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Research Article

The effect of mathematical modeling instruction on pre-service primary school teachers' problem solving skills and attitudes towards mathematics

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This research was performed as a single group pretest—posttest experimental design to determine the effect of mathematical modeling instruction on pre-service primary school teachers' (PPSTs) problem-solving skills and attitudes towards mathematics. Based on an online intervention due to the pandemic, the study involved 12 PPSTs who participated through Microsoft Teams. During the first week of the six-week mathematical modeling training, data gathering tools were employed as pre-test. A four-week implementation period followed, during which mathematical modeling activities were introduced and put into practice. A post-test using data collection tools was conducted during the final week of the study. This study revealed that mathematical modeling instruction positively enhanced the problem-solving skills of PPSTs. Mathematical modeling instruction improved the skills of PPSTs in understanding the problem and carrying out plan, but did not affect their skills of devising a plan and looking back steps. PPSTs' attitudes toward mathematics were also not affected by mathematical modeling activities.

Keywords: Pre-service primary school teachers; Problem solving; Mathematical modeling; Attitude towards mathematics

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1. Introduction

The state of the world today makes it clear that education needs to be updated. Parallel to these changes in the educational system, significant shifts have taken place, and a variety of strategies have been devised to address societal demands. Better education has been the goal of these strategies. Mathematics has key responsibilities in line with this purpose because the primary goal of education is to assist students in developing themselves and selecting a suitable profession by taking into account their abilities (Çiltaş, 2011). In the Primary School Mathematics Curriculum (Ministry of National Education [MoNE], 2018), it is aimed to train individuals who can develop and effectively use their mathematical literacy skills, express their own thoughts in the problem-solving process, understand mathematical concepts and use these concepts in their daily life. Since

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the main function of primary school is to prepare students for life, their primary purpose is to ensure that students are competent to solve the problems that they may encounter in daily life. It is thought that the effect of mathematical modeling is great in the process of revealing the mathematical knowledge of students while solving the problems they encounter in daily life.

Real-world problems are abstracted into mathematical language, analysed, and then a solution is tested through the process of mathematical modeling (Haines & Crouch, 2007). According to Verschaffel et al. (2002), mathematical modeling is the process of trying to express mathematically the events in real life situations and the relationships between these events and revealing mathematical patterns. Bukova Güzel and Uğurel (2010), on the other hand, defined mathematical modeling as expressing existing or fictional problem situations in fields other than the world of mathematics (physics, biology, sociology, politics, art, entertainment, etc.) by transferring them to the world of mathematics in the language of mathematics in addition to being a method representing the search for a solution with mathematical knowledge and approaches. Based on the definitions, it can be said that mathematical modeling activities and the basic skills aimed to be acquired in the curriculum overlap each other.

Teachers are supposed to provide students learning materials, motivate students, and take responsibility for students throughout the educational process in institutions where traditional methods of instruction are used (Zimmerman, 2000). However, students can actually take their own responsibilities and organize their learning in the learning-teaching process. In this case, the task of teachers is to use different teaching methods such as cooperative learning, discovery learning, project-based learning, and problem solving learning. Mathematical modeling can be used both as a learning method and as a learning material in teaching mathematics in terms of its features such as critical thinking and reasoning (Özturan Sağırlı, 2010). Blum (2011) stated that by using the mathematical modeling method in teaching mathematics, students will better understand real-life situations and subjects and develop different mathematical competencies.

It is crucial to provide students with complex problem situations so they can expand their mathematical thinking processes, learn new ideas, and get experience with complex problem situations in order to prepare them for daily life (Lesh & Zawojewsky, 2007). For this reason, it is not considered sufficient to memorize only the processes involving mathematical operations and to apply these mathematical operations to similar problem situations (Eraslan, 2011). Mathematical modeling enables us to understand the life going on around us, to find ways to cope with the problems we encounter in daily life situations, and to learn the areas of use of mathematics in our future professions (Verschaffel, 2002). They are mathematical modeling applications that enable us to realize the interconnections inside and outside of mathematics, to gain different perspectives on a subject, and to see applied mathematics in the best ways (Chamberlin & Moon, 2005). Niss (1989) explained why mathematical modeling and its applications should be included in the mathematics curriculum with the following five features:

- It nurtures creative problem-solving skills and abilities among students.
- Students' critical perspective develops with the use of mathematics in areas other than mathematics.
- Modeling and applications in teaching the subjects will provide students with practice in their current and future professional lives as individuals.
- Students create a balanced and visual mathematical picture in their minds by considering the role and characteristics of mathematics in the world.
- It helps students to understand mathematical concepts, methods, results and subjects and gain the necessary skills.

Mathematical modeling is a topic that has long been covered in mathematics curricula. Since 1988, mathematical modeling has been a significant part of the mathematics curriculum (Blomhøj & Kjeldsen, 2006). Mathematical modeling is seen as very important in the education systems of many countries such as Finland, Germany, Singapore, