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The Effects of Technology-Supported Mind and Concept Mapping on Students' Construction of Science Concepts The Effect of Mind Mapping in Science Education

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ABSTRACT The paper investigates the effect of technology-supported mind and concept mapping on learning science concepts, student opinions on preparing mind and concept maps,and the practices used. This paper, in which a quasi-experimental design with a pre test-post test control group was used, was carried out on 62 sixth graders during the "Systems in Our Body" unit. In experimental group 1 courses were conducted through technology supported mind mapping activities, while courses in experimental group 2 were conducted through technology supported concept mapping activities. The courses in the control group were conducted through activities in the science and technology curriculum. The results revealed that the students in experimental group 1 had a higher level of understanding concepts than the other groups. Students in experimental group 1 stated that it was fun and instructive to prepare mind maps; students in experimental group 2 stated that the concept maps were fun and instructive.

INTRODUCTION

Educating students to adapt to the rapid developments in science and technology and who learn are among the leading goals of education today. Accessing information and using it efficiently are highly important in terms of making daily life easier and adapting to the age they live in. According to the constructivists, knowledge is actively constructed by the individual who tries to make sense of the world (Duffy and Cunningham 1996; Ben-Ari 2001). Rather than transferring others' knowledge intact, the constructivist approach is based on constructing one's own knowledge (Horstman and White 2002). Based on the core notion that all learning occurs through constructing in the mind, constructivism requires individuals to take more responsibility and to be more active in the process of learning (Brooks and Brooks 1993). The aim in science and technology courses is to help students comprehend the notions and construct the relations between the notions. The science and technology curriculum emphasizes that information and communication technologies provide significant opportunities in developing and implementing scientific thinking, thus facilitating teaching science. Information and communication technologies should be utilized in teaching and learning environments as much as possible. Mind and concept maps are prepared utilizing computers, where the mental constructs displayed are highly essential as technology-supported tools supporting constructivism. Mind and concept maps can be used to visualize a complex notion.

Mind mapping is a technique that offers relationships and concepts together with key words that guide the brain and that represent and classify knowledge (Weideman and Kritzinger 2003). The mind mapping technique can be used to reveal existing cognitive schemes of the students at the beginning of the course, make necessary connections with existing knowledge during the course, and find misunderstandings at the end of the course. Mind mapping is a learning technique based on treating the processing of right and left hemispheres together and then integrating them (Buzan 2005). Mind maps, among other concept tools, are the most free and meaningful (Kommers 2002). According to Davies (2011), the purpose of preparing mind maps is to find creative associations between ideas.

Mind maps can be prepared both manually and on a computer. The software that helps eas-

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ily form mind maps is the "Mind Manager Programme". Using this programme is quite simple and, depending on one's choice, either the images or figures in the programme library or the ones downloaded from the internet can be used. "Mind Manager Programme" makes it easy to organize the connections between information and uses figures, colors, and expressions freely.

A learning technique that enables students to comprehend subjects as a whole and to establish connections between concepts (Novak and Gowin 2002) is concept mapping. Concept mapping is a graphic organizational technique in which students create node-and-link diagrams, where nodes represent concepts and links connecting the nodes represent relations among the concepts (Blunt and Kapicke 2014). Concept maps, which are formed by showing the relationship between two concepts and through linking words between these concepts, are essential for permanent and meaningful learning. Concept maps can help students combine their prior learnings and new learnings and to organize complex ideas (Zhao 2003). Concept maps can be used in organizing knowledge; discussing the meaning of the concepts with students; finding misconceptions, identifying alternative concepts, and removing misconceptions; improving high-order thinking skills; and assessing what is learned (Atasoy 2002). Concept maps enable individuals to have meaningful learning, which is defined as forming knowledge by combining prior learnings and existing concepts with new information and making the connections between concepts (Tekkaya 2003). The most important feature of a concept map is that it is a two-dimensional visual tool with a hierarchical order (Liu 2004). This is the main factor separating concept maps from mind maps. Unlike mind mapping, concept mapping is more structured (Davies 2011).

