The effects of using problem-based learning in science and technology teaching upon students' academic achievement and levels of structuring concepts

Didem INEL[1] and Ali Günay BALIM[2]

[1]Usak University, Faculty of Education, Department of Science Education, Usak, TURKEY

Email: dideminel@gmail.com

[2]Dokuz Eylul University, Faculty of Education, Department of Science Education, Izmir, TURKEY

Received 29 Jun., 2010
Revised 12 Dec., 2010

Contents

Abstract

The present study aimed to investigate the impact of the problem-based learning method used in science and technology teaching upon elementary school students' construction levels for the concepts concerning the "Systems in Our Body" unit in the science and technology course and their academic achievement. To this end, during the four-week experimental application process, the course was taught using the problem-based learning method in the experimental group and the control group curriculum was only based on the science and technology textbook. The study used two groups including the experimental (n=20) and control (n=21) groups, and the study used the pretest posttest control group semi-experimental design. The analysis of the obtained data revealed a significant difference in favor of the experimental group on students' scores on the academic achievement test and the open-ended questions that identified their construction levels for the concepts. This study should guide further studies and to help determine the effectiveness of the method in question on elementary school students.

Keywords: Science and technology teaching, constructivist approach and problem-based learning

Introduction

Education mainly aims to help students learn better and acquire higher order thinking skills that they are going to use throughout their lives. These skills include inquiry-learning skills and critical and creative thinking skills. Therefore, it is of great importance to create learning environments based on the constructivist approach to ensure that students play an active role in their own learning process and access knowledge through investigation and questioning. Constructivism is a student-centered learning approach, which maintains that students construct newly encountered information using the learning environments in which they are actively engaged (Juniu, 2006; Gijbels and Loyens, 2009). The constructivist approach argues that individuals' behaviors and ideas that develop later are based on their previously constructed ideas, and that learning is a process involving an association established by learners between their existing knowledge and new ideas and experiences (Tsai, 2002; Liang and Gabel, 2005). Thus, this approach suggests that when students construct new ideas or new concepts, they learn using their previous knowledge after a process of mental balancing, rather than by directly eliciting information from their teachers (Ben-Ari, 2001; Hsu, 2004). In learning environments based on the constructivist approach, students are active in the learning process and in charge of their learning (Brooks and Brooks, 2001), while teachers act as guides by providing students with suitable environments to construct knowledge (Taber, 2000). Constructivist learning environments bring individuals into closer social interaction and thus allow them to have rich learning experiences (Yaşar, 1998). Such active learning environments play an important part in achieving meaningful and retentive learning since they allow students to improve their problem-solving, creative thinking and critical thinking skills (Neo and Neo, 2009). Therefore, it is crucially important to create learning environments based on the constructivist approach, which allows students to use and thus improve their higher order thinking skills and helps their active participation in learning process. Today, various methods and techniques including cooperative learning, project-base learning, concept cartoons, concept maps and mind maps formed on the basis of the constructivist approach, and research has been conducted on the different characteristics of such methods and techniques (Duru and Gürdal, 2002; Rao, 2004; Valadares, Fonseca and Soares, 2004; Amma, 2005; Trevino, 2005; Brinkmann, 2005; Balım, İnel and Evrekli, 2008; Evrekli, Balım and İnel, 2009; Hulubova, 2008; Seo, Templeton and Pellegrino, 2008). Problem-based learning is one of the methods that helps create learning environments based on the constructivist approach.

The problem-based learning method has been described as a suitable method for constructivist approach since it allows students to associate their previous knowledge with newly acquired knowledge while working in cooperative groups to solve a daily life problem (Yenal, İra and Oflas, 2003; Tarhan and Acar, 2007; Tseng, Chiang and Hsu, 2008). Problem-based learning was developed in mid-1960s as an alternative method to the conventional approach and was first applied to the McMaster Medical Faculty in Canada (Bowdish et al., 2003; Loyens, Magda and Rikers, 2008). Problem-based learning has been employed since then in other fields including business, education, law, nursing and engineering (Chen, 2008; Massa, 2008). Problem-based learning is a learning method that uses problems as a basis for students to improve their problem-solving skills and to obtain knowledge (Uden and Beaumont, 2005). In the problem-based learning method, which highlights the use of real problems from daily life as a stimulus for learning, students work on scenario-based problems in a small group of 5-12 individuals (Berkel and Schmidt, 2000; Arts, Gijselaers and Segers, 2002). In problem-based learning environments, students learn new information while in the process of solving problems about daily life (Atan, Sulaiman and Idrus, 2005). For this reason, while conventional teaching uses problems to apply related concepts and principles at the end of the subjects in a unit, problem-based learning environments use problems as an instrument to improve students' problem solving skills and to teach them new concepts (Maudsley, 1999; Neville and Britt, 2007).

