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Investigation of Project-Based Learning Method in Teaching Programming in terms of Academic Achievement, Cognitive Load and Behavior Change1

Fatma UCA ÖZTÜRK[2]

Çanakkale Onsekiz Mart University

Muzaffer ÖZDEMİR[2]

Çanakkale Onsekiz Mart University

Durmuş ÖZBAŞI[3]

Çanakkale Onsekiz Mart University

Abstract

This study aims to reveal how project-based teaching method affects students' achievement, cognitive load and behaviors in programming teaching. In the study, the pretest-posttest, unequaled control group quasi-experimental model, which is one of the experimental models, was used. The participants of the study were sixth grade students who take the elementary school Information Technologies and Software lesson (N = 55). Achievement test, cognitive load scale and behavior management tool ClassDojo were used as data collection tools in the study. In the experimental group, the subjects were taught with project-based teaching method (student-centered and with teacher guidance). Besides, subjects in the control group were taught with traditional teaching method (teacher-centered). The implementation process took six weeks. Two-Factor ANOVA for Mixed Measures was used to examine the difference between the achievement of the groups. At the end of each lesson, the cognitive load scale was applied to the groups and the data obtained was analyzed by using the Cramer V Coefficient. During the study, the students got positive and negative scores according to their behaviors in the classroom, and the significance of the difference between the two percentages was tested according to their positive behavior percentages. As a result of the study, it was found that the academic achievement and in-class behavior scores of students who learned programming with project-based teaching method differed significantly from those who learned with the traditional method. In addition, it was concluded that project-based teaching method used in programming education did not make a significant difference on students' cognitive load.

Keywords: Academic Achievement, ClassDojo, Behavior Management, Programming Education, Project-Based Learning.

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[1]MSc., Faculty of Education, Çanakkale Onsekiz Mart University, Çanakkale, Turkey, ORCID: 0000-0002-4395-9698 **Correspondence**: fatmauca35@gmail.com

[2]Assoc. Prof. Dr., Faculty of Education, Çanakkale Onsekiz Mart University, Çanakkale, Turkey, ORCID: 0000-0002-5490-238X, Email: mozdemir@comu.edu.tr

[3]Assoc. Prof. Dr., Faculty of Education, Çanakkale Onsekiz Mart University, Çanakkale, Turkey, ORCID: 0000-0001-5078-477X, Email: dozbasi@comu.edu.tr

Introduction

Programming education has a great importance in making individuals acquire problem solving and algorithmic thinking, which are among 21st century skills (Çatlak, Tekdal, & Baz, 2015). It can be said that students who receive effective programming education can improve their problem solving, algorithmic and computational thinking skills at a good level. In addition, programming contributes to the development of students' skills such as logical and critical thinking. Kert and Uğraş (2009) argue that programming education should start at an early age, considering its contribution to individual development. Visual coding tools are useful in terms of facilitating learning for programming education that begins at an early age. Researchers have listed some of these benefits as follows (Akpınar & Altun, 2014; Demirer & Sak, 2016; Karabak & Güneş, 2013):

- Students can improve their computer literacy by using coding tools,
- It can increase their desire towards school and classes,
- It improves their problem solving and analytical thinking skills,
- It improves spatial thinking skills,
- They can design a product as a project and learn how to play a role in solving challenging problems,
- It improves cooperative working skills,
- It develops learning habits by doing and experiencing.

Programming education beginning at primary school age begins with block-based programming environments. The aim here is not for the student to write a program using syntaxes, but to build the algorithmic structure of the program using visual programming elements (Kaucic & Asic, 2011; Shu, 1999). Today, the most well-known visual programming environments are Scratch, Alice and Blocky (Powers et al., 2006). The fact that the interface of Scratch is user-friendly and that it appeals to the 8-16 age group and the beginners of programming, as well as its ability to embody abstract programming concepts enable students to learn programming by having fun (Yiğit, 2016). For this reason, Scratch, which is suitable for students over 7 years old, was chosen for programming teaching in the study.

The Challenges of Learning Programming

Incorrect practices in programming teaching methods that should be given to students from an early age also bring some difficulties (Çatlak, Tekdal, & Baz, 2015; İmal & Eser, 2009). One of these prominent difficulties is the lack of algorithmic thinking skills of students (Futschek, 2006). Since students who have not developed algorithmic thinking skills have difficulty in understanding algorithms (Futschek & Moschitz, 2010), it is very important to develop these skills before beginning to learn programming language (Ala-Mutka, 2004).