It is possible to prepare concept maps either manually or on a computer. One piece of software that enables preparing concept maps is "Inspiration". It is believed that it is possible for students to remember the concepts and information about the concepts more easily via different images and figures in the library of the "Inspiration" programme.

Using mind mapping and concept mapping techniques, the aim of this paper was to enable 6th grade students to meaningfully construct the subjects in the "Systems in our Body" unit in their minds. The research problem of the paper was "What is the effect of technology-supported mind and concept mapping, which are grounded on a constructivist approach, on students' comprehension of concepts and what are student opinions on these practices?" The research questions under the given research problem are as follows:

- Is there a statistically significant difference between the comprehension levels of students in experimental group 1(in which a technology-supported mind mapping technique based on a constructivist approach was used), experimental group 2 (in which a concept mapping technique based on a constructivist approach was used), and a control group (in which the science and technology curriculum was implemented)?
- What are the opinions of the students in experimental group 1 on preparing mind maps and on the practices carried out?
- What are the opinions of students in experimental group 2 on preparing concept maps and on the practices carried out?

The dependent variable has its variability investigated and on which the effect of theindependent variable is observed. The variability of the independent variable, conversely, will affectthe result (Buyukozturk 2003). The independent variable of the paper is technology-supported mind and concept mapping techniques based on a constructivist approach, while the dependent variable is students' comprehension of concepts and their opinions on the practices carried out.

This paper aims to contribute to meaningful learning of students by ensuring them to construct the concepts better through the integration of the science and technology curriculum while creating mind and concept maps using technologic software. The paper reveals the effect of creating concept and mind maps during science and technology courses on their learning of the concepts and on building relationships between concepts. There are various studies on the effect of mind mapping (Amma 2005; Akinoglu and Yasar 2007) and concept mapping (Rao 2004; Oner and Arslan 2005; Candan et al. 2006) on student learning in the literature. This paper focuses on the effects of mind and concept mapping on conceptual learning and it is believed that the involvement of students' opinions about the practices carried out will contribute to the literature.

METHODOLOGY

Research Design/Model

A quasi-experimental design with apre test-post test control group was used in the paper.

The experimental design, given in Table 1, was designed for the study. In Table 1, T_1 representsthe concept test; T_2 represents the open-ended question assessment tool; and T_3 represents the semi-structured interview form.

Research Sample/Working Group

Because the research is experimental, a study group was taken instead of choosing a sample group andthe equivalence of the groups was taken into consideration. Based on the pre-test score averages of the "Systems in our Body" concept test, two of the three 6th grade courses in the school were assigned as experimental groups and one was assigned as the control group. The research group involved a total number of 62 students (20 students in experimental group 1, 22 students in experimental group 2, and 20 students in the control group). The same teacher carried out the teaching activities in both groups during the research (information about the experimental application are given in Appendix B).

Data Collection Instrument and Procedure

The research data was collected through the concept test related to the "Systems in our Body" unit, as well as open-ended questions and voice recordings in which the semi-structured interview technique was used. Experimental study lasted for four weeks (16 lesson hours). During the experiment, students in experimental group 1 (N=20) carried out the activities in groups of four and prepared mind maps in "Support and Movement System", "Circulation System", and "Respiration System" topics. Students in experimental group 2 (N=22) carried out the same activities in four and five-persons groups and prepared concept maps on the same topics. Students in experimental group 1 later made the mind maps in "Mind Manager Programme" on computers and students in experimental group 2 made the concept maps in the "Inspiration" programme.

Development of Concept Test

For the content validity of the concept test questions prepared, of consideration is thatthe test included all of the outcomes related to the topic in the science and technology curriculum. The opinions of a field expert were taken from four academics, two research assistants, and three science and technology teachers; necessary changes were made based on suggestions, and the content and face validity of the test were ensured.

The test, which initially included 49 items, was implemented on 156 seventh grade students.

The item and test analyses of the concept test whose preliminary implementations were made are given in Appendix A.