In the conventional approach, students are seen as individuals who passively accept information; whereas, in problem-based learning environments where learning takes place through problems, students are regarded as individuals who can access information through research and who question information. Therefore, in problem-based learning, students assume greater responsibility for their own learning. Due to such transformation in students' roles, teaching by knowledge transfer from the teacher is much less frequent in problem-based learning than in the conventional approach (Yip, 2002). That is why in problem-based learning environments, teachers' roles also differ from those in the conventional approach. In such learning environments, teachers (guides) play a helper's role by assisting students to learn by themselves. The guide should not transfer his/her knowledge about a subject to the students so that the student can acquire learning skills through self-management, but the teacher should try to reveal his/her existing knowledge by encouraging students in cognitive activities (Dolmans et al., 2005). Thus, students will not rely on their teachers to learn; instead, they will become independent learners throughout their lives (Sungur and Tekkaya, 2006).

Recently, much research has been conducted on learning environments that use problem-based learning, a method that requires students to be responsible for their own learning and allow them to gain access to knowledge through investigation, inquiry, and criticism. In the light of such research, it could be argued that the problem-based learning method contributes to students in many ways. Most studies have concluded that problem-based learning has many positive effects. First of all, students improve their problem-solving skills in the process of problem-based learning as they resolve given problem cases by themselves (Murray-Harvery et al., 2005). Arguably, acquisition of such skills will assist them in solving problems that they encounter throughout their lives. Thus, it could be possible to raise individuals who can resolve the problems they encounter through inquiry, research, and cooperation. Problem-based learning improves students' communication and cooperative skills, along with their cognitive skills used in problem solving and thinking paths (Hämäläinen, 2004). Particularly in the learning process, it leads to the creation of knowledge through social communication by encouraging students to interact with their environment (Sungur and Tekkaya, 2006). Aiming to help students gain access to knowledge through group work, the problem-based learning method underlines the importance of cooperative learning and helps students improve their cooperative learning skills (Visshers-Pleijers et al., 2006). In this way, the process of problem-based learning not only encourages students to take responsibility in their own learning, but it also serves to improve teamwork skills (Hughes and Lucas, 1997).

Today, science and technology teaching has increased in importance since it positively contributes to the development of countries through innovation and discovery. Therefore, it is believed that the problem-based learning method will have positive effects for students in various aspects, for example, medical education (Alper, 2008; Raupach and diğerleri; 2010), nursing education (Lin and diğerleri, 2010), engineering education (Güzeliş, 2006; Awang and Ramly, 2008) and student teachers education (Dahlgren, Castensson and Dahlgren, 1998; Peterson and Treagust, 1998; Gürses and diğerleri, 2007; Park and Ertmer, 2007) vocational high school education (Arıcı and Kıdıman, 2007), primary school education (Sönmez and Lee, 2003; Araz and Sungur, 2007a; Araz and Sungur, 2007b). Research has also shown it will have positive contributions on achieving effectively teaching science and technology. It is particularly believed that the problem-based learning method will be effective in improving students' cognitive levels, or to put it in another way, their academic achievement and level of concept construction so that they can adapt to the changing and developing world. That is why the need arose to carry out the present study.

Purpose and Significance of the Study

Problem-based learning is usually defined as a learning method in which students are given ill-structured problems and they try to put forward meaningful solutions to these problems (Rhem, 1998). In problem-based learning environments, the process is initiated by giving students an event about daily life and they then work as scientists in the learning process and define the problem, identify the piece of knowledge they lack about the subject area, carry out research and propose solutions to the problem through discussion in group environment. Later, they test their ideas in different ways, such as experiments and observation. Thus, the method contributes to students' learning and allows them to construct their knowledge by discussing it in individual and group environments. Although the problem-based learning method has long been used in faculties of medicine and in nursing education, its use in science education is quite new (Şenocak, Taşkesenligil and Sözbilir, 2007). Therefore, there is a need to conduct the present study in order to identify the effects of the problem-based learning method on elementary school students. The study aims to investigate the impact of the problem-based learning method on elementary school students' academic achievement and levels of concept construction used in science and technology teaching.

Problem Statement of the Study

Does the use of the problem-based learning method have any effect on students' academic achievement and levels of concept construction in the unit of "Systems in Our Body" in an elementary-level science and technology course?

Sub-problems of the Study

1. Is there a significant difference between the posttest academic achievement scores of the students in the experimental group, which was taught using the problem-based learning method, and the students in the control group, who was taught only on the basis of the science and technology curriculum?

2. Is there a significant difference between the posttest levels of concept construction of the students in the experimental group, who was taught by the problem-based learning method, and the students in the control group, who was taught only on the basis of the science and technology curriculum?

Method

The study employed a non-equivalent, pretest-posttest control group design, as an experimental research method (Christensen, 2004; Cohen, Manion and Morrison, 2005). The sample group consisted of 41 seventh-grade students enrolled in an elementary school in Turkey. Table 1 is a symbolic representation of the study.

Table 1. *Symbolic representation of the study design*
T1= Open-Ended Questions to Determine the Levels of Concept Construction,
T2= Academic Achievement Test on the Unit

Groups	Pretest	Process	Posttest
Experimental Group	T1, T2	Science and Technology curriculum – Problem-based learning method	T1, T2
Control Group	T1, T2	Science and Technology curriculum	T1, T2

The study formed two groups including the experimental and control groups, and during the four-week experimental application process, the experimental group was taught using the problem-based learning (PBL) method, while the control group was taught on the basis of the science and technology curriculum. The data collection instruments were administered to the students in both groups before and after the experimental application.

