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Effects of the Instruction with Mathematical Modeling on Pre-service Mathematics Teachers' Mathematical Modeling Performance

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Effects of the Instruction with Mathematical Modeling on Pre-service Mathematics Teachers' Mathematical Modeling Performance[1]

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Abstract: The purpose of the study was to investigate the effects of the instruction with mathematical modeling on pre-service mathematics teachers' mathematical modeling performance. The participants were 24 pre-service elementary mathematics teachers. A mixed method approach was used to conduct the research. Each week, the participants were given two mathematical modeling problems and solved them as a group. After that, each group shared their solutions with the class so that there was an opportunity to focus on different solution methods. The data was collected via a pre and a post mathematical modeling test. SPSS package program was utilized in order to determine the significance level of the difference between the test results. One of the participants' solutions in the pre-test and in the post-test was also analyzed to enhance the results. The result showed that the instruction based on mathematical modeling improved pre-service teachers' mathematical modeling performance.

Introduction

Technological developments have created new problems that former generations had never encountered. As a consequence, there is an increasing demand for individuals who set a high value on mathematics, who have a high level of mathematical thinking and who can use mathematics in problem solving (MoNE, 2013). In Turkey, mathematics curriculum emphasizes the importance of training individuals to address these demands. Therefore, developing students' mathematical thinking and problem solving skills has become one of the major purposes of mathematics education (MoNE, 2011).

Blum and Niss (1989) stressed the importance of establishing relationship between mathematics and other disciplines; and reported that one of the major purposes of mathematics education is to get students acquire knowledge and skills of applying mathematics to different fields. Similarly, Bransford, Brown, & Cocking (1999) pointed out that most of the mathematical concepts should be given together in different contexts to get students make sense of them. According to Doruk (2010), mathematics education aims to create individuals who can generate effective solutions for problem situations in real life, and who can apply mathematics into real life by understanding the strong connection between mathematics and real life, and consequently create ones who enjoy mathematics instead of being afraid of mathematics. However, a teacher-centered teaching environment may not

[1]This study includes a part of a master's thesis by the first author.

serve for this aim since it may have a negative impact on transferring the students' knowledge into real life problems (Doruk, 2010).

Greer (1997) stresses that traditional verbal problems fail to show students the applications of mathematics in real life, since they do not encourage students to use mathematics effectively in real life, and to establish a relationship between mathematics, real life and other disciplines. For this purpose, real life problems which help students to understand the importance of mathematics should be included in curriculum in order to change the negative opinions of students towards mathematics (Huang, 2012; Kaiser & Schwarz, 2006).

Mathematical modeling is a process of solving real life problems (Özer-Keskin, 2008). Lesh and Zawojevski (2007) defined mathematical modeling as the process of defining, formulating, and interpreting a real life situation. Although there are many definitions of mathematical modeling, they have two common points. One of them is the emphasis on the connection between real life and mathematics, and the second one is considering mathematical modeling as a process. Özer-Keskin (2008) constructed the following diagram which illustrates mathematical modeling process, by using the definitions of mathematical modeling by Berry and Houston (1995) and Doerr (2007) (Fig. 1). According to the diagram, mathematical modeling process consists of five stages; which include understanding the problem, determining the variables, constructing the model, solving the mathematical problem, and lastly interpreting the model. As seen in Figure 1, the stages do not follow each other in a hierarchical order; they are all interrelated to each other. For example, a student who has difficulty in constructing the model may turn back to understanding the real life problem, which is the first stage of mathematical modeling process.