After the item analysis carried out following the implementation, 19 questions (the 1st, 3rd, 4th, 8th, 9th, 10th, 11th, 14th, 15th, 19th, 21st, 22nd, 27th, 31st, 38th, 39th, 44th, 45th, and 49th questions) were taken out of the test since their discrimination indexes were below .30 (Appendix A). Eight questions whose discrimination indexes were between .25 and .30 (the 2nd, 7th, 12th, 16th, 25th, 29th, 32nd, and 40th questions) were included in the test after their item roots and options were changed. As a result of the item analysis, which was carried out after the preliminary implementation of the test, 13 questions at a knowledge level of cognitive domain, 9 questions at the comprehension level,

Table 1: Experimental design

Group	*Before the experiment*	*During the experiment*	*After the experiment*
Experimental Group 1	Pre-test(T1)	Teaching via technology-supported mind mapping technique based on constructivist approach	Post-test (T_1, T_2, T_3)
Experimental Group 2	Pre-test (T1)	Teaching via technology-supported concept mapping technique based on constructivist approach	Post-test (T_1, T_2, T_3)
Control Group	Pre-test (T1)	Teaching via the Methods and Techniques used in Science and Technology Curriculum	Post-test (T_1, T_2)

and 1 question at the application level were taken out of the test. The final test, developed after the questions were chosen, involved questions of which 19 were at knowledge level, 10 were at comprehension level, and 1 was at application level. The questions taken out of the test after the preliminary implementation were not questions that ruined the content validity. The final version of the test included 30 multiple-choice questions. The average test difficulty was .43; KR-20 was .76.

Development of Open-ended Questions

A literature review of the "Systems in Our Body" unit was made and 17 open-ended questions were prepared, taking misconceptions observed in students into account. After the questions were shown to experts for their opinion and necessary corrections were made, the number of questions was taken down to 13. (Examples of open-ended questions are given in Appendix C.) These open-ended questions were implemented on 39 seventh grade students and whether or not the expressions used in the questions were understandable were checked and necessary corrections were made accordingly.

Development of Semi-structured Interview Form

Semi-structured interview questions were prepared to determine students' opinions regarding preparing mind/concept maps and the practice of doing this. Expert opinions were taken from three science educators for these questions. According to their feedback, relevant revisions were applied to ensure the content validity and questions were revised according to the expert opinionsand were then implemented on four students (two from experimental group 1 and two from experimental group 2) in order to finalize the questions. After the post-tests were implemented, semi-structured interviews with eight students from experimental group 1 and seven students from experimental group 2 were made.

Data Analysis

Quantitative data obtained from the concept tests were analyzed in SPSS.

Open-ended questions were scored and evaluated using a concept numeric assessment table. Considering the extent of the correctness of the questions, the questions were scored in the following way: 4 for "Sound Understanding"; 3 for "Partial Understanding"; 2 for Partial Understanding with Specific Misconception; 1 for Specific Misconceptions; and 0 for "No Answer" or "No Understanding" (Abraham et al. 1994). After the preliminary implementation, open-ended questions were then scored by three science and technology teachers according to the concept number evaluation table; the matching percentage of the scores was found to be 87 percent.

Voice recordings of the interviews were transcribed and their qualitative analyses were made. The analyses of the semi-structured interviews done with teachers and students were carried out in three steps: reduction of data, presentation of the data, and deductions (Miles and Huberman 1994; Patton 2002).

FINDINGS

Findings Related to the First Research Question

The first research question of the paper was whether or not there was a statistically significant difference between the comprehension levels of students in experimental group 1, experimental group 2, and the control group with regards to their comprehension levels of the concepts in the "Systems in Our Body" unit. Since the pre-test scores of the students in the experimental and control groups show a normal distribution ($p=0.190>0.05$) according to the Kolmogorov- Smirnov test, the group mean scores were compared with F-test, a parametric test, and the results are given in Table 2.

When the pre-test achievement means given in Table 2 are analyzed, the mean score of the group in which the mind mapping technique was used is 11.55, while the mean score of the group in which the concept mapping technique was used is 11.45, and the mean score of the control group is 11.70. Since the mean scores are quite close to each other and the "p" significance level is over 0.05, there is no statistically significant difference initially found.