Implementation of the PBL Method

In this study, in a four-week quasi-experimental application, courses in an experimental group were taught using the PBL method and courses in a control group were taught using only the existing science and technology curriculum in Turkey. Both groups were taught by the same science instructor. In applying problem-based learning to the experimental group, a modular approach was used. The author designed modules and scenarios that were included in problems about the unit "Systems in Our body". Four modules were used in the experimental application. A module consisted of three or four PBL sessions. In each module, real life problems were included in concepts about the digestive system, the excretory system, the nervous system and the endocrine system. The aim of the problems in the modules was to help the students learn concepts from the biology unit and to attract interest and attention to the lessons. The students were grouped into 4 groups of 5 students each. Students worked together, shared ideas and discussed in order to solve problems throughout the problem-based learning process. During the PBL session, the tutor only guided students in searching for information about concepts in modules, discussing ideas and solving problems. The academic achievement test on the "Systems in Our Body" unit and open-ended questions, used to determine the levels of concept construction, were administered to the students in both groups before and after the experimental application.

Data Collection Instruments

1. Academic Achievement Test on the Unit "Systems in Our Body"

In the study, an academic achievement test on the unit "Systems in our Body" was developed to determine the cognitive levels of seventh-grade students about the subjects of the digestive system, the excretory system, the control and regulatory systems, which were all covered under the unit "Systems in our Body." Validity process was given priority when developing the academic achievement test. The first aim was to achieve content validity in the validity process for the test. Thus, in test preparation, at least two questions were formulated for each acquisition included for the relevant subject in the science and technology curriculum, and the cognitive levels pertaining to the questions are shown in a table of specifications. At the end of this process, the first version of the academic achievement test of 48 multiple choice questions was produced. This version of the test was submitted to two professors and two research fellows, who are experts in their respective fields, to obtain their opinions so that face validity and content validity could be ensured. The experts were asked to present their opinions about the test items by marking them on the scales of "relevance to the scientific field," "relevance to the acquisitions" and "relevance to the cognitive domain." The options included "relevant" and "irrelevant." Agreement values for the experts' responses to the test questions were calculated using an agreement percentage. The expert agreement percentage for the test was determined to be 93% for the section on "relevance to the scientific field," 87.5% for "relevance to the acquisitions," and 85% for "relevance to the cognitive domain." Şencan (2005) argues that an agreement percentage over .70 represents a good level of agreement among experts. In addition, during the expert opinion stage for the test, necessary corrections were also made in line of expert opinions, seven questions were removed from the test as they were found irrelevant to the acquisitions, and two other questions that were relevant to the acquisitions were added. As a result, after necessary corrections were made, and certain irrelevant questions were removed from the test in line with expert opinions, the final version of the 43-item test was ready for the preliminary application. 370 seventh-grade students participated in the pilot administration of the test. An item analysis for the obtained data revealed item difficulty values for the test questions; items with a value between 0.351 and 0.765 were selected for the final version of the test. The test was found to have an average difficulty value of 0.50. Given the value, the test could arguably have a moderate difficulty level. Apart from item difficulty, item discrimination index was also calculated in the process of item analysis. Items with item discrimination power below 0.30 were removed from the test. Thus, items with an item discrimination index over 0.40 were included in the final version of the test without any changes, while items with item discrimination index between 0.30 and 0.40 were included after necessary corrections. At the end of the item analysis, the final version of the test consisted of 34 multiple choice questions. Finally, the reliability process was implemented for the test questions and the KR-20 value was found to be 0.89.

2. Open-Ended Questions to Determine the Levels of Concept Construction

Eleven open-ended questions were formulated about the "Systems in Our Body" unit in order to determine the students' levels of concept construction and to make comparisons between the control and experimental groups. Opinions were sought from three experts in order to determine the content and face validity of the open-ended questions. The experts' opinions were obtained using a scale that contains the sections of "relevance to the scientific field," "relevance to the acquisitions," and "relevance to the cognitive domain," which were ranked as "relevant" and "irrelevant." Then the experts were asked to state their corrections. The agreement percentage among the experts was determined to be 90% for the section of "relevance to the scientific field," 85% for the "relevance to the acquisitions" section, and 85% for "relevance to the cognitive domain" section. Given these values, there is arguably a good level of agreement among the experts. Furthermore, in this process, several seventh-grade students were asked to read the open-ended questions prior to the experimental application, and necessary corrections were made when there was anything unclear about the questions. The data obtained from the open-ended questions given to the experimental and control groups in the study as pretest and posttest were analyzed by three experts, and each question was rated within a score range of 0-4. Given correctness levels of the students' responses to these questions, responses to the open-ended questions were scored 4 for "fully correct," 3 for "partially correct," 2 for "slightly correct," 1 for "less correct," and 0 for "no response or fully incorrect' (Abraham, Williamson and Westbrook, 1994). The agreement among the total expert scores for each individual in the experiment and control groups was calculated by using intra-cluster correlation analysis. Şencan (2005) argues that intra-cluster correlation analysis is used to determine inter-expert agreement in data with continuous and normal distribution. Therefore, the data were first tested for fit to normal distribution and goodness of fit of the data obtained from the three experts to normal distribution was tested by Kolmogorov-Smirnov normal distribution test. The results of the analyses revealed a significance value above .05 and that the data had normal distribution. In the intra-cluster correlation analysis, expert agreement for the pretest was .86, while it was calculated as .95 for the posttest.