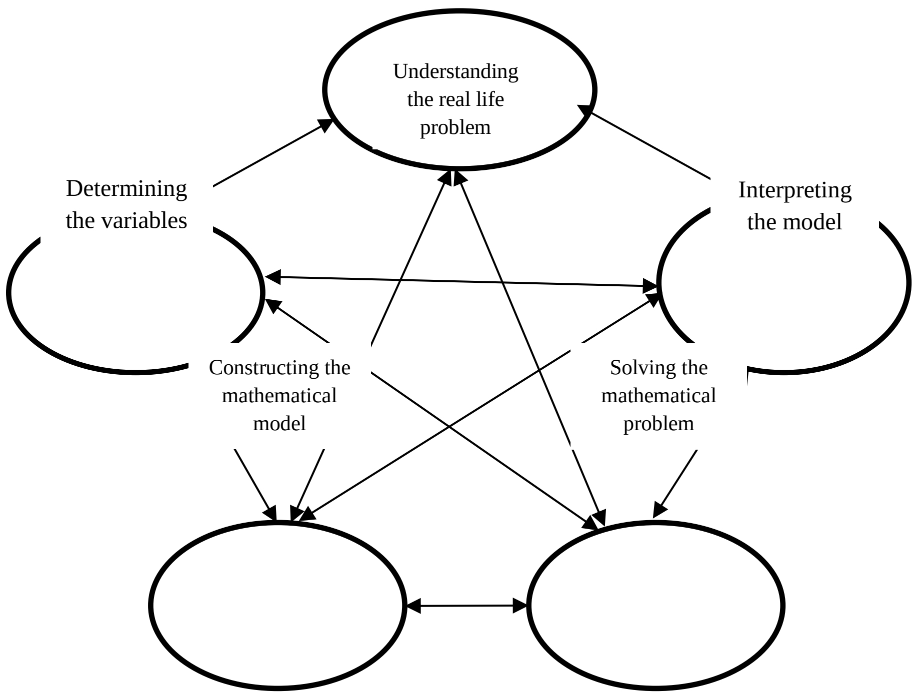

Figure 1: Mathematical Modeling Diagram (Özer-Keskin, 2008)

Doruk and Umay (2011) reported that mathematical modeling has a positive impact on students' ability to transfer their learning into real life. Therefore, it can be inferred that transferring mathematics into real life is directly connected with mathematical modeling. Mathematical modeling provides a variety of techniques for learning mathematics; it also enhances students' skills of applying mathematics in real life as well as it leads students to think more deeply about their learning (Zbiek & Conner, 2006). Since mathematical modeling problems lead students to generalize and make conjectures about their solution, the final product should be sharable. So, students should work in small groups while engaging in mathematical modeling problems in order to generate a sharable product. Group work gives students the opportunity to express their ideas more comfortably and to gain different perspectives; it also provides an enjoyable social environment for them (Antonius, Haines, Jensen, Niss, & Burkhardt, 2007; Erdamar & Demirel, 2010). Delice and Taşova (2011) stated that group work enhanced the students' performance while engaging in mathematical modeling problems. Similarly, Chamberlin and Moon (2008) suggested that richer solutions arise when mathematical modeling problems are solved as a group.

The emphasis on mathematical modeling has increased in recent years because of the results of the international studies like PISA (Program for International Student Assessment). PISA studies are conducted every 3 years, and aim to assess how students make sense of their knowledge, how they apply their mathematical knowledge to the extraordinary situations they encounter. The study evaluates 15-year-old students' fundamental skills in mathematics, science, and reading. According to the mathematical literacy results of PISA 2015, the score of Turkey is 420 whereas the mean score of all OECD (Organization for the Economic Co-operation and Development) countries is 461 (PISA National Assessment Report, 2016). Therefore, it can be inferred that the score of Turkey is lower than many other OECD countries.

Mathematics problems in PISA generally include real life situations which require mathematical skills for solving a problem. The failures in such a test increase the importance of problem solving and mathematical modeling skills, which were included in mathematics curriculum. Furthermore, curriculum reform requires that the teachers should change the content they teach and how they teach it (National Council of Teachers of Mathematics, 1991). In order to keep up with a change in curriculum, the role of teachers seems crucial. Teachers are expected to use mathematical modeling in classes and improve their students' mathematical modeling performance (Tekin-Dede, & Yılmaz, 2013). Therefore, the rationale of the current study is connected with one of the purposes of the mathematics curriculum. In this respect, pre-service teachers' knowledge and skills regarding mathematical modeling is important since they will become teachers in the future and use mathematical modeling in their professions. It would not be easy for students to improve their mathematical modeling performance if the teacher is not competent in mathematical modeling, and do not integrate it to mathematics lessons. Therefore, pre-service mathematics teachers' mathematical modeling performance is worth investigating. In this sense, the purpose of the current study is to investigate the effect of the instruction based on mathematical modeling on pre-service elementary mathematics teachers' mathematical modeling performance.

Methodology

The Design of the Study

The purpose of the study was to investigate pre-service mathematics teachers' mathematical modeling performance. In this study, qualitative and quantitative research methods were used together; therefore, the study was conducted by the use of mixed methods approach. A mixed methods approach is an effective research design since it benefits from the advantages of both qualitative and quantitative research methods (Creswell, 2008).

A single group pretest-posttest design was used as the quantitative part of the study. In this design, a pre-test is applied to one group, then the group is exposed to an experimental treatment; after the treatment a post-test is conducted. Therefore, there is an opportunity to observe whether there is an effect of the treatment over the results (Creswell, 2008). In the scope of the current study, mathematical modeling performance of one group were compared before and after the instruction based on mathematical modeling. The independent variable was the instruction based on mathematical modeling whereas the dependent variable was the mathematical modeling performance of pre-service elementary mathematics teachers.

In order to minimize the effects of some other factors on the participants' mathematical modeling performance, some variables were controlled by the researcher. For example, during the intervention process, the participants did not take any other course which may develop their modeling performance. Since this research design does not include any control group, there was a crucial limitation arising from the assumption that the difference between pre-test and post-test was due to instruction.

For the qualitative part of the study, samples from one of the participants' solutions were included. The purpose of using qualitative data was to enlighten the findings of the quantitative results, and to clarify mathematical modeling process. For this purpose, one of the participants' solutions to the sixth item in both tests were presented. Content analysis was conducted by analyzing the qualitative data (Fraenkel, & Wallen, 2005). In content analysis, human behavior is analyzed in an indirect way; and usually written content is analyzed. In the current study, the written responses of one of the participants were analyzed. Therefore, content analysis is proper for qualitative data analysis in the current study. Further information about content analysis process is presented in data analysis section.

Participants

The study was conducted with 24 pre-service elementary mathematics teachers who were at their second year in a public university in Turkey. In the study, convenience sampling was used. Pre-service elementary mathematics teachers who enrolled in an elective course called "Mathematics and Life" were selected as participants. All of the participants successfully completed General Mathematics and Calculus I courses. Calculus I course includes mostly limits, continuity and derivative concepts whereas General Mathematics course include basic concepts like functions, equations, sequence and series. Since the problems used in this study were mainly related to these concepts, it was assumed that the participants had prerequisite knowledge for solving the problems in the study.

Intervention Process

The study was conducted in the spring semester of 2015-2016 academic year, within the scope of an elective course called as "Mathematics and Life". The duration of the lessons was 3 lesson hours for each week during the semester. All of the lessons were conducted by the researcher. During the study, the researcher guided the students and managed the class discussions. In the first week, the pre-test was conducted. Pre-service teachers were given 90 minutes to complete the test. In the second week, the participants were given some brief information about what mathematical modeling is, how it is used in classroom, and in what ways it contributes to teaching and learning of mathematics. Different definitions of mathematical modeling were explained, and mathematical modeling process was discussed. The participants were also given a mathematical modeling problem as an example. Therefore, they had a chance to gain a concrete understanding of what mathematical modeling means. In the third week, the instruction based on mathematical modeling was started. As discussed in the previous section, since group work contributes to mathematical modeling process, pre-service teachers formed groups of two and worked together during semester. They were given two mathematical modeling problems, and solved them as a group every week. The teaching process continued in a similar way until the last week of the semester. The mathematical concepts and relevant real life context for each modeling problem of whole semester are presented in Table 1.

	Title of the Problem	Relevant Concepts	Real Life Context
1	Let's Enclose the Area	Derivative	field, fence, river
	Design of a Product	Derivative	oil box, expenditure
2	Car Parking Fee	Limits and Continuity	car parking, cost
	The Lake Pollution	Limits-Inequalities	environmental pollution
3	The Rate of Population Increase	Derivative	population increase
	Discharging the Tank	Derivative	tank, water
4	Absolute Convergence	Sequence and Series	fortune games
	Zeno's Paradox	Sequence and Series	land, area
5	Age Circles	Sequences	zoology
	Fruit Juice Package	Derivative	packaging, optimization
6	Turkey in the next century	Derivative-Functions	population increase
	Maximum Area	Derivative-Equations and Functions	farm, area
7	Doomsday Hour	Sequences	archeology, legend
	Popcorn Box	Polynomials- Functions-Derivative	Packaging
8	Water Tank	Graph of Functions-Derivative	software, water, tank
	Trekking Racetrack	Derivative	Trekking
9	Coffee Making	Geometrical Objects- Volume- Derivative	coffee, pot
	The Balloon	Geometrical Objects- Volume- Derivative	balloon
10	Pulling a Boat	Trigonometry-Derivative	boat, pier, rope
	An Ascending Balloon	Trigonometry-Derivative	balloon

Table 1: The concepts and relevant real life contexts for each modeling problem

As presented in Table 1, the problems used in the study were generally related to the concepts such as limits, derivative, trigonometry, sequences and series. The problems were appropriate for the participants, since they were at second grade and successfully completed Calculus I and General Mathematics courses which focus on the above concepts. The problem contexts were also familiar to all students since all of them contain basic situations from daily life, such as environmental pollution, population increase, and fortune games which were presented in Table 1. These problems were different from traditional non-routine problems since they provided opportunity to work in small groups and develop a sharable product. Furthermore, each problem contains a real life situation and requires interpretation of the results rather than making just mathematical calculations, which is essential for mathematical modeling process. In an ordinary mathematics course, the students may engage in some exercises mostly about simple calculations covering mathematical concepts like limits and derivative. However, these problems were beyond simple calculations and leaded the participants to think more deeply and conceptually about real life problems. For example, in one of the problems, pre-service teachers were asked to find the appropriate dimensions of a 330 ml fruit juice box in order to minimize the total cost of the box. At the end of the lesson, the results were discussed and compared with the real dimensions of the boxes.

For solving the problems, each group member was given a separate worksheet on which the problem was written. They were given enough time to read the problem carefully, to understand, and to think about it individually. After that, pre-service teachers started to work on the problem in collaboration with their group mates. In order to begin a class discussion, each group was required to share their results and solution methods with the class. In this way, the researcher's purpose was to make pre-service teachers focus on different solution methods. After a short break, the similar procedures were conducted for the second problem of the week; then the lesson was completed. The following weeks continued similarly. In the last week of the semester, the post-mathematical modeling test was conducted.

Data Collection

The data was collected via a pre-mathematical modeling test, and a post-mathematical modeling test to observe the change in pre-service teachers' mathematical modeling performance before and after the instruction. The detailed information about the instruments was given below.

Pre-Mathematical Modeling Test

The test consisted of 6 open-ended problems which were related to the concepts such as limits and continuity, derivative, sequences and series, functions. The problems were determined by the researcher by getting expert opinion. The related concept and real life context for each problem in the pre-test were given below (Tab. 2).

Number	Concept	Real Life Context	Reference
1	Derivative	sliding ladder	Thomas & Finney, 2011
2	Sequences	mobile phone, radiation	Çiltaş, 2011
3	Derivative	Stone, gravity, velocity	Thomas & Finney, 2011
4	Functions	population increase	Lial, Hungerford, Holcomb & Mullins, 2014
5	Limits and Continuity	post, fee	MoNE, 2011
6	Derivative	fence, area, expenditure	Erbaş et al., 2016

Table 2: The concepts and real life contexts of problems in the pre-mathematical modeling test

As shown in Table 2, each problem in the test contained a real life situation. The test was conducted by the researcher at the first week of the semester. Since the test included open-ended problems, pre-service teachers were given 90 minutes, which was assumed to be enough for answering all the questions in the test.