According to the Kolmorogov-Smirnov test conducted, because the post-test scores of the students in experimental and control groups show a normal distribution ($p=0.198>0.05$), the group mean scores were compared with F-test, a

Table 2: Comparison of concept test implemented in experimental and control groups as a pre-test on the"Systems in our Body" unit

Group	N	Arithmetic mean	Standard deviation	F	p
Experimental 1	20	11.55	4.57	0.021	0.980
Experimental 2	22	11.45	3.14		
Control	20	11.70	4.00		

parametric test, and the results are given in Table 3.

As seen in Table 3, the mean score of experimental group 1 is 17.25, while the mean score of experimental group 2 is 13.68, and the mean score of the control group is 13.15. The results of F-test analysis, conducted to test whether the mean scores of experimental and control groups are statistically significant, reveal that there is a statistically significant difference. Since "p" value is below 0.05, there is a statistically significant difference among groups' concept comprehension levels, in support of the experimental group in which the technology-supported mind mapping technique was used.

The results belonging to experimental and control groups obtained from the comparison of the concept evaluation scores of open-ended questions related to the "Systems in our Body" unit according to F-test are given in Table 4.

As is seen in Table 4, the mean score of experimental group 1 for open-ended questions is 26.75, while the mean score of experimental group 2 is 21.32, and the mean score of the control group is 17.85. Since "p" value is below 0.05, there is a statistically significant difference among groups' concept comprehension levels, in support of the experimental group in which the technology-supported mind mapping technique was used.

Findings Related to the Second Research Question

The second research question was stated as "What are the opinions of students in experimental group 1 on preparing mind maps and on the practices carried out?" This question was answered by 8 students in experimental group 1, in which the technology-supported mind mapping technique was used, via semi-structured interviews.The following findings were obtained.

Students in experimental group 1 were asked to compare the teaching of the "Systems in our Body" unit in a science and technology course with the teachings in other units. Students stated that there were differences in how the unit was taught, that they made experiments (30%) and mind maps (60%), and that courses were taught with more visuals (10%).

Some of the student statements are given below:

- *"We prepared mind maps in the "Systems in Our Body" unit. We did not do it in other units before."* (2nd student)

Table 3: Comparison of concept test implemented in experimental and control groups as a post-test on the "Systems in our Bbody" unit

Group	N	Arithmetic mean	Standard deviation	F	p
Experimental 1	20	17.25	5.99	3.368	0.041*
Experimental 2	22	13.68	5.84		
Control	20	13.15	4.34		

at *p<0.05 significance level

Table 4: Comparison of concept evaluation scores of experimental and control groups relating to the open-ended questions about the "Systems in our Body" unit

Group	N	Arithmetic mean	Standard deviation	F	p
Experimental 1	20	26.75	10.15	4.416	0.014*
Experimental 2	22	21.32	9.75		
Control	20	17.85	8.66		

at *p<0.05 significance level

- *"Yes, we were making experiments."* (3rd student)

Students in experimental group 1 were asked whether or not they liked preparing mind maps about the "Systems in Our Body" unit on a computer. All students interviewed answeredpositively: 28.55 percent of the students stated that it was fun, nice, and easy to prepare mind maps on a computer; 14.30 percent said they found more text and images; 28.55 percent said that they did research; and 28.55 percent said they learned better.

More student statements are given below:

- *"When I do it on a computer with my friends, I find more text and images."* (1st student)

"I make research and it is fun." (5th student)

Students in experimental group 1 were asked whether or not they wanted to prepare mind maps in different units in science and technology courses in 6th, 7th, and 8th grades. 50 percent of the students stated that the reason they wanted to prepare mind maps was that they learned better; 25 percent said they learned more easily; 12.50 percent said they learned how to research; and 12.50 percent said it was fun to learn by preparing mind maps.

Some the student statements are given below:

*"Because I learn to make research when I prepare mind maps."(*1st student)

"Because I learn more easily when I make mind maps." (6th student)

Students in experimental group 1 were asked aboutthe benefits of learning through preparing mind maps in science and technology courses. 25 percent percentof the students said they learned the unit better; 8.35 percent said they learned faster; 25 percent said they remembered what they learned better; 8.35 percent said their course grades increased; 16.60 percent said they were able to do research; and 8.35 percent said their manual skills improved.