Results and Interpretation

This part of the study investigates the effects of using problem-based learning in teaching science and discusses the data obtained for each sub-problem before and after the experimental application. The results of the data interpretation analysis is also reported.

Results and Interpretation concerning the First Sub-problem

The first sub-problem of the study was: "Is there a significant difference between the posttest academic achievement scores of the students in the experiment group taught by the problem-based learning method and the students in the control groups taught only on the basis of the science and technology curriculum?" In order to resolve the problem, the pretest and posttest academic achievement scores of the students in the experimental and control groups were compared using the Mann Whitney U test, a non-parametric statistical technique.

Table 2. *Results of the Mann Whitney U Test to Compare the Groups' Pretest Academic Achievement Scores*

GROUPS	N	Rank Average	Sum of Ranks	U	Z	p
EXPERIMENTAL GROUP	20	20.53	410.50	200.50	0.253	.801*
CONTROL GROUP	21	21.45	450.50			

* The difference is insignificant since p>.05.

An examination of the findings in Table 2 reveals the results of Mann Whitney U test for the pretest academic achievement scores of the students in the experimental and control groups did not show any statistical difference (Z=0.253; p=.801>.05). The rank average of the pretest scores of the experimental group students was 20.53, while the students in the control group had a pretest score rank average of 21.45. The close rank averages of the groups' pretest academic achievement scores indicate that before the experimental application, the experimental and control groups had somewhat equal pretest academic achievement levels.

Table 3. *Results of the Mann Whitney U Test to Compare the Groups' Posttest Academic Achievement Scores*

GROUPS	N	Rank Average	Sum of Ranks	U	Z	p
EXPERIMENTAL GROUP	20	25.55	511.00	119.00	2.382	.017*
CONTROL GROUP	21	16.67	350.00			

* The difference is significant since $p<.05$.

An examination of the findings in Table 3 shows that the results of the Mann Whitney U test applied to the posttest academic achievement scores of the students in the experimental and control groups revealed a statistically significant difference at the level of $p<.05$ ($Z=2.382$; $p=.017<.05$). The rank average of the posttest scores of the experimental group students was 25.55, while the students in the control group had a posttest score rank average of 16.67. The analyses had shown no significant difference between the rank averages of the groups' pretest academic achievement scores; however, an examination of the rank averages of their posttest academic achievement scores demonstrates that the students in the experimental group had higher academic achievement than those in the control group.This result indicates that the experimental group students attained higher success after the experimental application when compared to their peers in the control group.

Table 4. *Results of the Wilcoxon Signed-Ranks Test to Compare the Pretest-Posttest Academic Achievement Scores of the Students in the Experimental Group*

Academic Achievement Posttest-Pretest	N	Rank Average	Sum of Ranks	Z	p
Negative Rank	1	1.50	1.50	3.873	.000*
Positive Rank	19	10.97	208.50		
Equal	0				

* The difference is highly significant since $p<.001$.

As an examination of the findings in Table 4 shows there is a significant difference between the pretest and posttest academic achievement scores of the students in the experimental group ($Z=3.873$, $p=.000<.001$). The sum of their negative ranks for the experimental group students' academic achievement scores was found to be 1.50, while their sum of positive ranks is 208.50. Given the sum of ranks for the difference scores, the observed difference is in favor of positive ranks, or in other words, the posttest scores of the experimental group. On the basis of the results obtained, it could be argued that the use of the problem-based learning method in the science and technology curriculum significantly increased the academic achievement levels of the experimental group students.

Table 5. *Results of the Wilcoxon Signed-Ranks Test to Compare the Pretest-Posttest Academic Achievement Scores of the Students in the Control Group*

Academic Achievement Posttest-Pretest	N	Rank Average	Sum of Ranks	Z	p
Negative Rank	2	1.50	3.00	3.709	.000*
Positive Rank	17	11.00	187.00		
Equal	2	-	-		

* The difference is highly significant since p<.001.

As will be revealed by an examination of the findings in Table 5, there is a significant difference between the pretest and posttest academic achievement scores of the students in the control group (Z=3.709, p=.000<.001). The sum of the negative ranks for the control group students' academic achievement scores was found to be 3.00, while their sum of positive ranks is 187.00. Given the sum of ranks for the difference scores as a result of the analyses, the observed difference is in favor of positive ranks, or in other words, the posttest scores of the control group. On the basis of the results obtained, it could be argued that the science and technology curriculum significantly increased the academic achievement levels of the control group students.

Results and Interpretation concerning the Second Sub-problem

The second sub-problem of the study was formulated as follows: "Is there a significant difference between the posttest 'construction levels of the concepts regarding the subject' of the students in the experimental group taught by the problem-based learning method and the students in the control groups taught only by the science and technology curriculum?" In order to resolve the problem, the pretest and posttest concept construction levels of the students in the experimental and control groups were compared using Mann Whitney U test, a non-parametric statistical technique.

Table 6. *Results of the Mann Whitney U Test on the Pretest Concept Construction Levels of the Students in the Experimental and Control Groups*

GROUPS	N	Rank Average	Sum of Ranks	U	Z	p
EXPERIMENTAL GROUP	20	22.18	443.50	186.50	0.614	.539*
CONTROL GROUP	21	19.88	417.50			

* The difference is insignificant since p>.05.

