Enriching Project-Based Learning Environments with Virtual Manipulatives: A Comparative Study

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Abstract

Problem statement: Although there is agreement on the potential of project-based learning (PBL) and virtual manipulatives (VMs), their positive impact depends on how they are used. This study was based on supporting the use of online PBL environments and improving the efficacy of the instructional practices in PBL by combining the potentials of PBL and VMs.

Purpose of the study: The purpose of this study is to investigate the effect of a PBL environment enriched with VMs by comparing it with a traditional PBL environment. The comparison is focused on academic achievements in Quadratic Equations and Polynomials subjects and attitudes towards mathematics courses.

Methods: Since randomly assigning students to groups was not possible, a quasi-experimental design was used in the study. One experimental group (EG; $N = 30$) and one comparison group (CG; $N = 30$) were used in the study. While the comparison group was taught with traditional PBL activities, the experimental group received some other PBL by using the web enriched with VMs. Participants in the EG and the CG were pre-tested and post-tested with an Achievement Test (AT), including 25 questions about Polynomials and Quadratic Equations subjects. The changes in attitudes were investigated by an attitude scale.

Findings and Results: The statistical analysis indicates that EG students significantly outperformed CG students with respect to AT results. The change in attitudes towards mathematics courses was not statistically significant among the two groups.

Conclusions and Recommendations: The results of the study provided some empirical evidence about the positive effects of VMs that are used to

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enrich PBL environments. Although changes in attitudes have not been seen, positive academic achievements have been revealed in two subjects. Based on the study, it is concluded that the combination of VMs and PBL may be an effective way to enhance students' understanding of mathematics subjects and to improve their academic achievements.

Keywords: virtual manipulatives, project based learning, teaching mathematics, comparative analysis

Introduction

Project-based learning (PBL) suggests learning environments in which projects support learning. PBL has been used successfully in various courses in secondary and tertiary education (Hennessy, 2006; Jonassen, Howland, Moore, & Marra, 2003). Educators agree that working on projects is an engaging activity for students, and PBL has valuable potential for facilitating and enhancing learning (ChanLin, 2008). PBL includes problem-solving and exploration processes to drive learning. By working with the projects, students engage in real-world contexts by applying logical tasks that involve the skills and concepts to be learned. Bednar, Cunningham, Duffy, and Perry (1992) define PBL as an instantiation of education theory, research, and practice in constructivism. According to their definition, PBL guides students to assume a real-life role and apply the tools of a knowledge domain in creating a project.

Similarly, along with the improvements in information technology and the popularity of the Internet, educators have begun using e-learning technologies to improve learning outcomes (Hernández-Ramos & Paz, 2010; Linn et al., 2000; Şendağ & Odabaşı, 2009). The ePBL approach is derived from the PBL approach and combines the advantages of web-based learning environments (WBLE) with PBL. Krajcik, Czeniak, and Berger (1994) explain that PBL generally includes six steps: Refining questions, finding information, planning, designing and conducting experimental work, analyzing data, and sharing artifacts. In order to achieve these steps, various tools have been used to construct and enrich ePBL environments, such as webquests, blogs, forums, social networking or others. Most of these tools generally help in sharing information, collaboration, or cooperation. Liu, Lou, Shih, Meng, and Lee (2010) point out that PBL environment should provide an environment to acquire knowledge emerging from a student's work within experimental work. This gives us an idea that one of the key factors for designing ePBL environments is student-content interactivity. One type of useful tools for developing interactive learning environments on the web is virtual manipulatives (VMs). Although research studies on VMs have illustrated their positive effects on enhancing students' understanding, there is a limited number of studies showing that the VMs are used in PBL applications (Moyer, Bolyard, & Spikell, 2002; Steen, Brooks, & Lyon, 2006). Therefore, this study discusses the potential outcomes of combining VMs and PBL environments.

In related studies section, research studies about PBL, ePBL, and VMs are discussed briefly, and the need for this study is addressed.

Related Studies

PBL can be administered either in classrooms or in the outdoors. In contrast to outdoor activities, the web is generally used to facilitate activities in ePBL applications (Markham, Mergendoller, Larmer, & Ravitz, 2003). Students can be allowed to access the information in a variety of forms and use information for completing the tasks by ePBL. In this context, some researchers found that students in ePBL applications showed better performances than those who completed projects in the traditional way (Barak & Dori 2005; Jonassen et al., 2003; Guthrie, 2010), and they expressed that ePBL has enhanced the students' investigations of real-life problems in a scientific manner. In another study, the researchers investigated the positive effects of ePBL on students' attitudes (Morgil, Seyhan, Alsan, & Temel, 2008). While some ePBL applications exist in science, the examples for mathematics courses are limited. Al-A'ali (2008) focused on the challenges and opportunities of using ePBL in mathematics lessons. The study noticed improvement in grades and students' motivation. During project tasks, students should work on plans, experiments, or designs to solve problems. This will require students to interact with content or perform operations with information. Durmuş and Karakırık (2006) point out that, for mathematics education, VMs may provide interactive environments in which students could pose and solve their own problems to form connections between mathematical concepts and operations and then get immediate feedback that might lead them to reflect on their conceptualization.

VMs are digital objects that can be used as stand-alone resources or as components for constructing learning environments to enhance conceptual understanding (NCTM, 2000; Reimer & Moyer, 2005). Research studies have shown that VMs may have a positive impact on both the higher-order thinking and motivation of students (Finkelstein, Adams, Keller, Kohl, Perkins, Podolefsky et al., 2005; Huppert & Lazarowitz, 2002; Hsu & Thomas, 2002; Zacharia, 2007). Reimer and Moyer (2005) showed that students' interactions with the virtual base-10 blocks improved their expressions in both writing and drawings related to their conceptual understanding of the regrouping process in mathematics. Also, some other studies promulgated the idea that VMs can support or enhance the learning of mathematical concepts (Chin & Teou, 2009; Steen, Brooks, & Lyon, 2006) and can positively affect the attitude toward mathematics (Mc Neil & Jarvin, 2007; Patricia, 2001).

Analyzing the literature about ePBL environments shows that these environments have some limitations on student-context interactions. In addition, the distributed feature of information resources or the use of knowledge resources other than those teachers suggested may cause some challenges in ePBL.

In this sense, VMs can be used not only as a learning setting tools, but they can also be used as information resources solely by providing manipulations to the students. Thus, VMs can allow students to conduct experiments or to simulate procedures or processes. Therefore, this study aimed to combine the potentials of PBL and VMs to determine the efficacy of the ePBL instructional practices. The differences in this study are the provision of a learning environment enriched with

VMs so the students find information for their projects from the VMs and also the use of VMs to construct new knowledge through their manipulation.

Therefore, this experimental study aimed to evaluate students' learning outcomes of an ePBL environment enriched with VMs for teaching mathematics. The major purposes were:

1. To compare the learning outcomes (achievements and attitudes) of ePBL and traditional PBL environments.
2. To explore students' work and learning as a result of their experiences with the ePBL environment.

Method

Research Design

The study compared learning outcomes of two different PBL environments. Since randomly assigning students to groups was not possible, a quasi-experimental design was used in the study. The study utilized a pre-test/post-test nonequivalent control group design.

Research Sample

One experimental group (EG; N = 30: 14 male, 16 female) and one comparison group (CG; N = 30: 15 male, 15 female) were used in the study. Both of the students in the EG and the CG received a mathematics course from the same teacher in 9th grade. They have only a little introductory knowledge about quadratic equations and polynomials. Thus, their backgrounds about the subjects can be considered similar.

Research Instrument and Procedure

The first step of the study was developing fifteen VMs related to the *Polynomials* (n=6) and *Quadratic Equations* (n=9) subjects of a 10^{th} grade mathematics curriculum. Two mathematics education academicians and two mathematics teachers' reviews were taken to revise the VMs. The objectives for the learning domains used in this study are presented in Table 1.

Table 1

The Learning Domains Used in this study

Learning Domains	Sub domains	Project #
Polynomials	Operations on Polynomials	Project 1
	Division of P(X) to (X – A). (X – B)	Project 1
Quadratic Equations	Solution of Equations which can be transformed in to quadratic equations	Project 2
	Relations among roots of equations and equation coefficient	Project 2
	Forming Quadratic Equations which the roots are given	Project 3

Some example screenshots from the VMs are shown on Figure1.

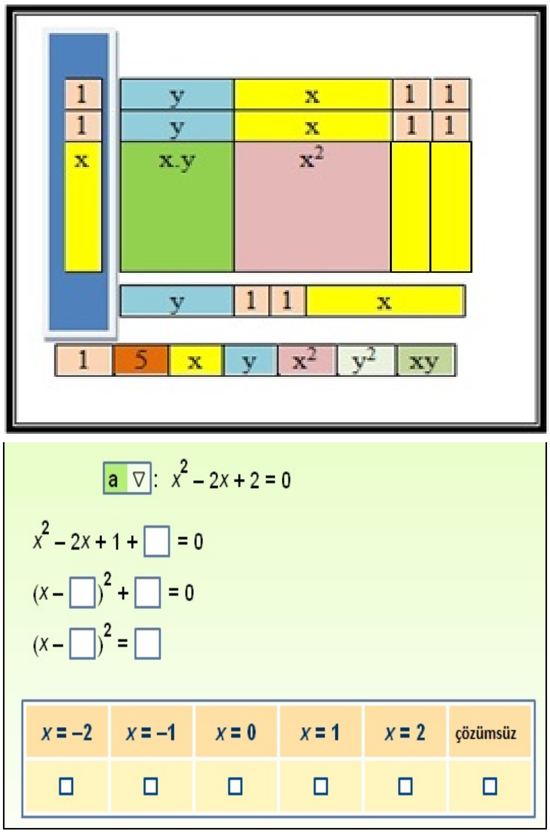

Figure 1. Example VMs used in the projects.

During the first four week process, both the EG and CG received the same lessons from the same teacher using a traditional method. The traditional teaching method was teacher-centered and included discussions in which the subjects were presented by or discussed with the instructor. The teaching materials were traditional mathematics materials, and knowledge was transmitted to students generally by writing on a board or presenting from a projector. The teacher provided the facts and presented some new concepts in this period. Before the experimental study, the researcher gave some information about VMs to the teacher so she gained experienced in using VMs, and she developed an idea about how to use them for PBL.

After four weeks, both the EG and CG groups received three projects about Polynomials and Quadratic Equations subjects. Two weeks for each project (6 weeks in total) were provided for the students. In two groups during the project process, the teacher delivered only short explanations about the projects. In the EG setting, to the teacher recommended that students use VMs for projects. She explained to the EG students how to use the VMs in projects. Both the EG and CG students worked in groups of three students. In the EG and CG groups, most of the students were provided with almost all of the typical PBL stages. After the problem statement was given by the teacher; students tried to identify the information needed to understand the problem, find resources to gather information, generate possible solutions, and analyze the solutions. After completing the projects, both ePBL and traditional PBL groups presented their projects in the classroom. In both the EG and CG, the teacher gave the problems and evaluated the solutions in the classroom. Only the EG students used VMs in gathering information and in doing experiments to solve problems. In addition, both in the EG and CG, the teacher observed member behaviors in the groups, data they found, the method of doing the experiments, or the interaction of group members during the process. She did not allow students to interact across groups. She asked the EG students to write how they acted in using VMs while they were dealing with the projects.

During the intervention EG students could directly use VMs to solve two problems. One of the problems was about using algebra tiles in polynomials, and the other was related to degree of polynomials (Project 1.3). They referred to three different VMs that included concepts and procedures in order to complete Project 1.2. Students could enter the parameters related to the operations on polynomials. Project 2 was about the objective of "Relations among roots of equations and equation coefficient." In this sense, students practiced on three other VMs forming quadratic equations, identifying the factors of x and y. They provided solutions for Project 2.1 and Project 2.2 by using experiences they gained from these three VMs. The details of the projects and the selected correct answers for the projects are shown in Appendix 1.

In the CG, students were not aware of the VMs repository. They were told to complete projects, such as completing traditional homework, by performing research on the internet, by referring to teachers' notes, and by reading text books. They found various examples and used them to develop interpretations about the solutions for the problems in the projects. In addition, they used wiki, forums, and some web sites specialized for school mathematics.

Validity and Reliability

An Achievement Test (AT) was administered to EG and CG students. The test included 25 items about the learning outcomes regarding the polynomials and quadratic equations sub-learning domains. It was developed through the opinions of three field experts. The distributions of the item weights were determined according to the learning outcomes by using a table of specifications. The reliability of the test was calculated (α=0.81) by administering the test as a pilot study in two other ($n1$=36, $n2$=35) 10th grade students. The students' responses were evaluated over 100 points.

The changes in students' attitudes were measured by the Mathematics Attitude Questionnaire (MAQ) by administering it at the beginning and at the end of the study. The MAQ was developed and validated by Duatepe and Çilesiz (1999). The questionnaire consists of 38 items related to students' opinions about their mathematics courses. It has been used in similar research studies to determine attitude changes towards mathematics (Çakıroğlu, 2010; Tekerek, Yeniterzi, & Ercan, 2011). To examine the students' attitudes, the ratings of the respondents were determined on a five-point Likert-type scale ranging from strongly disagree (1) to strongly agree (5). In addition, 8 selected students from the EG were interviewed to explore their work and learning as a result of their experiences in the ePBL environment. In interviews, most of the questions posed to the participants were similar; some extra questions related to respondent answers were asked as well.

Data Analysis

The findings were coded thematically, and the themes and frequencies are presented. The themes were interpreted and utilized to elaborate upon the quantitative data regarding changes in both achievement and attitude. The web statistics were also used to determine the users and use rates of VMs for the projects.

Results

The quantitative and qualitative data is analyzed for determining both the changes in academical achievements and attitudes and exploring the students experiences.

Comparison of Academic Achievements and Attitudes

Changes in academic achievements

The independent t-test results on pre-test scores (t(58)= -0.830; p= 0.410) show that there was no significant difference among the mean scores of the groups. The averages of pre-test scores were close to each other (EG(M= 40.4; SD= 10.41 and CG (M= 42.43; SD= 11.37)). This reflects the similar backgrounds of the students in the EG and in the CG before the intervention. According to the independent t-test results, a statistically significant difference between the mean scores of post-tests of EG (M= 60.20; SD= 13.88) and CG (M= 50.60; SD= 11.78) students was found ($t_{(58)}$= 2.88; p= 0.005) at the 0.05 level of significance. The result points out the students in the EG who received projects in ePBL were outperformed students in the CG. Table 2 summarizes the pre-test and post-test statistical results in the EG and in the CG.

Table 2

T-Test Results on Pre-test (AT) Scores of Students in the EG and in the CG

Tests	*Group*	*n*	*M*	*SD*	*df*	*T*	*p*
Pretest	EG	30	40.40	10.41	58	-.830	.410
	CG	30	42.73	11.37			
Posttest	EG	30	60.20	13.88	58	2.88	.005
	CG	30	50.60	11.78			

The effect of treatment on student achievements in the EG and CG was examined by a paired-samples t-test as illustrated on Table 3.