The reasons for the difficulties students experience in learning programming can be listed as; (a) the necessity of having more than one knowledge and skill (knowledge of foreign languages and algorithms, logical and mathematical thinking) during programming (Mannila, Peltomaki, & Salakoski, 2006); (b) the lack of motivation (Gomes & Mendes, 2007); (c) the low self-efficacy beliefs of students towards programming learning (Korkmaz, 2013); (d) students' negative attitudes towards programming (Anastasiadou & Karakos, 2011; Farkas & Murthy, 2005; Korkmaz & Altun, 2013; Özyurt & Özyurt, 2015); and (e) ineffectiveness of traditional teaching methods for teaching/learning programming (Askar & Davenport, 2009; Byrne & Lyons, 2001; Cevahir & Özdemir, 2017; Futschek, 2006).

Project-based Learning Method in Programming Education

Programming taught with traditional teaching methods is usually teacher-centered and students cannot be active while learning with these methods.

However, one of the constructivist methods, project-based teaching, is student-centered and can lead students to higher levels of thinking. Besides, it directs students to research and help them find solutions to important problems by working collaboratively.

Many studies have reached a consensus on the fact that project-based learning improves the knowledge and skills of students in problem solving (Albanese & Mitchell, 1993; Dabbagh & Denisar, 2005; Strobel & Van Barneveld, 2009). In this context, it is significant to examine the effect of project-based learning method on programming education.

Cognitive Load and Programming Education

Cognitive load theory emphasizes that we have a short-term memory with a limited capacity to cope with information, encountered for the first time and which is not in long-term memory (Paas, Renkl, & Sweller, 2004). It is known that the data that short-term memory can store is limited (Zhang & Wang, 2009), and the individual's learning action ends in case of excessive cognitive load (Pass et al., 2004). Some researchers have suggested that it is difficult to reduce cognitive load in the programming learning process (Mead et al., 2006; Renkl & Atkinson, 2003; Stachel et al., 2013). Mason, Cooper, and Wilks (2015) reported that some programming environments are complex and increase cognitive load. Therefore, the teaching process should be organized in a way to reduce the burden on working memory. It is thought that project-based learning can speed up information processing of students and can be beneficial in terms of not being overloaded cognitively. Thus, in this context, achievement and cognitive load of students are important variables in determining the efficiency of project-based learning method (Clark, Nguyen, & Sweller, 2011).

Behavior Management in Project-Based Learning

Leading a classroom effectively determines the level of a teacher's performance. If teachers do not have good classroom management, their classroom can be full of confusion and chaos, and learning can be difficult for students. There is the possibility of chaos and confusion in a classroom which is managed ineffectively and this may cause difficulty for students.

According to Barbetta, Norona, and Bicard (2005), "As teachers, one of our main responsibilities is to help our students learn. Learning is difficult in chaotic environments." Ward (2015) states that effective classroom management plays an influential role in the behavior of all students while performing a task. Accordingly, it can be said that learning will be easier and negative behaviors may decrease when students work on a task in a classroom in which a project-based learning method is applied.

Purpose of the Study

The aim of this study is to investigate the effect of programming teaching performed with project-based learning on students' achievement, cognitive load and their behaviors. Accordingly, answers to the following questions are investigated in the current study;

In programming teaching;

1. Do students' academic achievement differ significantly when they are exposed to project-based learning or traditional teaching?
2. Do students' cognitive load differ significantly when they are exposed to project-based learning or traditional teaching?
3. Do students' in-class behaviors differ significantly when they are exposed to project-based learning or traditional teaching?

Method

Participants of Study

The participants of the study (N=55) consist of sixth grade elementary school students who took the "Information Technologies and Software" course in the second semester of the 2017-2018 academic year. It was randomly decided which class would be the experimental (N=29) and which would be the control group (N=26).

Table 1. Demographic Characteristics of Participants

	Experimental Group	Control Group
Female	17	16
Male	12	10
Total	29	26

Research Design

In the study, a quasi-experimental model with pre-test and post-test unequaled control groups (Karasar, 2017) was used. The research design of the study and the tools for data collection are presented in Table 2. An academic achievement test was applied to both groups as a pre-test. Project-based learning was used in the experimental group while traditional teaching method was used in the control group. During the implementation process, a scale measuring cognitive load was applied to both groups and the behaviors of the students were observed. Finally, the academic achievement test was reapplied to both groups as a post-test.

Data Collection Tools

In this study, The Scratch Academic Achievement Test prepared by Yüksel (2017) was used. There are 28 multiple choice questions in the achievement test. KR-20 reliability coefficient of the achievement test is 0.8, the average difficulty is 0.70 and the average discrimination power is 0.33.

Cognitive load scale developed by Paas and Van Merrienber (1993) which was adapted to Turkish by Kılıç and Karadeniz (2004) was used to measure the cognitive effort of students (to measure the level of cognitive difficulty). The Cronbach Alpha internal consistency coefficient of the scale is 0.78 and the Spearman Brown split half-test correlation is 0.79. The likert scale is a 9-point scale. The scale, which consists of a single item, measures how much effort the learners make while performing a task or work. The cognitive load scale was applied to the students at the end of each lesson during the implementation process.

How project-based learning method would cause a change in the positive and negative behaviors of students was measured with ClassDojo. Which positive and negative behaviors should be observed in the classroom and how many points should be given in each behavior were decided by examining the studies in the literature (Maclean-Blevins & Muilenburg, 2013; Saeger, 2017; Turan, Avinc, Kara, & Goktas, 2016; Ward, 2015). Through the implementation, learners got positive points for their positive behaviors and negative points for their negative behaviors. Immediate feedback was given to the behaviors of the students during the lesson on the interactive board via ClassDojo. The behavioral developments of the students were recorded with ClassDojo during the implementation process in both groups.

Table 2. Research Design and Data Collection Tools

Data Collection Tools			
Group	**Before the Implementation**	**During the Implementation**	**After the Implementation**
Experimental Group (Project-Based Learning)	*Academic Achievement Test (Pre-test)	*Observation of Students' Behavior (ClassDojo) *Cognitive Load Scale	*Academic Achievement Test (Post-Test)
Control Group (Traditional Teaching Method)	*Academic Achievement Test (Pre-test)	*Observation of Students' Behaviors (ClassDojo) *Cognitive Load Scale	*Academic Achievement Test (Post-Test)

Data Analysis

SPSS 20.0 (Statistic Package for Social Sciences) program was used to analyze the data of the study. For the first study question, Two-Factor Anova for Mixed Measures was used. This analysis includes two factors; the first factor shows different implementation process conditions (e.g., experimental, control groups), while the second factor is repeated measurements used to describe a change with time (e.g., pretest-posttest) during an implementation (Büyüköztürk, 2016). The first factor of the study includes the experimental group in which project-based learning method was applied to determine the academic achievement of the students and the control group was exposed to the traditional teaching method. On the other hand, the second factor includes pre-test and post-test measurements applied to both study groups.

The data collected with the cognitive load scale is at the classification level. Thus, a nonparametric analysis method was used in the analysis of cognitive load data as suggested by Büyüköztürk (2016). The cognitive burden while students are learning programming with different teaching methods is expressed in nine different dimensions. In cases where two categorical variables have more than two categories, Cramer V coefficient is used to show the change together (Özbaşı, 2009; Özdamar, 2004). Cramer V is an effect size measure for the Chi-Square test of independence. It measures how strongly the two categorical domains are related (IBM, 2019). Therefore, Cramer V coefficient was calculated for the second research question of the study.

Regarding the third research question of the study, the behavior scores obtained through ClassDojo were analyzed.

The significance of the difference between the two percentages was used to test the significance of the difference between positive behavior percentages. Testing the significance of the difference between two percentages is achieved as z value by dividing the difference between the two percentages by the standard error of this difference. The z value can be interpreted as the unit standard deviation in the normal distribution curve. For .05 level of significance, the z value should be equal to or greater than 1.96 (Akhun, 1982).

Results

Findings on the Academic Achievement Test

The average and standard deviation values for the first research question (Do students' academic achievement differ significantly when they are exposed to project-based learning or traditional teaching?) are given in Table 3, and the results of Two-Factor ANOVA for Mixed Measures are given in Table 4.