An examination of the findings in Table 6 reveals that the results of Mann Whitney U test, applied to compare the pretest average scores for concept construction levels of the students in the experimental and control groups, did not show any statistical difference (Z=0.614, p=.539>.05). The rank average of the pretest scores of the experimental group students was 22.18, while the students in the control group had a pretest score rank average of 19.88. The close rank averages of the groups' pretest scores for concept construction levels indicate that before the experimental application, the experimental and control groups had somewhat equal construction levels of the concepts regarding the subject.

Table 7. *Results of the Mann Whitney U Test on the Posttest Concept Construction Levels of the Students in the Experimental and Control Groups*

GROUPS	N	Rank Average	Sum of Ranks	U	Z	p
EXPERIMENTAL GROUP	20	26.63	532.50	97.50	2.935	.003*
CONTROL GROUP	21	15.64	328.50			

* The difference is highly significant since p<.01.

An examination of the findings in Table 7 shows that the results of Mann Whitney U test, applied to compare the posttest average scores for concept construction levels of the students in the experimental and control groups, revealed a statistically significant difference (Z=2.935, p=.003<.05). The rank average of the posttest scores of the experimental group students was 26.63, while the students in the control group had a posttest score rank average of 15.64. As a result, there was no significant difference between the groups' concept construction levels before the experimental application; however, an examination of the rank average of their posttest scores for concept construction levels demonstrates that the students in the experimental group had higher concept construction levels than those in the control group.

Table 8. *Results of the Wilcoxon Signed-Ranks Test on the Pretest-Posttest Concept Construction Levels of the Students in the Experimental Group*

Concept Construction Posttest-Pretest	N	Rank Average	Sum of Ranks	Z	p
Negative Rank	1	1.00	1.00	3.883	.000*
Positive Rank	19	11.00	209.00		
Equal	0				

* The difference is highly significant since p<.001.

As revealed by the results in Table 8, there is a significant difference between the pretest and posttest scores of concept construction levels for the students in the experimental group (Z=3,883, p=.000<.001). For these experimental group students, the negative sum of ranks of the scores of concept construction levels was found to be 1.00, while the positive sum of ranks of their scores was 209.00. Given the sum of ranks for the difference scores, the observed difference is in favor of positive ranks, or in other words, the posttest scores of the experimental group. On the basis of the results obtained in the analyses, it could be argued that the use of the problem-based learning method in the science and technology curriculum significantly enhanced the concept construction levels of the experimental group students.

Table 9. *Results of the Wilcoxon Signed-Ranks Test on the Pretest-Posttest Concept Construction Levels of the Students in the Control Group*

Concept Construction Posttest-Pretest	N	Rank Average	Sum of Ranks	Z	p
Negative Rank	3	2.67	8.00	3.737	.000*
Positive Rank	18	12.39	223.00		
Equal	0				

* The difference is highly significant since p<.001.

As shown by the results in Table 9, there is a significant difference between the pretest and posttest scores of concept construction levels for the students in the control group at the level of $p<.001$ ($Z=3.737$; $p=.000<.001$). For the control group students, the negative sum of ranks of the scores of concept construction levels was found to be 8.00, while the positive sum of ranks of their scores was 223.00. Given the sum of ranks for the difference scores, the observed difference is in favor of positive ranks, or in other words, the posttest scores of the control group. These results suggest that the science and technology curriculum significantly enhanced the concept construction levels of the control group students.

Discussion and Conclusion

Problem-based learning is defined as "learning as a result of a study process to comprehend or solve a problem" (Dabbah et al., 2000). In this process, students are in charge of their learning and gain access to knowledge through research and exchange of ideas with their peers. This study investigates the effect of using problem-based learning, a method that encourages students to be active in learning process, in science and technology teaching in elementary school seventh-grade students' academic achievement and concept construction levels. The current section discusses the results obtained using data analysis.

Discussion and Conclusion Concerning the First Sub-problem

While there was no significant difference between the groups' mean academic achievement scores before the experimental application, a significant difference was found between the groups' academic achievement after the application in favor of the experimental group. This result indicates that the experimental group students attained higher success after the experimental application when compared to their peers in the control group. As a result, it can be argued that the use of the problem-based learning method in science and technology teaching is more effective in enhancing students' academic achievement than simply using the science and technology curriculum. Certain studies have been found that confirm the present study's results with regard to the sub-problem in question. A similar study by Sungur, Tekkaya and Geban (2006) investigated the impact of using the problem-based learning method in the human excretory system unit on tenth-grade students' academic achievement. The study found a significant difference between the groups' academic achievement in favor of the experimental group. In their study, Tarhan and Acar (2007) studied the effects of problem-based learning method upon eleventh-grade students' academic success. This study also revealed a significant difference between the students' academic success in favor of the experimental group. Gordon et al. (2001) stated that problem-based learning, which is a constructivist method, is a valuable instrument that can be used to enhance elementary school students' success. Drawing upon the previous studies on the problem-based learning method, Chang (2001) noted in a study that if applied "well," the problem-based learning method may have positive effects on students' learning or improvement of their academic achievement. As a conclusion, as demonstrated by the studies in the literature, the problem-based learning method implemented at various stages positively affects students' academic achievement. With the problem-based learning method, students rely on their previous knowledge to identify the problem given in a scenario, resolve it, and thus, learn new information by actively participating in the learning process. Within this process, students find the opportunity to discuss their knowledge in group environment and make up for the shortcomings in their existing knowledge through exchange of information in the group environment. Moreover, students identify their own learning fields in the learning process, conduct required research and propose different ideas to solve the problem. In summary, problem-based learning helps students learn by discussing their existing knowledge and the information they obtain in social group environments and by resolving a problem using higher-order thinking skills. Therefore, the problem-based learning method is results in positive development in students' academic achievement.