Table 3

T-Test Results for Pre-test and Post-test Scores in the EG and CG

Group	*Test*	*n*	*M*	*SD*	*df*	*t*	*p*
EG	Pre-test	30	40.4	10.41	29	-9.54	.000
	Post-test	30	60.2	13.88			
CG	Pre-test	30	42.73	11.37	29	-4.89	.000
	Post-test	30	50.60	11.78			

There was a significant difference in the mean scores in the EG for the pre-test (M= 40.4; SD= 10.41) and for the post-test (M: 60.2; SD= 13.88), and a significant difference exits in the means scores in the CG for the pre-test (M: 42.73; SD=11.37) and post-test (M= 50.6; SD= 11.78). This result reflects that both ePBL and traditional PBL treatments provided a positive effect on achievements.

Changes in attitudes

The mean scores come from the EG, and the CG attitude scales were analyzed by an independent samples t-test for two groups. The results of the t-test are shown in Table 5.

Table 5

T-Test Results on Pre-attitude Scale Scores of the EG and the CG

Scale	*Group*	*n*	*M*	*SD*	*df*	*t*	*p*
Pre- Attitude	EG	30	3.18	.85	58	.73	.46
	CG	30	3.03	.72			
Post- Attitude	EG	30	3.53	.74	58	1.70	.093
	CG	30	3.21	.72			

According to the independent t-test results, there was no statistically significant difference between the groups in the mean scores of pre-attitude scale (($t_{(58)}$= -0.73; p= 0.46) at the 0.05 level of significance). Also, after the intervention, no significant difference occurred among the EG and the CG [$t(58) = 1.70$, $p < .05$]. The influence of VMs to the students' attitudes in the EG and the CG was determined by a paired-samples t-test presented in Table 6.

Table 6

T-Test Results for Pre-attitude and Post-attitude Scale Scores in EG

Groups	Scale	n	M	SD	df	t	p
EG	Pre-attitude scale	30	3.18	.85	29	-4.04	.000
	Post-attitude scale	30	3.53	.74			
CG	Pre-attitude scale	30	3.03	.72	29	-2.7	.01
	Post-attitude scale	30	3.21	.72			

The results showed that a significant difference occurred for both EG and CG in the means for pre-attitude and post-attitude scores. For the EG: (M= 3.18; SD= .85 and M= 3.53, SD= 0.74); [$t_{(29)}$= -4.04, p<.05]. For the CG: (M= 3.03; SD= 0.72 and M= 3.21; S= 0.72); [$t_{(29)}$= -2.77, p< .05]. These results reflect that both the EG and CG students had positive attitudes after the projects. In sum, with the treatment, students in the EG had better performance compared with those in the CG, and in both the CG and the EG, the resulting attitudes after treatment were positive.

Work and Experiences of Participants

Web records. The web records shown in Table 9 were used as quantitative data for interpreting the support of VMs in achievement and attitude changes.

Table 9

Web Records to Interpret the Support of VMs

VM#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sub Domain	P1	P1	P2	P2, P3	P3	P3	Q1	Q1, Q2	Q2	Q2, Q3	Q2, Q3	Q2, Q3	Q3	Q1	Q3
Problems Used	1.1, 1.2	1.1	1.2, 1.3	1.2, 1.3	1.3	1.2 , 1.3	2.1	2.1, 2.2	2.2	2.2, 2.3	2.2, 2.3	2.2, 2.3	2.2, 2.3	3.1,	3.1,
Frequency	24	20	18	19	28	18	23	28	25	17	19	27	24	22	25

As shown on Table 9, all of the VMs are used in the EG for all projects in which the usage frequency is between 17 and 28. VM5 was most frequently preferred in doing Project 1. VM8, VM9, and VM12 were the most commonly used for studying on Project 2. VM14 and VM15 had similar usage rates for Project 3.

The data from the web statistics was used to choose eight participants to interview. Two of the eight students were below the average, four of them were at the average, and two were selected from students above the average. The questions posed to them were chosen considering their VM usage rates. The interviews generally included inquiry into how they benefited from VMs, behaviors during VM use, contributions of VMs on solving problems, and understanding concepts in projects. The responses of students were coded thematically, and the themes are listed in Table 8.

Table 8

The Interview Theme

Theme		Sub-Theme	*f*
Enhancing learning	Pos.	Understanding better	8
		Learning quickly	7
		Learning permanence	2
		Correcting misunderstandings	5
	Neg.	Proceeding Slowly	1
Attitude toward course	Pos.	Not feeling embarrassed	8
		Enjoy the course	8
		Interested in course	7
		Well motivated	8
		Spending too much time studying mathematics	6
	Neg.	Similar examples on projects	7
		Get tired	2
		Get stressed	6
		Distracted attention	1
		Anxiety about exams	5
Behaviors during the course	Pos.	Intensify the previous subjects	8
		Learn from mistakes	6
		Feel independent from teacher	6
		Take self responsibility in the course	7
	Neg.	Not enough time to do projects	3
Other		Technical problems	2

Pos: Positive, Neg: Negative

Enhancing learning. In this section, some responses that illustrate the main themes and ideas are selected from the interviews.

> Q: How can you describe the learning environment you met while working on the projects?
>
> Selected responses:
>
> S6: This site proved to be very useful for working on projects. It is difficult to find a large amount material together elsewhere. I have studied hard to complete the projects. I think the projects were beneficial for me and have given me good knowledge. The tasks in the problems have played an important role in my understanding.
>
> S8: I corrected some of my mistakes with regard to quadratic equations. Also, it was useful to understand the daily use of mathematical subjects. However, I would have liked to see some examples related to the exams here.

The opinions of S6 and S8 specify that an ePBL environment may be useful to enhance learning in permanency, correcting previous mistakes, and remedying the misconceptions by associating to the previous and the present knowledge. S8 identified the limitation of exam questions in VMs.

Attitude towards the course. In this section, responses that outline attitudes toward the course are selected.

> Q: While doing your projects, which activities did you enjoy or dislike? Please explain the reasons?
>
> S7: I believe all of the projects should be in this format. Before the projects, on occasions I did not understand why we need to learn certain subjects. However, I found the web made the studying of the projects very enjoyable.
>
> S6: Overall, it was a good experience, but I think some activities took a lot of time; sometimes there were similar problems which appeared to be repetitive.
>
> Q: What were the main differences between projects with VMs and your previous projects?
>
> S1: Here online, I don't see the teacher near me; it is very good for me. Because sometimes I forget what I will do when she is near me.
>
> S3: Course was not so difficult with the projects. I can say I felt very comfortable.
>
> S5: Sometimes the VMs were a teacher for me; I took quick feedbacks, and these feedbacks were very useful for completing the projects.

It was seen that participants stated feeling comfortable with independence from the teacher and they felt comfortable learning from mistakes.

Discusssion and Conclusions

In the study, the students' roles in the ePBL environment were almost similar to the students' roles of PBL in classroom. (Krajcik et al., 1994). The main roles of students in PBL may be summarized in Figure 2.

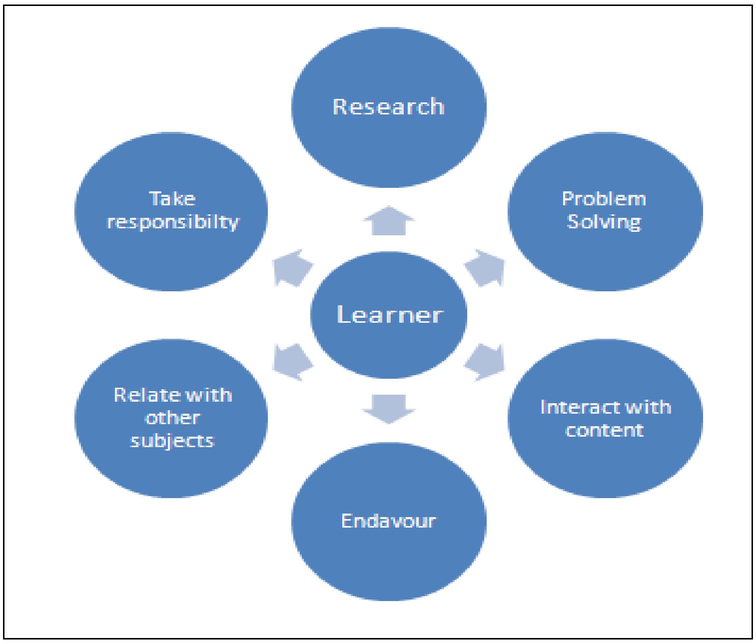

Figure 2. Students' roles in PBL settings.

In the study, students in the EG were not delivered the acquisitions directly; they were expected to explore the concepts while working on the VMs. In the ePBL environment, a number of students could benefit from VMs in order to solve the problems and construct new knowledge. Thus, in the research phase, students found the VMs that they needed to understand concepts and solve problems. In the problem solving phase, students tried to develop solutions for the problems. During this process they worked on the activities of VMs by manipulating parameters or other tools related to the problem. The nature of the projects determined that participants were responsible for research, trying alternatives, and finding the best solutions for the problems on VMs. It was a real endeavor for students to work on the VMs for the first time. The activities were related to different outcomes so they needed to work on more than one VM in order to perform the requirements. So, in the ePBL environment, students could construct new knowledge by building on their current knowledge through interactions with the VMs. This also refers to the constructivist theory that learners construct knowledge through activities and their learning based on experiences (Hernández-Ramos & Paz, 2010). These results suggest that ePBL enriched with VMs does have a more positive effect on academic achievements than traditional PBL activities. In an ePBL environment, manipulating parameters, changing the figures on the activities, separating the shapes into segments, or joining the segments helped students to explore mathematical concepts and to solve problems.

There was no significant difference in the post-attitude scores for ePBL and PBL environments. One reason may be that both of the two group students did not have previous experience in projects that include all phases of the PBL. This was the first time they worked intensively on gathering information, discussing, making different predictions, making plans for solutions or experiments, or trying experiments. The point to be emphasized is that ePBL environments allow students to take pleasure in and take interest in working on projects using VMs. In both traditional PBL and ePBL groups, achievement and attitude scale scores had improved during the treatment. In this sense the idea of McGreal (2004), which is about learning with ePBL, can offer huge opportunities to access and act on much knowledge, and information supports the results of this research.

Students in the ePBL group enjoyed and were interested in working on VMs in the ePBL environment. They did not feel embarrassed. Also, the ePBL environment encouraged them to take responsibilities on their own learning and improved their abilities to do so. Taking their own responsibility may support them in completing their projects. Besides, there were some factors that influenced student attitudes towards mathematics courses. The students indicated that sometimes they got tired and got stressed about not being able to bring up the projects in the limited given time. Also, a few students explained that their attention grew distracted sometimes on the Internet. These kinds of responses were parallel to the results of some other web based PBL applications (Lee, 2001; Steen et al., 2006). As Hakkarainen (2009) emphasized, ePBL offers a good model to support students' knowledge and skills, and students will benefit from learning with and about technology. In addition, another study has presented that both academic achievements and attitudes were positively changed (Morgil et al., 2008). Muller, Buteau, Ralph, and Mgombelo (2009) focused on students' projects in which they developed and implemented their own VMs, and they observed that students also have dedication, pride, and ownership in their mathematical work. In another work about VMs, Salajan et al. (2009) found that the visual and interactive activities had the potential to induce positive outcomes in mediating the students' conceptualization of difficult theoretical notions. In spite of the fact that there are some similarities in the results of this study and other ePBL studies, the main difference is that, in those studies, VMs did not a play key role in the ePBL environment.

In addition, the study has some limitations. The style of teaching in two environments might have little influence on achievements. The teacher sometimes thought that students in the EG could have some technical problems in using VMs, so she may have spent more time for the EG students. The traditional teaching in both the EG and the CG in the first four weeks of the study may have provided positive impact in improving the achievements. Besides, in both the EG and in the CG, the basic variables (subject, time, teacher) were the same, so this influence can be considered unremarkable.

Ultimately, researchers have come to an agreement that students learn best through a PBL approach in which they are able to explore knowledge with the advantage of technological tools (Blumenfeld et al. 1991; Linn et al., 2000). This study put forward some evidence that the potential of VMs may be considered in the context of these kinds of technological tools.

In this study a PBL environment enriched by combining the potentials of VMs and PBL was explored. Students enjoyed working with VMs and found the activities interesting and helpful for understanding concepts and solving problems. This paper provided hints that students may benefit from working with VMs in a PBL environment, just as they do in traditional PBL settings. In this sense, some of the major conclusions of the study are:

- The VMs in parallel with the curricula make it possible to develop projects and use them in PBL settings.
- The appropriate projects enriched with VMs may have positive effects on achievements and attitudes in mathematics classrooms. In order to develop good projects, repetitions in activities should not be allowed, and the duration of the projects should be tailored.
- It is not easy to prepare projects with VMs, so teachers should be encouraged to use VMs. Also, both the quality and the quantity of VMs must be adequate.
- Well-designed technological infrastructure is important for the success of ePBL environments.

In the current study, only one teacher's experiences with VMs in an ePBL environment were discussed. In future work, multiple teachers' perceptions should be investigated to determine the use of VMs in various contexts. Although in this study the data about academic achievements was collected with only test items and web statistics, this did not provide an opportunity to elaborate on the conceptual understanding. So, other data collection instruments like clinical interviews and open-ended questions may be required in future works.

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Proje Tabanlı Öğrenme Ortamlarının Sanal Manipülatifler ile Zenginleştirilmesi: Karşılaştırmalı bir Çalışma

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Özet

Problem Durumu

Yapılan araştırmalarda öğretmenler ve araştırmacıların projeler üzerinde çalışmanın öğrenciler için öğrenmeyi kolaylaştırıcı ve geliştirici bir potansiyele sahip olduğu yönünde düşünceleri olduğu ortaya koyulmaktadır. Bunun yanında web teknolojilerinin de öğrencilerin üst düzey düşünme yeteneklerini destekleyici araçlar olarak değerlendirildiği bilinmektedir. Bu çerçevede proje tabanlı öğrenme (PTÖ) ve çevrimiçi öğrenmenin potansiyellerini birleştirerek sunmaya çalışan yeni bir yaklaşım olarak, çevrimiçi proje tabanlı öğrenme (ePTÖ) yaklaşımı gelişmeye başlamıştır. ePTÖ ortamlarında akademik başarıyı arttıran önemli faktörlerden birisi öğrenci ile içerik etkileşimi olarak gösterilmektedir. Bu çerçevede etkileşimli öğrenme ortamları tasarımında kullanışlı araçlardan birisi olarak sanal manipulatifler (SM) dikkat çekmektedir. Birçok çalışmada SM tabanlı web araçları, öğrencilerin öğrenmelerini yapılandırmacı yaklaşım çerçevesinde geliştirebileceği yönünde sonuçlar yer almaktadır. Nitekim SM'lerin ve PTÖ'nün olumlu etkilerine yönelik bir uzlaşma söz konusu olsa da her ikisinin de potansiyellerinin kullanıldıkları bağlama göre değişebilir olduğu açıktır. Bütün bunlarla birlikte, SM'lerin ve çevrimiçi PTÖ ortamlarının potansiyellerini tam olarak ortaya koyacak kanıtlara hala ihtiyaç vardır. Bu bağlamda bu çalışmada, SM'lerin çevrimiçi PTÖ ortamlarında kullanılmasının öğrenme üzerindeki etkilerini inceleyerek; SM'lerin ve PTÖ'nün potansiyellerinin buluşmasıyla ortaya çıkan öğrenme ortamının potansiyelini değerlendirmeye çalışılmaktadır. Çalışmada öncelikle SM ve PTÖ'nün potansiyelleri ele alınmış, ardından çevrimiçi ortamda SM'ler PTÖ yaklaşımı çerçevesinde öğrencilere sunularak etkileri araştırılmıştır.

Araştırmanın Amacı

Bu araştırmada web ortamında gerçekleştirilen proje tabanlı öğrenme ile geleneksel proje tabanlı öğrenme ortamının akademik başarılar ve matematik dersine yönelik tutumlar üzerindeki etkisi karşılaştırılmaya çalışılmaktadır. Bu doğrultuda bir grubun SM'ler ile çalışmaları istenirken, geleneksel ortamda öğrencilerin internet, ders kitapları vb. gibi geleneksel araştırma yollarını kullanmaları istenmiştir.

Araştırmanın Yöntemi

Araştırma yarı deneysel olarak yürütülmüştür. Deney grubu; 14 kız, 16 erkek öğrenciden oluşurken, kontrol grubu; 15 kız, 15 erkek öğrenciden oluşmaktadır. Öncelikle 10. sınıf matematik dersi konularından polinomlar ve 2. derece denklemler

konularının kazanımlarına yönelik SM'ler hazırlanarak bir web sitesine aktarılmıştır. İlgili konular, çalışma süresince deney ve kontrol gruplarının her ikisine de geleneksel yollarla aynı öğretmen tarafından anlatılmıştır. Dört hafta sonunda öğrencilere bu iki konu ile ilgili üçer adet proje verilmiş, öğrencilerin deney ve kontrol gruplarında farklı şekilde projeleri aynı sürede yapmaları planlanmıştır. Deney gurubu öğrencileri projeleri yaparken çevrimçi ortamdaki SM'lerden yararlanmaları şeklinde yönlendirilirken; kontrol grubu öğrencilerinin aynı projeleri geleneksel ödevleri yapar gibi, internet, kütüphane, ders kitapları vb. kaynaklardan araştırarak yapmaları istenmiştir. Projelere başlamadan önce deney grubunda öğretmen öğrencilere projeleri yaparken SM'lerden nasıl yararlanacakları yönünde açıklamalar yapmıştır.

Farklı iki PTÖ ortamında akademik başarılardaki değişimdeki etkilerini belirlemek için çalışma başında ilgili konulara yönelik ön testler, çalışma sonunda ise son test uygulanmıştır. Matematik dersine yönelik tutumlardaki değişimleri ortaya koymak amacı çalışma başında ve sonunda Matematiğe Yönelik Tutum Anketi uygulanmıştır. Ayrıca deney grubu öğrencileri arasından seçilen sekiz öğrenci ile mülakat gerçekleştirilerek, SM'leri kullanımları süresince yaşadıkları deneyim ortaya konulmaya çalışmıştır. Bununla birlikte SM'lerin projelerdeki kullanım durumunu belirlemek için web sitesindeki kayıtlardan yararlanılmıştır.

Araştırmanın Bulguları

Her iki grubun ön testlerden aldıkları puanlar bağımsız t-testi ile analiz edildiğinde çalışma başlangıcında gruplar arasında anlamlı bir fark olmadığı görülmüştür ($t_{(58)} =$ -0.830; p= 0.410). Grupların son test puanları arasında yapılan bağımsız t-testi sonucunda gruplar arasında deney grubu lehine anlamlı farklılık bulunmuştur. Deney Grubu (M= 60.20; SD=13.88) ve Kontrol Grubu (M=50.60; SD= 11.78) , ($t_{(58)}$= 2.88; p=0.005). Kontrol grubu öğrencilerinin akademik başarılarına yönelik ön test puanları ile, son test puanları arasında anlamlı farklılık bulunurken ($t_{(29)}$= -4.89; p= 0.000), deney grubu öğrencilerinin de ön test ve son test puanları bağımlı t testi ile analiz edildiğinde son testler lehine anlamlı bir farklılık görülmüştür. Çalışma öncesinde iki gruptaki öğrencilerin ilgili konulardaki ön bilgileri arasında anlamlı farklılık yokken, çalışma sonunda akademik başarılar arasında oluşan anlamlı farkın; deney grubuna yapılan müdahaleden kaynaklandığı görülmektedir. Ancak deney grubunda SM'lerin kullanılması matematik dersine yönelik tutumlarda deney ve kontrol grubu arasında anlamlı fark oluşturmamıştır. SM'lerin çevrimiçi PTÖ'de akademik başarı ve tutumlara etkisini derinlemesine ortaya koyabilmek için nicel veriler yanında deney grubundan rastgele seçilen 8 öğrenci ile mülakatlar yapılmıştır. Bu öğrencilerle yapılan mülakatlar analiz edildiğinde öğrenmeyi destekleme, derse yönelik tutum, dersin işlenişi gibi temalar ortaya çıkmış, bu temalarda öğrencilerin genel olarak olumlu düşünceler geliştirdikleri belirlenmiştir.

