they are influenced from the knowledge they already knew.

It has been found out, that the method is effective for testing. It helps to determine the level of the students' knowledge before the instruction (Reiska et al., 2008). Concept mapping as an assessment tool, gives better overview of the students' mentality and the structure of it, than ordinary assessment tools (Gouli, Gogoulou & Grigoriadou, 2003). Some authors point out, that the weakness of the concept mapping method is that for novice it is hard to create the structure and for instructors it is hard to evaluate the result (Chang et al., 2005).

In this study we attempted to analyze how students link concepts before and after the learning process, what kind of new relationships between concepts they create after learning process and are there any dissimilarities in the maps that are composed by students who had studied from different materials.

2 Methodology and data collection

We examined differences in students' motivation and learning outcomes as resulting from two different teaching methods. For the first group visual material was presented in traditional paper form. For the second group the material was presented via the computer animation. We examined what kind of concept maps were created by the students before and after the studying process and what kind of differences were between the knowledge tests before and after the learning.

The selection consisted of 41 students from gymnasium final grade (about 18 years old students), who had designed concept maps before. The animation and knowledge tests were represented in the Moodle learning environment, which was familiar for the students from previous lessons. The study took place two days, so the number of students varied: 29 students created concept maps before and after the studying process (see Fig. 1.), but all of them answered to the both knowledge tests.

We created similar materials for those who studied from paper-based instruction and for those who followed the animation. In both cases the material contained identical information (as a text or as a voice), figure of process and pictures of the topic. Students studied individually from the materials (see Fig. 2.). We followed the main multimedia principles while the animations had created (Mayer & Moreno, 2002; Ruiz et al., 2009). The animation explained invisible processes of micro stage. It was interactive- students had the ability to use control tabs. The animation was two- dimensional and we did not use many different colours, high speed and molecule models in the animation. The animation contained voice explanation, the most important facts and rules were accentuated textually. Excessive effects (fast moving, incoming, contrasting colours etc) were not used.

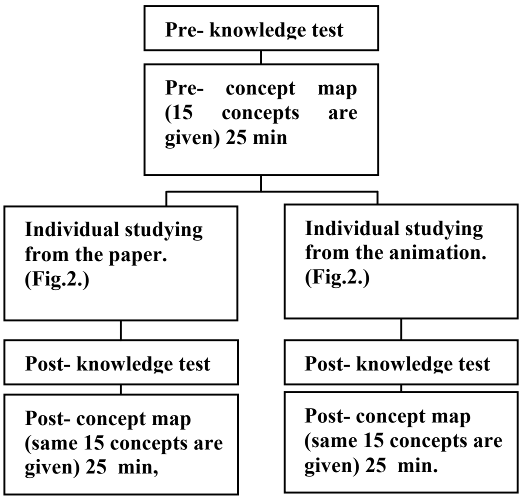


Figure 1. Design of data collection

Before and after the studying process the students were asked to (see Fig. 1.):

1) answer to 7 questions from the test of knowledge (open-ended and multiplied choices questions);
2) create a concept map from 15 concepts. They had 25 minutes for that (the concepts were: electrolytic dissociation, hydration, ion, water, salt, ionic bond, covalent bond, cation, anion, destroying the bond, formation the bond, crystal, molecular substance, non-molecular substance and solution).

Data was analyzed in 4 groups:

1) before studying:
    - students who had used the animation,
    - students who had learned from the paper;
2) after studying:
    - students who had used the animation,
    - students who had learned from the paper.