Table 3. Descriptive Statistics for the Programming Achievements of the Experimental and Control Group Students

	PRE-TEST			POST-TEST		
GROUP	**N**	$\bar{X}$	**S**	**N**	$\bar{X}$	**S**
Experimental Group (project-based learning)	29	12.68	4.17	29	24.89	3.82
Control Group (traditional education)	26	13.30	5.51	26	20.76	3.72

As seen in Table 3, the academic achievement test average score of the students in the experimental group increased from pre-test 12.68 to post-test 24.89. For the students in the control group, this value increased from 13.30 to 20.76. According to these results, an increase in academic achievement was observed in both groups. However, the difference between the pre-test and post-test scores of the students in the experimental group (12.21 points) was higher than that of the students in the control group (7.46 points).

Table 4. The Result of Two-Factor ANOVA Test for Mixed Measures

Source of Variance	Sum of Squares	Sd	Average of Squares	F	p
Inter-subjects	981,854	54			
Group (Experimental/Control)	84,414	1	84,414	4,985	.030
Error	897,440	53	16,933		
Intra-subjects	3915.627	55			
Measurement (Pretest-Posttest)	2651.663	1	2651.663	126,655	.000
Group*Measurement	154,354	1	154,354	7,373	.009
Error	1109.610	53	20,936		
Total	4897.481	109			

In Table 4, it was determined that the academic achievements of two groups (experimental and control) taught with two different teaching methods differed from pre-application to post-application. In other words, the common effects of different treatment groups and repeated measurement factors on academic achievement were significant [F (1-53) = 7.373, p<.05]. Thus, it can be said that the project-based teaching method is more effective than the traditional teaching method in increasing the success of students in programming teaching.

In this study, the effectiveness of only two different teaching methods in increasing academic success in teaching programming was tested. Therefore, the common effect test of group and measurement factors was emphasized. The analysis also includes basic impact tests of the group and measurement. According to the findings obtained from the two basic impact tests, a significant difference was found between the pre-test and post-test scores of the participants who learned with project-based and traditional teaching methods [F (1-53) = 4.985, p<.05]. This test does not consider the change of groups from pre-test to post-test. In addition, regarding the main effect of the measurement, a significant difference was seen between the academic achievement score averages of the participants before and after the application, without group distinction [F (1-36) = 126.655, p<.05]. This finding shows that programming achievements change depending on the teaching methods applied when there is no group discrimination.

Finding on Cognitive Load Measurement

The results of the Cramer V Test regarding the second study question (Do students' cognitive load differ significantly when they are exposed to project-based learning or traditional teaching?) are given in Table 5.

Table 5. Cramer V Test Results

	Value	P
Item 1 (How much effort did you make while learning the concept of linear logic structure?)	.323	.454
Item 2 (How much effort did you make while learning the concept of motion panel?)	.451	.083
Item 3 (How much effort did you make while learning the concept of events panel?)	.221	.846
Item 4 (How much effort did you make while learning the concept of sound panel?)	.418	.143
Item 5 (How much effort did you make while learning the concept of pen panel?)	.466	.102
Item 6 (How much effort did you make while learning the concept of loop structure?)	.372	.269
Item 7 (How much effort did you make while learning the concept of looks panel?)	.320	.464
Item 8 (How much effort did you make while learning the concept of sensing panel?)	.356	.325
Item 9 (How much effort did you make while learning the concept of data panel?)	.337	.397
Item 10 (How much effort did you make while learning the concept of decision structure?)	.527	.018
Item 11 (How much effort did you make while learning the concept of operators panel?)	.449	.135

p<0.05

When the Table 5 is examined, it is seen that the Cramer V value is low and it is not statistically significant. However, Cramer V value for the question (How much effort did you make while learning the concept of decision structure?) asked to the students with item 10 was significant (p <.05). In other words, a significant difference was found between the experimental and control group students in terms of cognitive load for this item. In other words, while the students in the experimental group learned the concept of "decision structures", which is one of the programming subjects, they were less cognitively loaded than the control group.

Finding on the Behavior Change

In search of answers to the third research question (Do students' in-class behaviors differ significantly when they are exposed to project-based learning or traditional teaching?), students' behavioral scores were obtained through ClassDojo and these scores were analyzed. On ClassDojo, participants' behavior scores were added to their profile information as positive scores when they showed positive behavior and negative scores when they showed negative behavior. In addition, the students' "behavior that needs improvement" scores were calculated for both groups through ClassDojo. The four-week behavior scores of the groups before the experimental procedure are given in Chart 1.