Some student statements are given below:

-*"I can remember better."*(3rd student)

-*"We make research. We learn more and faster."*(8th student)

Findings Related to the Third Research Question

The third research question was "What are the opinions of students in experimental group 2 on preparing concept maps and on the practices carried out?" This question was answered by 7 students from experimental group 2, in which the technology supported concept mapping technique was used, through semi-structured interviews. The following findings were obtained.

Students in experimental group 2 were asked to compare the teaching of the "Systems in Our Body" unit in their science and technology course with the teachings in other units. Students stated that there were differences in how the unit was taught and that they did activities (5.20%), experiments (5.20%), and concept maps (36.80%). In addition, they said they used computers in this unit (31.60%), they learned better (5.20%) and easier (5.20%), the courses were better (5.20%), and their research skills improved (5.20%).

Some student statements are given below:

- *"We learn easier when we haveactivities. We improve our research skills..."*(1st student)

- *"We made concept maps.We logged on to"Inspiration". For instance, when we made the circulation system, we wrote circulation systemon the top. We labeled arrows downward. When giving examples, we did not put them in boxes."* (4th student)

Students in experimental group 2 were asked whether or not they liked preparing concept maps about the "Systems in our Body" unit on a computer. All of the students interviewed were positive. 28.60 percent of the students stated that it was fun to prepare concept maps on a computer; 14.20 percent said it was enjoyable to use a computer; 28.60 percent said that they learned the concepts related to the topic by preparing concept maps on a computer; and 28.60 percent said that preparing concept maps in the "Inspiration" programme helped them remember what they learned.

Some student statements are given below:

- *"It is a very nice programme. When we forget what we did, we can look at them in the programme."* (2nd student)

-*"It is more fun to make things on a computer."* (5th student)

Students in experimental group 2 were asked whether or not they wanted to prepare concept maps on a computer in different units in the science and technology courses in 6th, 7th, and 8th grades. Students said that it was more instructive and fun to do the practices this way. 10 percent of the students stated that they learned by preparing concept maps on the computer; 10 percent said they understood the topics better; and 30 percent said preparing concept maps helped them revise what they learned and thus helped them to remember better. In addition, they said that the courses taught by preparing concept maps were better (20%) and easier (30%).

Some student statements are given below:

- *"Because it is better. We learn on the computer and make better mapping."* (1st student)
- *"Because we have the chance to repeat our units. I also learned very easily."(*3rd student)

Students in experimental group 2 were asked about the benefits of learning through preparing concept maps in science and technology courses. 25.00 percent of the students said they comprehend the unit better; 12.50 percent said they learned more easily; 25 percent said they repeated the unit; 25 percent said they remembered what they learned; and 12 percent said they learned to use the computer. In light of the answers given to this question, it is possible to say that concept maps help students to understand the topics better, to repeat the units, and to remember what they learned.

Some student statements are given below:

- *"Because it is better. We learned on the computer and..."* (1st student)
- *"I can repeat the topic. I also can see what was incorrect, so it is very nice for me."*(3rd student)

DISCUSSION

Although there was not a statistically significant difference in pre-test results of experimental and control groups in the concept test on "Systems in Our Body", there was a statistically significant difference in their post-test results on their concept comprehension levels, in support of the experimental group in which the technology-supported mind mapping technique was used. Also, when the scores of the experimental and control groups from open-ended questions were compared, there was a statistically significant difference in support of experimental group1. When the groups' mean scores were analyzed, themean score of experimental group 1 was higher than the mean score of experimental group 2 and the control group. In 9 open-ended questions, the rate of correct answers in experimental group 1, in which courses were taught via a technology-supported mind mapping technique, was higher compared to other groups. Alternatively, in4 open-ended questions the rate of correct answers in experimental group 2 was higher compared to other groups. Although the experimental group in which the mind mapping technique was used had the highest concept comprehension levels, the concept comprehension levels of the group in which concept mapping was used was higher than the control group. In their studies, Rao (2004), Aykanat et al. (2005), Oner and Arslan (2005), Candan et al. (2006), and Chiou (2008)found that concept mapping was more efficient on students' learning than traditional teaching. Amma (2005), Abi-El-Mona and Adb-El-Khalick (2008), and Balim (2013) found that mind mapping has more positive effects on academic achievement than traditional teaching. In addition,Balim (2013) stated in his research that mind mapping was efficient for retention of knowledge. Dhindsa et al. (2011) found that the mind map teaching approach had more positive effects on the quality of students' cognitive structures than traditional teaching.