Discussion and Conclusion Concerning the Second Sub-problem

While there was no significant difference between the groups' concept construction levels before the experimental application, a significant difference was found between the groups' concept construction levels after the application in favor of the experimental group. This result indicates that the experimental group students improved their levels of constructing the concepts concerning the subject after the experimental application more than their peers in the control group. As a result, it can be argued that the use of the problem-based learning method in science teaching is more effective in enhancing students' ability to learn the concepts in a biology unit by constructing them in their minds, rather than simply using the science and technology curriculum. One question that requires an answer is to what extent science teaching curricula allows students to gain access to science concepts (Kılıç and Sağlam, 2009). Thus, it is of crucial importance to determine the effect of the problem-based learning method upon conceptual development. A similar study concluding problem-based learning has positive effects on students' conceptual development was carried out by Akınoğlu and Tandoğan (2007) with seventh-grade students. Studies have demonstrated that the problem-based learning method positively influences students' conceptual development and keeps misconceptions at a low level. The present study revealed that problem-based learning positively affects concept learning. This positive change is arguably caused by the active role played by students in the process of problem-based learning from problem identification to solving the problem and also by the opportunities they found in group environments to construct their knowledge. In sum, students identify the information they lack during the problem-based learning process, make up for these shortcomings in their knowledge about a subject, share information in group environment, and thus, have the opportunity to construct their knowledge in social and cognitive terms. Therefore, given these aspects of the problem-based learning method, it is believed to be more effective on students' levels of constructing the concepts about a biology unit. This result demonstrates that the problem-based learning method enhances students' levels of constructing the concepts about a biology unit in the process of an experimental application. Thus, it could be argued that using the problem-based learning method in learning process positively contributes to students' learning by constructing the concepts about a biology unit in their minds. As a result of the interpretation of the data obtained from the research, the following recommendations are noted.

- The study examined certain effects of using problem-based learning on seventh grade students in an elementary school in the unit on "the Systems in our Body." Given that the study dealt with a unit in biology, it is believed that further research is needed about the feasibility of the problem-based learning method in units concerning different disciplines in the science and technology course.

- It is argued that the problem-based learning method can be used to ensure better construction in students' minds for the concepts in science and technology course.

- It is believed that pre-service science teachers should be provided with the knowledge and skills concerning the characteristics of the problem-based learning method and its use in science teaching.

References

Abraham, M. R., Williamson, V. M. & Westbrook, S. L. (1994). A cross-age study of the understanding of five chemistry concepts. *Journal of Research in Science Teaching*, *31*(2), 147-165.

Akınoğlu, O. & Tandoğan, R. Ö. (2007). The effects of problem-based active learning in science. education on students’ academic achievement, attitude and concept learning. *Eurasia Journal of Mathematics, Science and Technology Education, 3*(1), 71-81.

Alper, A. (2008). Attitudes toward problem based learning in a new turkish medicine curriculum. *World Applied Sciences Journal, 4*(6), 830-836.

Amma, C. (2005). *Effectiveness of computer based mind maps in the learning of biology at the higher secondary level*. New Delhi: ICDE International Conference (November, 19-23, 2005).

Araz, G. & Sungur, S. (2007a). The interplay between cognitive and motivational variables in a problem-based learning environment. *Learning and Individual Differences*, *17*(4), 291-297.

Araz, G. & Sungur, S. (2007b). Effectiveness of problem-based learning on academic performance in genetics. *Biochemistry and Molecular Biology Education*, *35*(6), 448-451.

Arıcı, N. & Kıdıman, E. (2007). Mesleki ve teknik orta öğretimde probleme dayalı öğrenme yönteminin akademik başarıya ve öğrenmenin kalıcılığına etkisi. *E-Journal of New World Sciences Academy, 1*(3), 44-53.

Arts, J. A. R., Gijselaers, W. H. & Segers, M. S. R. (2002). Cognitive effects of an authentic computer-supported, problem-based learning environment. *Instructional Science, 30*(6), 465-495.

Atan, H., Sulaiman, F. & Idrus, R. M. (2005). The effectiveness of problem-based learning in the web based environment for the delivery of an undergraduate physics course. *International Education Journal, 6*(4), 430-437.

Awang, H. & Ramly, I. (2008). Creative thinking skill approach through problem-based learning: pedagogy and practice in the engineering classroom. *International Journal of Social Sciences*, *3*(1), 18-23.