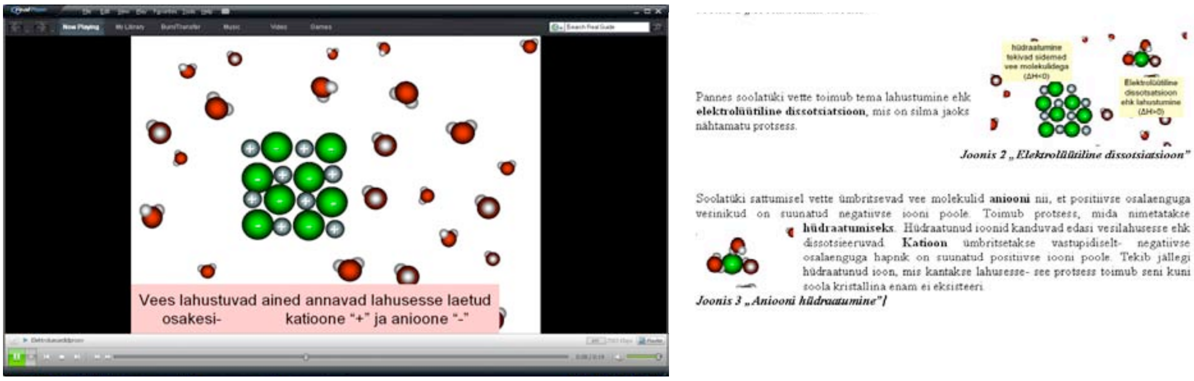


Figure 2. Screenshot of the animation and a part of the paper based instruction

The results were assessed by the changes between the results of the knowledge tests and concept maps. While we were looking at the concept maps, created after animation, we saw a visual similarity (which did not exist before the learning process). That was the reason we created a classification:

1. Propositions, consisted only concepts of the diagram (see Fig. 3.) (was presented in the studying material),
2. propositions, which consisted concepts from the diagram (see Fig. 3.) and outside of it,
3. propositions which contained concepts only outside of the diagram concepts (see Fig. 3.).

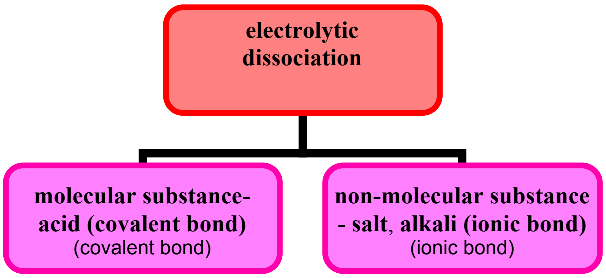


Figure 3. Diagram that was presented in the animation and on the paper

3 Results

Comparing concept maps, which were made after studying from the paper or the animation, we could see changes in the structure of maps. By their structure, the concept maps of the animation- learned students had become more similar to each other. They seemed to contain a sort of copied information, which was presented in the diagram of the animation. This diagram was also presented on the paper, but the reproduction rate in the concept maps was rare.

Comparing the concept maps before and after the learning process we can notice following (see Fig. 4.):

1) The number of generated propositions had changed: students, who had studied from the paper represented more propositions with the concepts of internal and external to the presented diagram concepts. When we account the number of conjunctions of animation- learned students' pre-maps and after-study- maps, we could see changes. Animation- learned students created less propositions after learning process. The number of propositions of diagram inside concepts was extremely increased, but as a result, the total sum of the propositions was smaller than the same result of paper studied students.

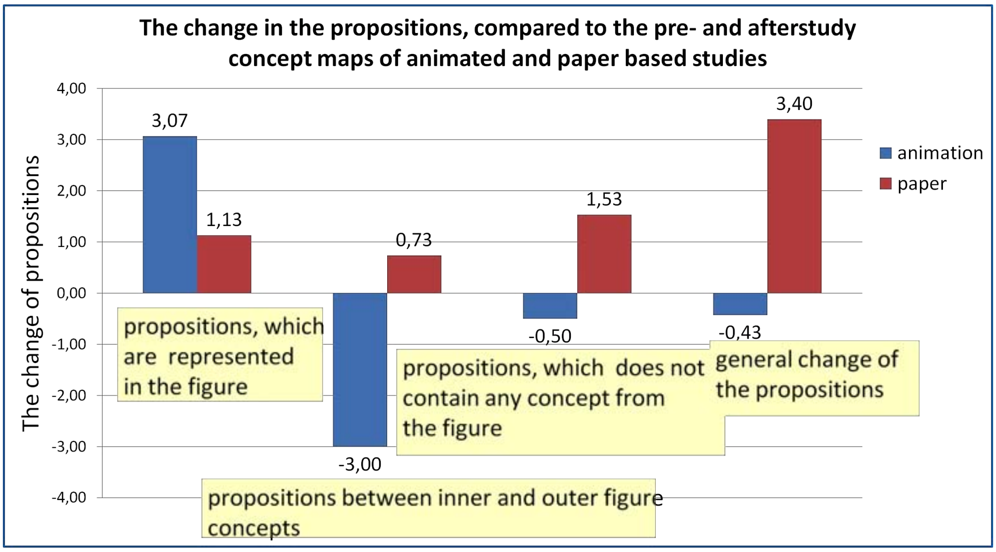


Figure 4. Changes in propositions of concept maps- comparing before and after study maps