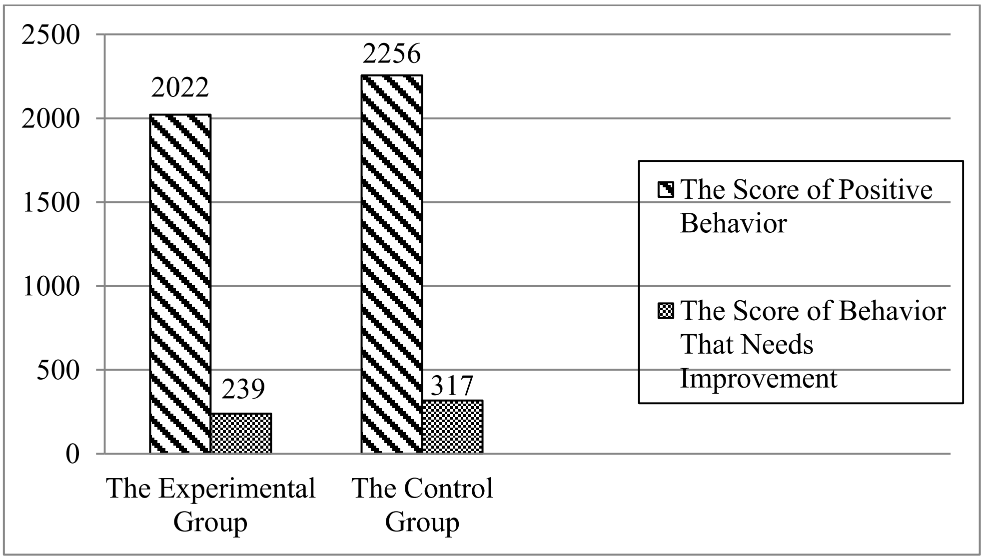

Chart 1. The Four-week Behavior Scores of the Groups Before the Experimental Procedure

When Chart 1 is examined, it is seen that 2022 of the total 2261 behaviors in the experimental group are positive, and 2256 of the total 2573 behaviors in the control group are positive. Since the total behavior scores followed in both groups are different from each other, the difference between the positive behavior percentages of the groups can be examined. The percentages of four-week behavior scores of the groups before experimental procedure are given in Chart 2.

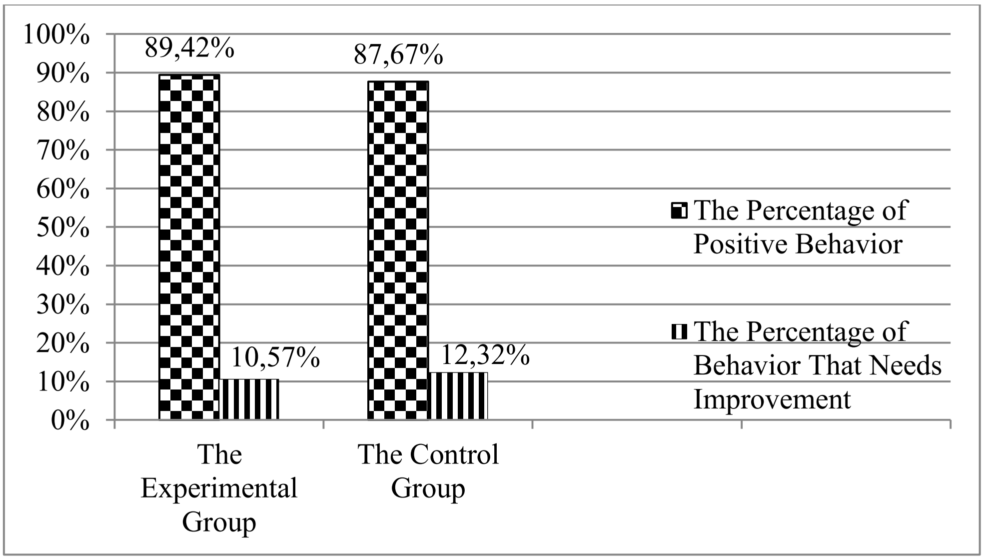

Chart 2. The Percentages of Four-week Behavior Scores of the Groups Before Experimental Procedure

When Chart 2 is examined, it is seen that the "positive behavior" percentage of the experimental group is 89.42% and the control group is 87.67%. The statistical significance of the difference between the percentages of "positive behavior" of the two groups was tested and the z-value was calculated as 1.90. This critical ratio value calculated was less than 1.96 which is required for the significance of .05 level. Therefore, the difference between the two percentages is not significant at the .05 level. Thus, it can be accepted that there is no difference between the percentages of the two universes before the experimental procedure.