Post-Mathematical Modeling Test

Similar to the pre-test, the post-mathematical modeling test was prepared by the researcher by getting expert opinion. The questions in the post-mathematical modeling test were similar to the questions in the pre-mathematical modeling test in terms of the mathematical concepts and difficulty level. Like the pre-test, the post-test consisted of 6 open-ended problems. The relevant concepts and real life context of the problems were presented below (Tab. 3).

Number	Concept	Real Life Context	Reference
1	Derivative	street, hike	Thomas & Finney, 2011
2	Sequences	medicine, illness, virus	Çiltaş, 2011
3	Derivative	rock, explosion	Thomas & Finney, 2011
4	Functions	economics	Lial et al., 2014
5	Limits and Continuity	parking, fee	Lial et al., 2014
6	Derivative	fence, area, expenditure	Erbaş et al., 2016

Table 3: The concepts and real life contexts of problems in the post-mathematical modeling test

As shown in Table 3, each problem in the post-test contained a real life situation. The test was conducted by the researcher in the last week of the semester. Pre-service teachers were given 90 minutes to solve the problems in the post-test.

Data Analysis

The pre-mathematical modeling test and the post-mathematical modeling test which were used as data collection tools of the study consisted of open-ended questions. Therefore, the scoring of the both tests was made by the use of analytical scoring scale (Tab. 4), which was developed by Özer-Keskin (2008). The maximum score of each item in the test was 10 points. Therefore, the total score of each test was 60 points.

Steps	Categories	Score
Understanding the Problem	If the problem is understood completely.	2
	If the problem is understood partially.	1
	If the problem is not understood.	0
Determining the Variables	If the variables are determined completely.	2
	If the variables are determined incompletely.	1
	If the variables are not determined.	0
Constructing the Model	If the model is constructed properly.	2
	If the model is constructed incompletely.	1
	If the model is not constructed.	0
Solving the Mathematical Problem	If the answer is found correctly.	2
	If there is a calculation error, or only some part of the problem is solved correctly.	1
	If the answer is not found correctly.	0
Interpreting the Solution to Real Life	If the solution is interpreted to real life properly.	2
	If there is wrong expression in any part of the interpretation of the solution.	1
	If there is no interpretation, or the solution is interpreted to real life wrongly.	0

Table 4: Analytic scoring scale (Özer-Keskin, 2008)

According to the scale, five steps of mathematical modeling were scored as 0, 1 and 2 depending on how each step was performed by the participant. For example; in the first problem of pre-mathematical modeling test, there was a ladder leaning on the wall of a house and it started to slip down to the ground. After giving this information, the problem asked for the answers of 3 questions at an instant that the ladder reaches a certain distance from the house: the rate of change of the slipping of upper part of the ladder, the rate of change of the area of the triangle surrounded by the ladder, the house and the ground; and the rate of change of the angle between the ladder and the ground. For this problem, a participant was considered to understand the problem if he/she could organize the givens in the problem and wrote properly what the problem asks for. In this step, the participant may have constructed a diagram or made a written comment that indicated he/she understood the problem statement. For the second step, the participant was expected to specify the variables by using proper letters such as x and y. In the process of constructing the model, a trigonometric equation must be generated. For this problem, the participant who could construct the correct equation was given 2 full points without checking whether the equation was solved correctly or not. In the step of solving the mathematical problem, it was checked whether the solution of the participant was correct or not; if there were any calculation mistakes, the solution was accepted as partially correct, and the participant was given 1 point. If there was not any attempt to solve the equation, 0 point was given. The last step of mathematical modeling, which was interpreting the solution to the real life, required the interpretation the numeric answer found in the previous step. For this problem, if the answer was a negative number, then it would indicate a "decrease" whereas a positive number indicated an "increase". In other words, if a participant found the rate of change of the area of the triangle negatively, he/she was expected to make the interpretation that "the area of the triangle is getting smaller".

The SPSS 20 package program was used to analyze the quantitative data obtained from the pre-test and the post-test. In order to determine the significance level of the difference of the scores from the pre-test and the post-test, paired samples t test was used. In order to use a parametric test, there are two assumptions that must be hold. The data must be normally distributed, and obtained independently from each other (Green et al., 2000). Before the analyses, the researcher checked whether these assumptions were held or not. For determining the normal distribution of the data, the kurtosis and skewness were examined.

The qualitative data of the study consisted of samples from one of the participants' solution paper. The solution of the participant was analyzed by doing content analysis (Fraenkel, & Wallen, 2005). There are two types of content which are manifest content and latent content (Fraenkel, & Wallen, 2005). Manifest content refers to the obvious, surface content; whereas latent content refers to the meaning underlying what is shown (Fraenkel, & Wallen, 2005). In the current paper, the written responses of one participant's solution to the last items in the pre-test and the post-test were included as a qualitative data. Since the researcher cannot directly obtain the scores taken from each mathematical modeling step, interpretation of the meaning underlying the participant's solution was required. Therefore, the content in this case can be referred as latent content. After the participant's solutions were examined, the researcher started the coding process. In the study, as mentioned before, analytic scoring scale developed by Özer-Keskin (2008) was utilized. The five mathematical modeling steps are used as previously defined categories. In each category; there are three coding units (Tab. 4). The results were presented by the help of tables which demonstrate the scores of the participant in each mathematical modeling step. For each step, an explanation was written in order to indicate the reason for the given scores. To sum up, quantitative data of the study aimed to investigate the effect of the instruction with mathematical modeling on the participants' mathematical modeling performance. The qualitative data focused on just one participant's solutions and provided opportunity to examine the progress of the participant step by step.

Result

The SPSS 20 package program was used to analyze the data obtained from the pre-mathematical modeling test and the post-mathematical modeling test. For determining the normal distribution of the data, the kurtosis and skewness values were examined. For the data obtained from pre-mathematical modeling test, the kurtosis value was 0.667 and the skewness value was 0.663, whereas the kurtosis and skewness values of the data obtained from the post-mathematical modeling test were 0,032 and -0,885, respectively (Tab. 5).

	N	Min.	Max.	$\bar{X}$	SD	Skewness	Kurtosis
Pre-test	24	0	41	15.08	9.87	.633	.667
Post-test	24	15	53	39.12	10.62	-.885	.032

Table 5: Descriptive statistics of the pre-test and the post-test scores

Since kurtosis and skewness values were between -1 and 1, it was accepted that the data had a normal distribution (George & Mallery, 2003). Moreover, the data obtained from the mathematical modeling tests were collected independently. Therefore, it was accepted that parametric test assumptions were held. Therefore, the analysis continued with the paired sample t test. In order to compare the pre-test and the post- test results of the participants, paired samples t test was conducted in significance level of 0.05.

	Mean	N	Std. Deviation	T	df	P
Pre-test	15.08	24	9.872	**8.884**	23	.000*
Post-test	39.12	24	10.629			

***p<.05**

Table 6: Measures obtained from the testing of significance of the difference between the pre-test and the post-test scores

As shown in Table 6, there was a significant difference between pre-mathematical modeling test and post-mathematical modeling test scores ($t_{(23)}$=8,884: p<.05). In order to determine the direction of this difference, the mean values of the test scores were compared. The result showed that post-test scores were significantly higher than the pre-test scores.

The statistical analysis of the tests indicated an increase in the mathematical modeling performance of the pre-service teachers. For further analysis, an example was given from the solutions of a participant who increased the test score at the end of the instruction. The participant got 5 points from the 6^{th} question of pre-mathematical modeling test. The 6^{th} question was as follows:

In a factory, there is a need for a new space for storage. The logistics director of the factory thinks that a rectangular region next to the company should be proper for the storage. To enclose the rectangular area, fences will be used. One side of the rectangular region will include the wall of the company building. Also, because there is a highway in front of the factory building as shown in below figure, the fence used for this side should be higher and safer. Therefore, the price of the fence which will be used for the front edge is 300 TL per meters whereas the price of the fence for the other two sides is 200 TL. The logistic director wants to minimize the cost of the fences which will be used. Calculate the side lengths of the region and the cost of the fences. If a more expensive fence was used for the front side (i.e. 400 TL per meter), how would the side lengths of the storage region and the total cost change?

The participant's response to this question is given below (Fig. 2). The English translation of the participant's handwriting is also given in parenthesis.

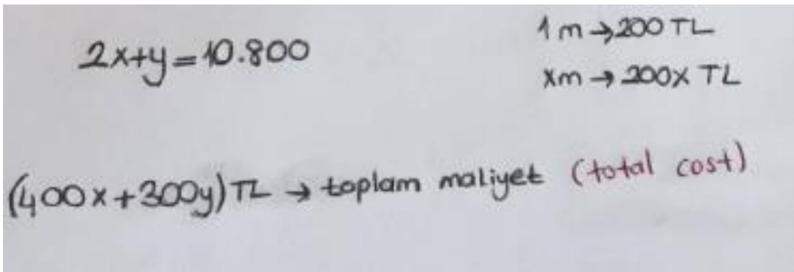

Figure 2: The solution of one participant to the 6th item on the pre-test

The solution showed that the participant formed an equation by determining the variables conveniently, and expressed the total cost mathematically. The scoring of the solution according to each step and detailed information about the solution were presented in Table 7.

Steps	Score	Information
Understanding the Problem	2	Pre-service teacher wrote the givens in the problem properly; hence it was accepted that she understood the problem.
Determining the Variables	2	Pre-service teacher determined the variables required for the solution as x and y properly.
Constructing the Model	1	Pre-service teacher tried to form an equation but could not because she did not take the derivative of the total cost function and equalize it to zero.
Solving the Mathematical Problem	0	Pre-service teacher did not make any calculations to solve the problem.
Interpreting the Solution to Real Life	0	Since pre-service teacher could not solve the problem, she could not make any interpretation.
Total	5	

Table 7: The Scoring of One of the Participants' Solution to the 6th Item on the Post-test

The participant increased her score at the end of the treatment and got 9 points from the 6th question of the post mathematical modeling test. The 6th item was as follows:
A farmer wants to enclose an area of 5400 m^2 of his whole land next to the river by using a fence, and plans to use there as a field for planting. He thinks that there is no need to encircle the side next to the river. The farmer has two different fence materials. The price of the fence for the opposite of the river is 30 TL per meter whereas the price of the fence for the other sides is 20 TL per meter. According to the given information, calculate the total cost by determining the sides of the field. If a cheaper fence (i.e. 10 TL per meter) was used for the two sides (not the side opposite the river) how would the sides of the field and the total cost change?

The solution of the pre-service teacher to this question is given below (Fig. 3).