All interviewed students in experimental groups 1 and 2 stated how the "Systems in Our Body" unit was taught differently from other units. Students in experimental group 1 stated that they made experiments and mind maps in this unit and that more visuals were used. Students in experimental group 2 stated that they did activities, experiments, and concept maps, that they understood the unit better and easier with the use of the computer, the courses were fun, and their research skills improved. Holland et al. (2004) made students work with mind a mapping programme ("Mind Manager") in a computer lab. Later, they were asked questions about mind maps and teaching concepts via mind maps. Students stated that they understood the concepts, made better organization of knowledge, that the mind maps could be used in other media, that it was easy to learn and use the mind mapping programme, it was useful that the programme could be transferred to Word and Powerpoint, and that they would continue using mind maps and "Mind Manager". Similarly, in his research Balim (2013) did semi-structured interviews with seventh grade students about preparing mind maps.Students said that mind maps were educational, entertaining, and useful.

CONCLUSION

At the end of this research, it is possible to say that technology-supported mind and concept mapping techniques have positive effects on students' comprehension of science concepts. Furthermore, these techniques positively affect students' opinions about understanding science concepts better and easier and about how the courses are taught.

RECOMMENDATIONS

In light of the findings of the present research, the following suggestions can be made:

Teachers should reveal prior learnings and can find out how students make connections between concepts if students prepare mind and concept maps in science and technology courses, either manually or on computer. Using these techniques, teachers could reveal students' existing knowledge in a short time. It is believed that visual tools, such as mind and concept maps, used in science and technology courses could improve students' interest in the course. Mind and concept mapping techniques in different units in science and technology courses and in different grades, and their effect on students' cognitive, affective, and psychomotor domains can be evaluated.

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Appendix A: Item and test analyses of the concept test of the "Systems in Our Body" unit

Item No.	*Item difficulty (p)*	*Item discrimi-nation(d)*
1	0.737	0.199
2	0.724	0.259
3	0.449	0.000
4	0.321	0.182
5	0.577	0.342
6	0.513	0.494
7	0.449	0.272
8	0.429	0.242
9	0.429	0.142
10	0.391	0.199
11	0.321	0.191
12	0.410	0.270
13	0.513	0.363
14	0.186	-0.003
15	0.295	0.087
16	0.244	0.275
17	0.245	0.415
18	0.449	0.403
19	0.487	0.196
20	0.474	0.325
21	0.295	0.076
22	0.288	0.154
23	0.500	0.363
24	0.359	0.424
25	0.340	0.270

Item No.	*Item difficulty (p)*	*Item discrimi-nation (d)*
26	0.615	0.499
27	0.282	0.184
28	0.468	0.445
29	0.423	0.261
30	0.244	0.391
31	0.314	0.219
32	0.462	0.297
33	0.564	0.477
34	0.577	0.405
35	0.487	0.475
36	0.622	0.408
37	0.692	0.520
38	0.404	0.194
39	0.295	0.100
40	0.186	0.265
41	0.590	0.383
42	0.429	0.329
43	0.673	0.391
44	0.250	0.131
45	0.410	0.015
46	0.391	0.375
47	0.333	0.329
48	0.442	0.384
49	0.192	0.089

Appendix B: About the experimental application

Fig. 1. An activity in Experimental group 1

Fig. 2. Technology-supported mind mapping

Fig. 3. Technology-supported concept mapping

Appendix C: Examples of open-ended questions

1. We cannot bend our waist as our arm. We cannot move our neck as much as we move our fingers. Why do you think that it is so?
2. Emre, who was driving back home from his friend’s birthday party had a traffic accident because he lost steering control. The traffic police who came to the scene stated that Emre was injured and bleeding out and so, he urgently needed a blood transfussion. Emre’s blood type was written as A Rh’on his driving license.
   a) Considering the case given above, please explain the importance of knowing your blood type.
   b) Fron which blod types can Emre take bloood?