The behavior scores obtained for both groups for six-weeks during the experimental procedure are given in Chart 3.

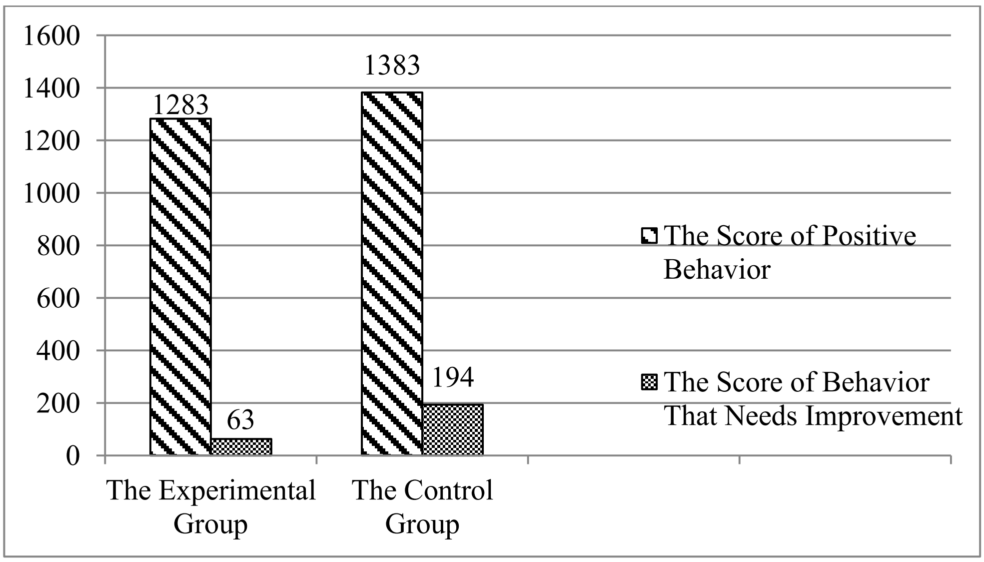

Chart 3. The Six-week Behavior Scores of the Groups During the Experimental Procedure

When Chart 3 is examined, it is seen that 1283 of the total 1346 behaviors in the experimental group are positive, and 1383 of the total 1577 behaviors in the control group are positive. Since the total behavior scores followed in both groups were different from each other, it was observed that the difference between the positive behavior percentages of the groups could be examined. Chart 4 shows the six-week behavior percentages of the groups during the experimental procedure.

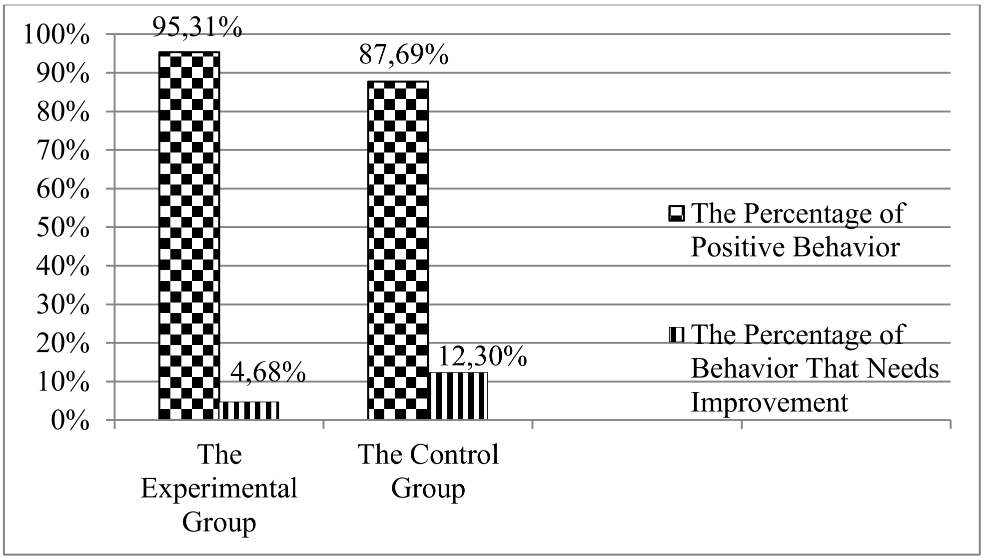

Chart 4. The Six-week Behavior Percentages of the Groups During the Experimental Procedure

When Chart 4 is examined, it is seen that the percentages of “positive behavior” are 95.31% in the experimental group and 87.67% in the control group. The statistical significance of the difference between the percentages of “positive behavior” of the two groups was tested and found to be z = 7.25. This critical ratio value calculated is higher than 1.96 which is required for the significance of .05. Thus, it can be accepted that there is a difference between two percentages during the experimental procedure. It can be said that the experimental group students were more successful than the control group students in terms of “positive behavior” percentage.

The extent to which the "positive behavior" percentages of students increased when they worked on a task and to what extent the percentages of “behavior that needs improvement" decreased were examined. The percentages of the experimental group's "positive behavior" and "behavior that needs improvement" scores before and during the experimental procedure are given in Chart 5.

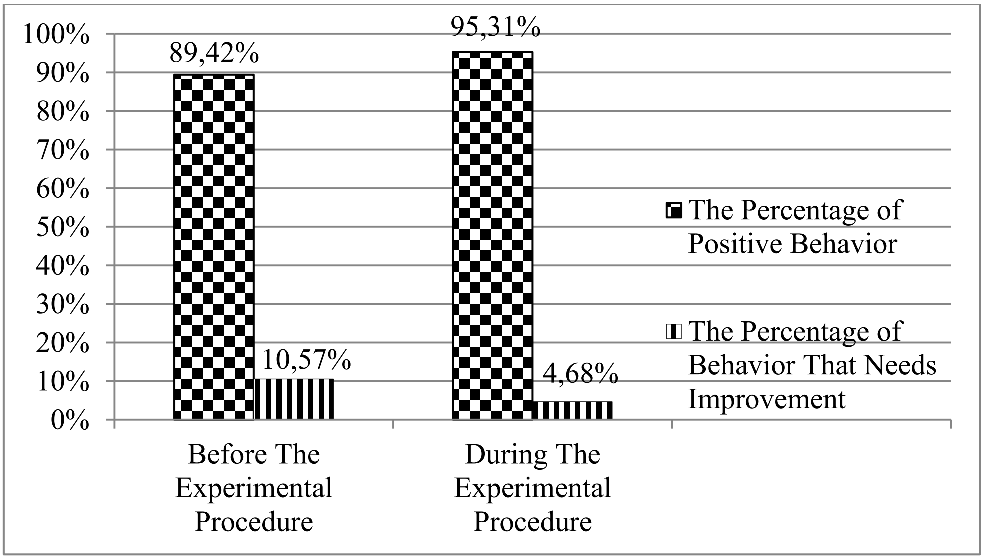

Chart 5. The Percentages of the Experimental Group's "Positive Behavior" and "Behavior That Needs Improvement" Scores

When Chart 5 is examined, it is seen that the percentage of "positive behavior" of the experimental group before the experimental procedure was 89.42%, and 95.31% during the experimental procedure. In addition, the percentage of "behavior that needs improvement" by the students in the experimental group was 10.57% before the experimental procedure and 4.68% during the experimental procedure. Considering the behavior percentages recorded in both processes in general, it is seen that the difference of 6% is in favor of the experimental application process. Based on this, it can be said that the use of project-based teaching method in programming education increases in-class positive behaviors and decreases negative behaviors.

Discussion and Conclusion

How project-based learning affects the achievement, cognitive load and behaviors of students in programming teaching was investigated in the current study. The participants of the study were taught with the method, project-based learning for 6 weeks in the experimental group in a student-centered mode while the participants in the control group were taught with the traditional teaching in a teacher-centered mode.

The dependent variables of the study are composed of the achievement, cognitive load and behavior change, whereas the independent variables are project-based learning and traditional teaching.

The Effect of Project-based and Traditional Teaching Methods on Academic Achievement of Students

The academic achievement level of students learning programming with project-based learning method was found to be significantly higher than the achievement level of students learning programming with the traditional learning method. This finding is consistent with the results of the studies conducted in the field (Atıcı & Polat, 2010; Dede, 2008; Peng, Wang, & Sampson, 2017). In addition, the result of the study complies with the results of the studies in different fields where the effectiveness of project-based learning method is examined (Acaray, 2014; Akgül, 2011; Alioğlu, 2014; Altun, 2008; Fırat, 2008; Gündüz, 2014; Övez, 2007; Özbek, 2010; Redmond, 2014).