Araştırmanın Sonuçları ve Önerileri

Bu çalışma ile çevrimiçi PTÖ'nün geleneksel PTÖ'nün temel aldığı yapılandırmacı yaklaşımın farklı bileşenlerini içerdiği görülmektedir. Nitekim araştırma, problem çözme, içerik ile etkileşim, sorumluluk alma, diğer konular ile ilişkilendirme ve projeyi tamamlama için gayret etme gibi PTÖ bileşenlerinin çevrim içi PTÖ ortamında çalışan öğrenciler tarafından da gerçekleştirildiği görülmüştür. Ayrıca SM'lerin web ortamında yapılacak PTÖ uygulamaları için önemli araçlar olabileceği belirlenmiştir. Öğrenciler bu tür ortamlardan geleneksel PTÖ ortamları kadar faydalanabilmişlerdir. SM'ler ile desteklenen web ortamının potansiyelinin oluşan yeni öğrenme ortamını geliştirmek için ayrı bir katalizör görevi gördüğü söylenebilir. Bu ile öğrencilere yapılan test ile akademik başarıları belirlenmiştir. Gelecek çalışmalarda SM'lerin kavramsal anlamalar üzerindeki etkilerini belirlemek amacıyla açık uçlu sorular içeren testler ve klinik mülakatlar gerçekleştirilebilir.

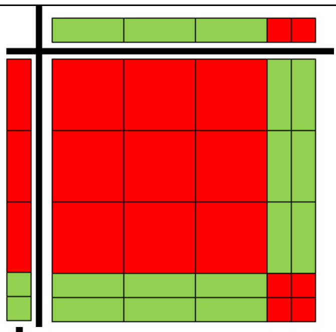
Anahtar Sözcükler: Sanal manipülatifler, proje tabanlı öğrenme, web tabanlı öğrenme, matematik öğretimi

Appendix 1. Selected problems from projects

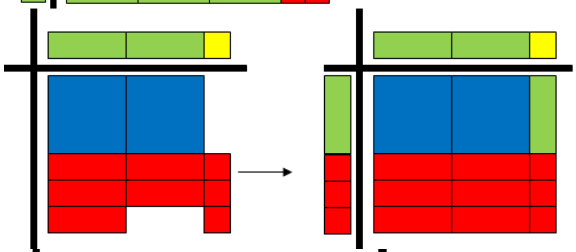
Projects Domain	Problems
Polynomials	1. *Show the problems with algebra tiles and simplify the result polynomial.*
Project 1.1.	a) (3x+2).(3x-2) =? b) $(2x^2-5x-3)/(2x+1)=?$ c) $(6x^2+x-1)/(2x+1)=?$ …
Project 1.2.	The difference of volumes of rectangular prism and a cube of are requested. A length of the one dimension of the cube (X) is 1 unit smaller than the smallest dimension of rectangular prism and the other dimension is 1 unit greater than the smallest dimension. The third dimension is … Develop a polynomial to find differences between rectangular prism and a cube Find the value of X (X<5) which makes this difference minimum?
Project 1.3.	Develop 2 polynomials having 3 terms in which the degree of P(x)*Q(x) is 14 and the degree of P(x)/Q(x). Find the sum of P(x) and Q(x) polynomials (b<a) for x=1 value.
Project 2.1.	A football stadium director knows that if he charges 10TL per accommodation, the team could count with 5000 visitors. He also knows that if he makes 1TL of discount he would have 200 visitors more. Make a model for the money earned from the visitors.
Project 3.1.	The roots for the x2-4x+3 equations is x1, x2. Develop a quadratic equation which has the roots having values two more.

Some Selected Answers from Projects

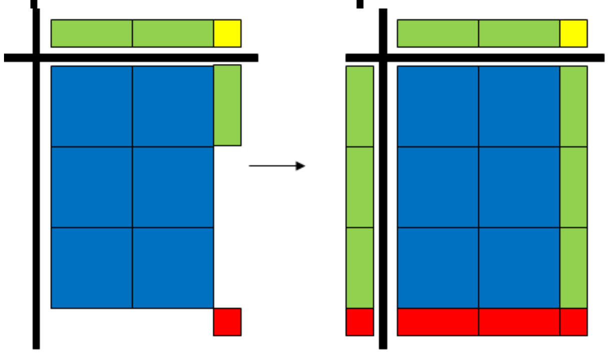
1.1.a. (3x+2).(3x-2) $=9x^2-4$



1.1.b. $(2x^2-5x-3)/(2x+1)= x-3$



1.1.c. $(6x^2+x-1)/(2x+1) =3x-1$



1.2. Rectangular prism: VR=(x+1)*(x+2)*2*(x+2)-3

Cube: VC=x*x*x

VR-VC= x3+7x2+7x+2 (has minimum value for 1)

1.3. a+b=13, a-b=5, a=9, b=4,

P(x)=4x9-2x2+5, Q(x)=3x4+3x2-6 P(x)+Q(x)= 4x9+3x4 + x2-1, P(1)+Q(1)=7

2.1. Price=10-x (where x are the amount of money reduced from the original price)
Visitors=5000+200x(first 5000 and then a hundred for each dollar of reduction)
Money earned = price * visitors
M(x)=(10-x)(5000+200x)= -200 x2 + 50000-5000x

3.1. x1=3, x2=1 (x-5)(x-3)= x2-8x+15