2) There was a change in the centrality of the concepts. Students from the animation group had created less links between the concepts, than they had done before the learning process - the number of the propositions had decreased with several concepts. Comparing data with the group, who had studied from the paper- based instruction, we can notice that students, who had studied from the paper based instruction, linked more concepts than those who had studied from the animation. Finally we noticed that in the animation group the centrality of concepts had extremely increased in some of the concepts (are shown in the diagram), those concepts were presented in the figure.

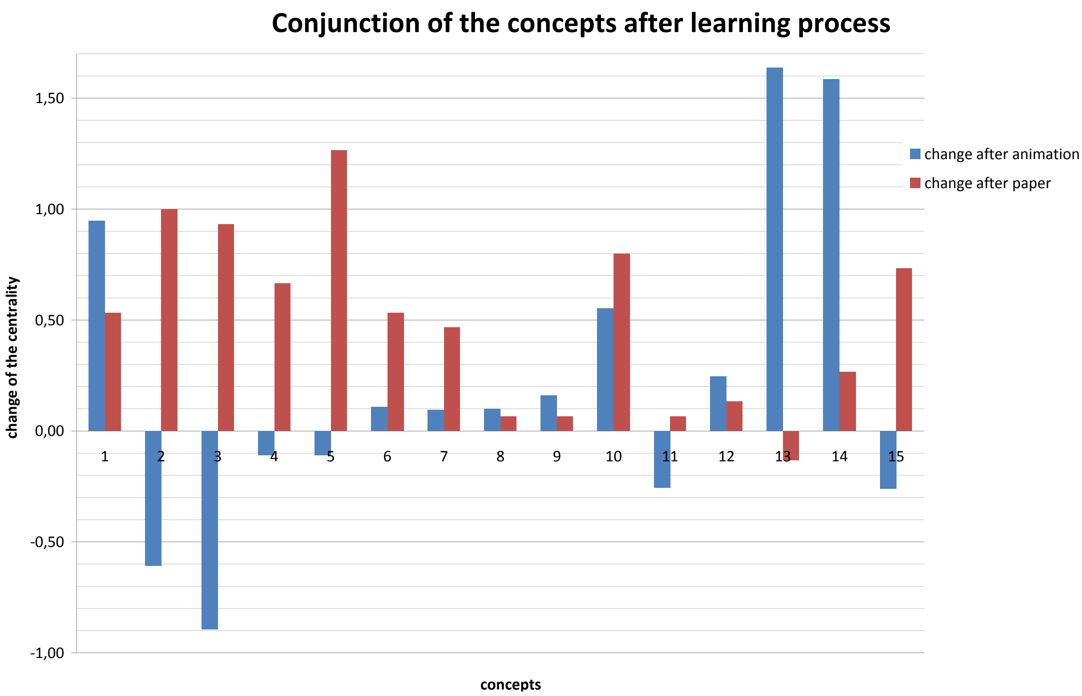


Figure 5. Conjunction of concepts before and after learning process

In the Fig. 5.: numbers were given to every used concept (1=electrolytic dissociation, 2=hydration, 3=ion, 4=water, 5=salt, 6=ionic bond, 7=covalent bond, 8=cation, 9=anion, 10=destroying the bond, 11=formation bond, 12=crystal, 13=molecular substance, 14=non-molecular substance, 15=solution). We can see that the negative change is mainly represented in the group of animation between the out figure concepts. More propositions had created with the main concepts of the figure: as electrolytic dissociation, molecular substance and non-molecular substance.

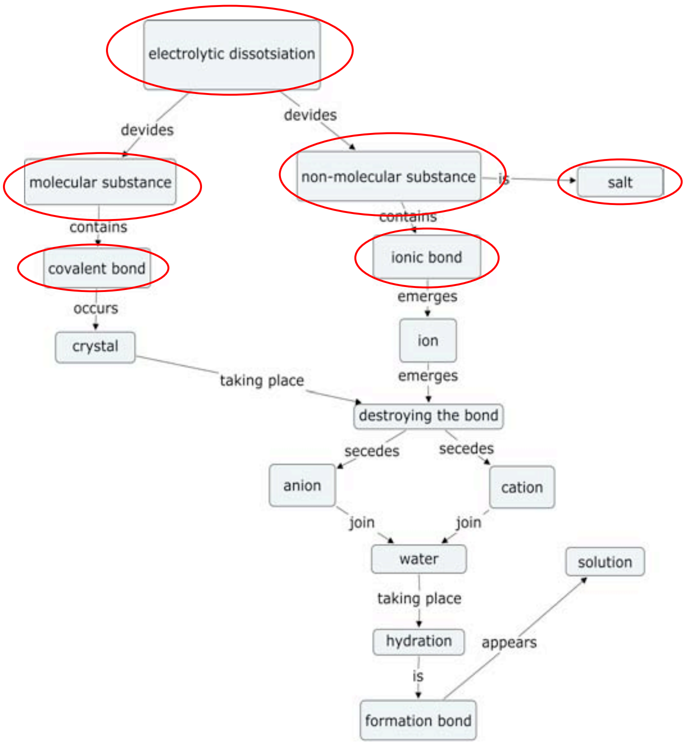


Figure 6. Concept map- created after animated study. Concepts from the diagram are circled.

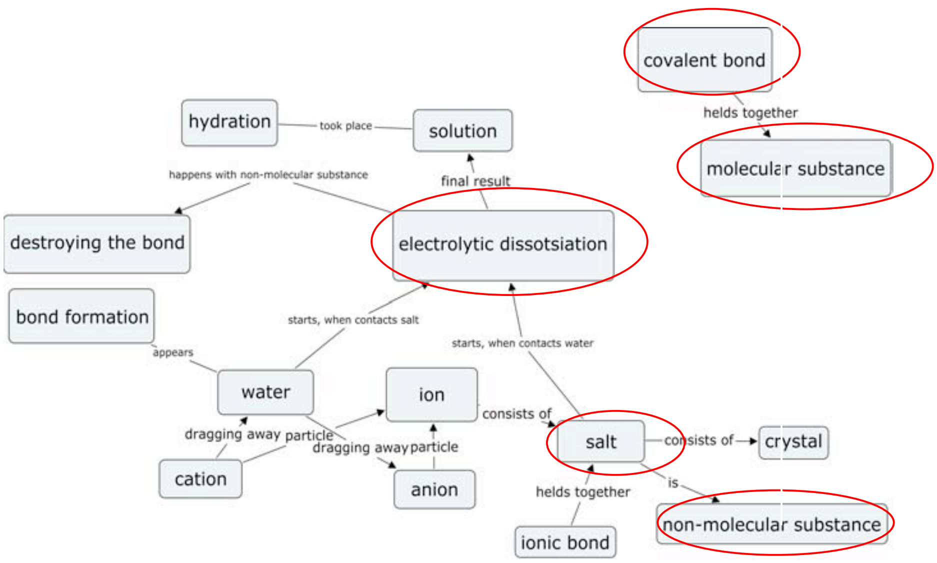
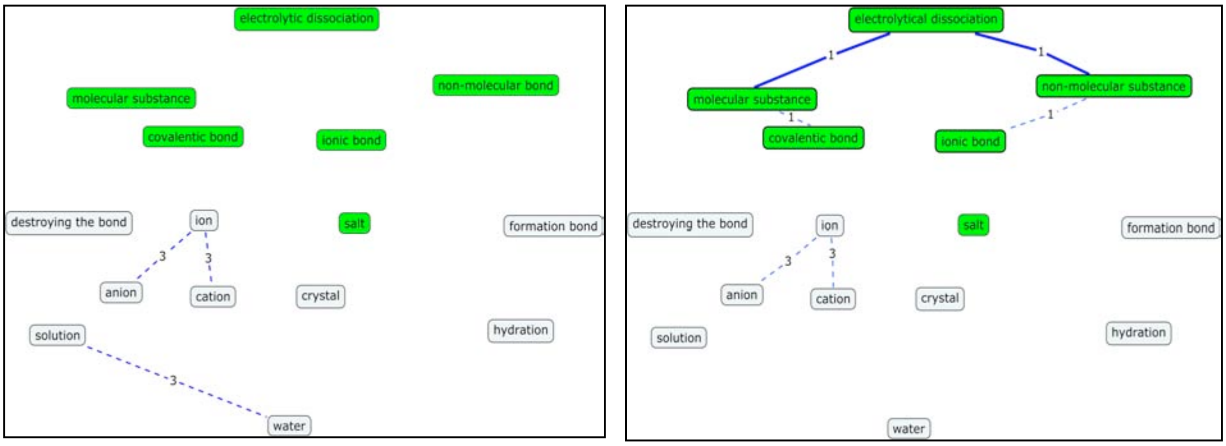


Figure 7. Concept map- created after the paper instructed study. Concepts from the diagram are circled.

After analyzing students' made concept maps, we created the concept maps of the groups (from the most presented propositions). We can notice the change of centralities and structures of the maps after studying process. The links between the concepts were numbered by the classification that was created after the presented figure (see Fig. 3.).



a) **b)**

Figure 8. Comparison of the group concept map: a) before the animation b) after the animation

Propositions, concepts that are linked with a line, were represented in the 100% of student's maps; dotted line proposition was created in the 84,1%- 57,1% of maps. Terms, which are darker, were represented in the figure. Propositions: ion- cation, ion- anion and water- solution are used in chemistry lesson often. Propositions: electrolytic dissociation- molecular substance and electrolytic dissociation- nonmolecular substance were presented in the figure.

As a conclusion we can say: a) the results of knowledge tests were similar of both groups (there were not significant differences, which would depend on the studying method); b) students, who had studied from the animation, represented the structure of the figure (which was in the animation and paper based instruction); they create less links with concepts than before the studying process; c) students, who had studied from the paper based instruction, had created more propositions and all of them had created differently structured concept maps. In that study the structure of the concept maps (created propositions) and the number of the propositions depended on the individual studying method.

4 Discussion

This study confirmed that teachers should use visualisation tools – such as animations- purposefully during the learning process. Understanding visualised material is easier than to read information from the paper- based instruction. As human beings are lazy by character so students would like to find the easiest way to understand difficult processes - at least to show to the teacher that they had understood the theme. Understanding paper-based instruction needs concentration and conceptualising skills. That could be the reason why the main change of the data occurs in concept maps, made after the animated study- there were not many different propositions. A student, who had studied from the paper based instruction, had to analyze the information and to connect the fact with rules and other facts- she had to know the background. A student, who had studied from the animation, did not need to analyze the process deeply, she did not have to know (or create) the background of the concept. Students from the animation group got the whole information from the presentation and so they did not have to create their own understanding- the concept maps were similar and reminded the structure of the figure, which they had seen before.

Studies have pointed out that using animation in the lesson helps to increase learning motivation. It makes difficulty-understood problems easily understandable. Students explained the necessity and feasibility of the animation: *"… such teaching is more interesting and engaging, animation helps to understand the topic easily and clearly. Very often there is no use of explaining the theme only verbally, because the student is unable to imagine the process realistically and that is the reason she does not create links with other concepts and it is hard to memorize it…, …these (*animations*) makes the material understandable. With them it is easy to understand the motion of the particles and it is easy to explain everything, verbal explanations will justify it all…,… I am not able to concentrate enough to understand everything, it is much easier to study with the animation and teacher…"*

Some intriguing questions arose while conducting this study: What do we expect as the learning outcome from the student? Do we prefer factual knowledge of concepts to the ability to connect concepts with each other

and a using them widely? Should we raise students' motivation to learn some subject, while we same time retard the ability to analyze the process? How much should a student study individually in front of the computer?
In this study we used the animation by itself. There was no communication between students and a teacher. Every student followed the animation individually. In the future we should find out if there are any variations, when a teacher uses the animation as a visualization tool in the lesson.
We got some ideas for the future studies. It would be useful to compare the animation impact on long-term memory. While students like to follow animations in the lessons, we should analyze what kind of influence they have to the learning process, when the lesson is instructed by the teacher. In the future studies we should examine more, how students are influenced, when there is a structured figure in the presentation- how they are able to link the concepts with each other.

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