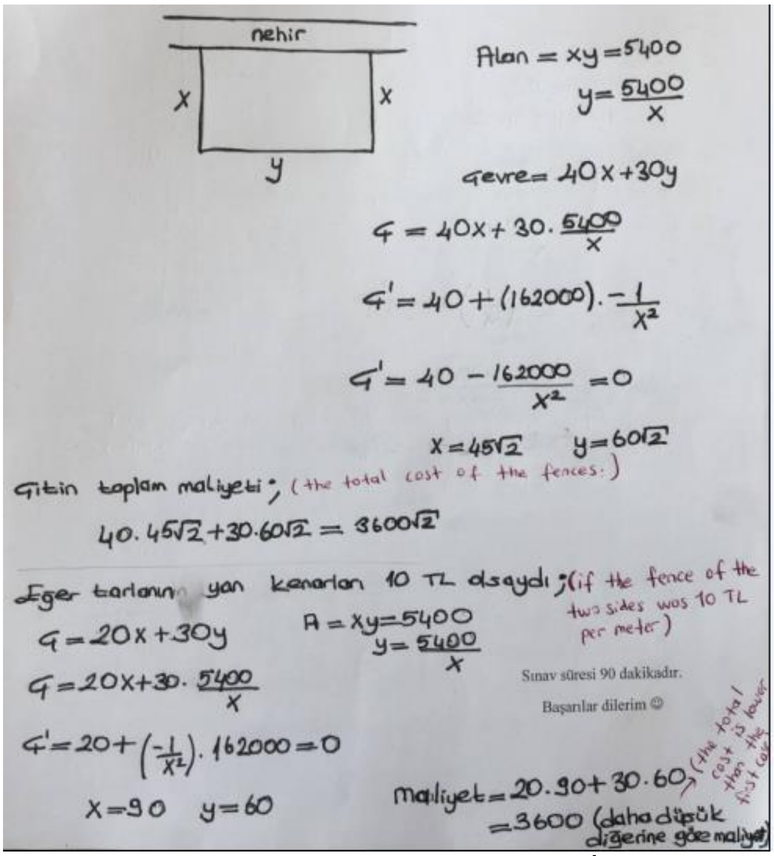

Figure 3: The solution of one participant to the 6th item on the post-test

The solution indicated that the participant organized the givens in the problem properly, expressed them mathematically, and solved the problem correctly by constructing the equation which was necessary to solve the problem. The detailed information about the problem and the scoring were given below (Tab. 8).

Steps	Score	Information
Understanding the Problem	2	Pre-service teacher understood the problem completely.
Determining the Variables	2	Pre-service teacher determined the variables as x and y, conveniently.
Constructing the Model	2	Pre-service teacher constructed the convenient model which was an equation for this problem.
Solving the Mathematical Problem	2	Pre-service teacher reached the right answer of the problem by following proper operations.
Interpreting the Solution to Real Life	1	Pre-service teacher just interpreted that the cost decreasing but she did not mention that the edges of the field is decreasing.
Total	9	

Table 8: The Scoring of One Participant's Solution to the 6th Item in the Post-test

Discussion

The quantitative and qualitative analyses suggested that the instruction based on mathematical modeling affected the mathematical modeling performance of pre-service elementary mathematics teachers positively. Similar to this study, the results of the studies by Çiltaş (2011), Ikeda et al. (2007), and Özer-Keskin (2008) suggested that pre-service mathematics teachers' mathematical modeling performance can be improved by the instruction based on mathematical modeling. In the current study, as mentioned in the methodology section, quantitative data were collected by a pre-test and post-test in which open-ended mathematical modeling problems were included. On the other hand, qualitative data included some samples from one of the participants' solutions of one item in the pre-test and post-test. Generally, pre-service teachers demonstrated a low level of performance about mathematical modeling before the instruction. The paired-samples t test between the pre-test and the post-test scores concluded that there was a statistically significant increase in mathematical modeling test scores from pre-test to post-test. Furthermore, the samples from the participant's work supported the conclusion that there was an increase in pre-service teachers' performance on mathematical modeling after the instruction.

The increase in pre-service teachers' mathematical modeling performance may have been due to the instruction based on mathematical modeling. Mathematical modeling enabled pre-service teachers to think deeply on real life problem situations and to focus on conceptual knowledge about the mathematical concepts which were presented through modeling problems. Furthermore, group work might have been increased the students' mathematical modeling performance by enabling them to express their ideas more comfortably, and providing them different perspectives. Similar to the current study, studies by many researchers suggested the use of mathematical modeling because it contributes to mathematical modeling performance of the individuals (English and Watters, 2004; Kartallıoğlu, 2005; Muşlu, 2016; Olkun, Şahin, Akkurt, Dikkartin, & Gülbağcı, 2009; Yıldırım and Işık, 2015).

In conclusion, it can be suggested that mathematical modeling problems should be used in mathematics classes from beginning of primary education until the end of tertiary education in order to make students benefit from these experiences, and to enhance their mathematical modeling performance. In the study, pre-service teachers studied as groups of two in the study. Future researchers might encourage students to work as groups of 3 or more in order to reinforce the group interaction.

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