Balım, A. G., İnel, D. & Evrekli, E. (2008). Fen öğretiminde kavram karikatürü kullanımının öğrencilerin akademik başarılarına ve sorgulayıcı öğrenme becerileri algılarına etkisi. *İlköğretim Online, 7*(1), 188-202.

Ben-Ari, M. (2001). Constructivism in computer science education. *Journal of Computers in Mathematics and Science Teaching, 20*(1), 45-73.

Berkel, H. J. M. V. & Schmidt, H. G. (2000). Motivation to commit oneself as a determinant of achievement in problem-based learning. *Higher Education, 40*(2), 231-242.

Bowdish, B. E., Chauvin, S. W., Kreisman, N. & Britt, M. (2003). Travels towards problem based learning in medical education. *Instructional Science*, *31*(4-5), 231-253.

Brinkmann, A. (2005). Knowledge maps-tools for building structure in mathematics. *International Journal for Mathematics Teaching and Learning.*

Brooks, J. G. & Brooks, M. G. (2001). *In Search for Understanding the Case for Constructivist Classrooms*. New Jersey: Prentice Hall.

Chang, C. Y. (2001). Comparing the impacts of a problem-based computer-assisted instruction and the direct-interactive teaching method on student science achievement. *Journal of Science Education and Technology, 10*(2), 147-153.

Chen, N. C. (2008). An educational approach to problem-based learning. *The Kaohsiung Journal of Medical Sciences, 24*(3), 23-30.

Christensen, L. B. (2004). *Experimental Methodology*. Boston, MA: Pearson Allyn and Bacon.

Cohen, L., Manion, L. ve Morrison, K. (2005). *Research Methods in Education (5th Edition)*. London, NewYork: Routledge Falmer.

Dabbah, N. H., Jonassen, D. H., Yueh, H. P. & Samouilova, M. (2000). Assessing a problem-based learning approach to an introductory instructional design course: A case study. *Performance Improvement Quarterly, 13*(3), 60-83.

Dahlgren, M. A., Castensson, R. & Dahlgren, L. O. (1998). PBL from the teachers' perspective. *Higher Education, 36*(4), 437-447.

Dolmans, D. H. J. M., Grave, W. D., Wolfhagen, I. H. A. P. & Vleuten, C. P. M. V. D. (2005). Problem-based learning: Future challenges for educational practice and research. *Medical Education, 39*(7), 732-741.

Duru, M. K. & Gürdal, A. (2002). *İlköğretim fen bilgisi dersinde kavram haritasıyla ve gruplara kavram haritası çizdirilerek öğretimin öğrenci başarısına etkisi.* Orta Doğu Technical University, Ankara: 5th National Congress on Science and Mathematics Education.

Evrekli, E., Balım, A. G. & İnel, D. (2009). Mind mapping applications in special teaching methods courses for science teacher candidates and teacher candidates' opinions concerning the applications. *Procedia - Social and Behavioral Sciences*, *1*(1), 2222-2226.

Gijbels, D. & Loyens, S. M. M. (2009). Constructivist learning (environments) and how to avoid another tower of Babel: Reply to Renkl. *Instructional Science, 37*(5), 499-502.

Gordon, P. R., Rogers, A. M., Comfort, M., Gavula, N. & Mcgee, B. P. (2001). A taste of problem-based learning increases achievement of urban minority middle-school students. *Educational Horizons, 79*(4), 171-175.

Gürses, A., Açıkyıldız, M., Doğar, Ç. & Sözbilir, M. (2007). An investigation into the effectiveness of problem-based learning in a physical chemistry laboratory course. *Research in Science & Technological Education, 25*(1), 99-113.

Güzeliş, C. (2006). An experience on problem based learning in an engineering faculty. *Turkish Journal of Electrical Engineering & Computer Sciences*, *14*(1), 67-75.

Hämäläinen, W. (2004). Problem-based learning of theoretical computer science. Savannah: Georgia: 34th ASEE/IEEE Frontiers in Education Conference (20-23 September).

Hsu, L. (2004). Developing concept maps from problem-based learning scenario discussions. *Issues and Innovations in Nursing Education, 48*(5), 510-518.

Hughes, L. & Lucas, J. (1997). An evaluation of problem based learning in the multiprofessional education curriculum for the health professions. *Journal of Interprofessional Care, 11*(1), 77-88.

Hulubova, R. (2008). Effective teaching methods-project based learning in physics. *US-China Education Review, 5*(12), 27-35.

Juniu, S. (2006). Use of technology for constructivist learning in a performance assessment class. *Measurement in Physical Education and Exercise Science, 10*(1), 67-79.

Kılıç, D. & Sağlam, N. (2009). Development of a two-tier diagnostic test to determine students' understanding of concepts in genetics. *Eurasian Journal of Educational Research, 36*, 227-244.

Liang, L. L. & Gabel, D. L. (2005). Effectiveness of a constructivist approach to science instruction for prospective elementary teachers. *International Journal of Science Education*, *27*(10), 1143–1162.

Lin, C. F., Lu, M. S., Chung, C. C. & Yang, C. M. (2010). A comparison of problem-based learning and conventional teaching in nursing ethics education. *Nursing Ethics, 17*(3), 373-382.

Loyens, S. M. M., Magda, J. & Rikers, R. M. J. P. (2008). Self-directed learning in problem-based learning and its relationships with self-regulated learning. *Educational Psychology Review, 20*(4), 411-427.