On the other hand, Kızkapan and Bektaş (2017), who reached the conclusion that project-based learning method does not increase the success of students, reported the reasons for this in their study. To the researchers, one of the reasons may the fact that students cannot adapt project-based learning method since they are used to traditional teaching; the second, the group members in the project-based learning group may not understand each other, the third, the students in this group may have a fear of the method and finally that the subject may not have attracted the attention of the students. This is supported by the findings of Başaran (2005) as he states that fear of failure in a task can negatively affect learning and academic achievement.

To recap, the students' achievement scores in the current study increased in project-based learning group. This may be due to the fact that the students who learned programming by doing and experiencing in a meaningful way probably increased their scores.

The Effect of Project-based and Traditional Teaching Methods on Cognitive Load of Students

In the study, cognitive load levels of the students were also investigated. The cognitive load levels of the students while teaching programming with project-based learning method was analysed. The reason why the problem-based learning method was chosen was that this method enables students to concretize abstract issues that they have difficulty for. The results indicated that there is not a significant difference in cognitive levels of students in both methods students are exposed to while learning programming.

Although project-based learning method increases the success of students, it does not seem to have an effect on the cognitive levels of students. The reasons for these findings may be that students have probably encountered the programming course for the first time in their lives and that they are not used to project-based learning method. Many students with no experience may have a cognitive difficulty at the beginning of learning programming (Smith, Cypher, & Tesler, 2000).

Şişman and Küçük (2018) found in their study that the cognitive load levels of pre-service teachers were generally high in the robotic programming lesson. They reported in their study that pre-service teachers had high cognitive load as they had just started programming but as teachers gained experience, their cognitive load levels decreased. The reason of this might be the fact that programming requires combined use of skills such as mathematics, analytical thinking skills, problem solving and technology use which is difficult to learn and which takes time since it requires experience (Lahtinen, Ala-Mutka, & Jarvinen, 2005; Wang & Chen, 2010).

The Effect of Project-based and Traditional Teaching Methods on In-class Behaviors of Students

It was observed that there was no significant difference between the behaviors of both groups of students, that is, the students in both groups were found to be equal to each other before the implementation. During the implementation, there was a statistically significant difference was found between the groups in favor of the experimental group students. The positive behavior percentages of the experimental group students were found to be higher than the control group students.

Based on all these results, it can be said that the use of project-based teaching method in programming teaching increases the percentage of positive in-class behaviors of students and decreases their negative behaviors. This result is consistent with the study of Redmond (2014) who studied how the use of project-based teaching method will affect behavior management in the classroom. The researcher (2014) stated that there are positive developments in students individually (in the aspects of being on the task, participating, directing, completing a study, working hard). In addition, there are many studies demonstrating the positive effects of ClassDojo on behaviors (Chiarelli, Szabo, & Williams, 2015; Garcia & Hoang, 2015; MacLean-Blevins, 2013; Maclean-Blevins & Muilenburg, 2013; Saeger, 2017; Wachendorf, 2017).

However, in another study, it was indicated that ClassDojo did not have a positive effect on student behavior (Elliott, 2017; Ward, 2015; Wilson, 2017). The reasons why ClassDojo did not have a positive effect were indicated as; it did not arouse attention of the students, and the determined behaviors sounded abstract and were not suitable for them.

What is aimed with the behavioral management tool, ClassDojo, was to improve students' self-regulated learning by increasing their positive behaviors and decreasing their negative behaviors since it is important for any student to develop his self-regulation skill to be successful (Zimmerman, 1996). As a result, it could be said that project-based learning method in teaching programming ensures a positive development in the behaviors of students.

Project-based learning method in programming teaching was examined in terms of academic achievement, cognitive load and behavior change and the following results have been reached:

In programming teaching;

- project-based learning method is more effective in increasing academic achievement compared to the traditional learning method,

- project-based learning method did not make a significant difference on cognitive load of students,
- project-based learning method increases the positive behaviors of students and decreases the behaviors that need to be improved.

According to the observations carried out in the study, students in the project-based learning method group made more effort to complete their projects and this made them successful. In addition, the positive behaviors of the students working on the projects increased due to their active participation. The fact that students learn programming newly, and their fear of failure had a negative effect on decreasing cognitive load.

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