Massa, N. M. (2008). Problem-based learning. a real-world antidote to the standards and testing regime. *The New England Journal of Higher Education, 22*(4), 19-20.

Maudsley, G. (1999). Roles and responsibilities of the problem based learning tutor in the undergraduate medical curriculum. *British Medical Journal, 318*, 657–661.

Murray-Harvey, R., Curtis, D. D., Cattley, G. & Slee, P. T. (2005). Enhancing teacher education students' generic skills through problem-based learning. *Teaching Education, 16*(3), 257-273.

Neo, M. & Neo, T. K. (2009). Engaging students in multimedia-mediated constructivist learning – students' perceptions. *Educational Technology and Society, 12*(2), 254-266.

Neville, D. O. & Britt, D. W. (2007). A problem-based learning approach to integrating foreign language into engineering. *Foreign Language Annals, 40*(2), 226-246.

Park, S. H. & Ertmer, P. A. (2007). Impact of problem-based learning (pbl) on teachers' beliefs regarding technology use. *Journal of Research on Technology in Education*, *40*(2), 247-267.

Peterson, R. F. & Treagust, D. F. (1998). Learning to teach primary science through problem-based learning. *Science Education, 82*(2), 215-237.

Rao, M. P. (2004). *Effect of concept mapping in science on science achievement, cognitive skills and attitude of students.*International Conference To Review Research On Science, Technology And Mathematics Education, Goa, India (13-17 December 2004).

Raupach, T., Munscher, C., Pukrop, T., Anders, S. & Harendza, S. (2010). Significant ıncrease in factual knowledge with web-assisted problem based learning as part of an undergraduate cardio-respiratory curriculum. *Advances in Health Sciences Education, 15*(3), 349-356.

Rhem, J. (1998). Problem-based learning: an introduction. *The National Teaching and Learning Forum, 8*(1), 1-4.

Seo, K. K., Templeton, R. & Pellegrino, D. (2008). Creating a ripple effect: Incorporating multimedia-assisted project-based learning in teacher education. *Theory into Practice*, *47*(3), 259-265.

Sonmez, D. & Lee, H. (2003). *Problem-based learning in science*. ERIC Clearinghouse for Science, Mathematics, and Environmental Education. http://www.stemworks.org/digests/EDO-SE-03-04.pdf. (Son erişim: 22. 03. 2007).

Sungur, S. & Tekkaya, C. (2006). Effects of problem-based learning and traditional instruction on self-regulated learning. *The Journal of Educational Research*, *99*(5), 307-317.

Sungur, S., Tekkaya, C. ve Geban Ö. (2006). Improving achievement through problem-based learning. *Educational Research, 40*(4), 155-160.

Şencan, H. (2005). *Sosyal ve davranışsal ölçümlerde güvenilirlik ve geçerlilik.* Ankara: Seçkin Yayıncılık.

Şenocak, E., Taşkesenligil, Y. & Sözbilir, M. (2007). A study on teaching gases to prospective primary science teachers through problem-based learning. *Research Science Education, 37*(3), 279-290.

Taber, K. S. (2000). Chemistry lessons for universities?: A review of constructivist ideas. *University Chemistry Education*, *4*(2), 63-72.

Tarhan, L. & Acar, B. (2007). Problem-based learning in an eleventh grade chemistry class: 'Factors affecting cell potential.' *Research in Science & Technological Education, 25*(3), 351-369.

Trevino, C. (2005). Mind mapping and outlining: Comparing two types of graphic organizers for learning seventh-grade life science. Unpublished Doctoral Dissertation, Texas Tech University.

Tsai, C. C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education*, *24*(8), 771-783.

Tseng, K. H., Chiang, F. K. & Hsu, W. H. (2008). Interactive processes and learning attitudes in a web-based problem based learning (pbl) platform. *Computers in Human Behaviour, 24*(3), 940-955.

Uden, L. & Beaumont, C. (2005). *Technology and Problem-Based Learning*. Hershey, PA, USA: Information Science Publishing.

Valadares, J., Fonseca, F. & Soares, M. T. (2004). *Using conceptual maps in physics classes. concept maps: theory, methodology, technology.* Pamplona, Spain: Proceedings of the First International Conference on Concept Mapping.

Visshers-Pleijers, A. J. S., Dolmans, D. H. J. M., Grave, W. S. D., Wolfhagen, I. H. A. P., Jacobs, J. A. & Vleuten, C. P. M. (2006). Student perceptions about the characteristics of an effective discussion during the reporting phase in problem-based learning. *Medical Education, 40*, 924-931.

Yaşar, Ş. (1998). Yapısalcı kuram ve öğrenme-öğretme süreci. *Anadolu Üniversitesi Eğitim Fakültesi Dergisi*, *8*(1-2), 68-75.

Yenal, H., İra, N. & Oflas, B. (2003). Etkin öğrenme modeli olarak: soruna dayalı öğrenme ve yüksek öğretimde uygulanması. *Sosyal Bilimler Dergisi, 1*(2), 117-126.

Yip, W. (2002). Students' perceptions of the technological supports for problem-based learning. *Education and Information Technologies, 7*(4), 303-312.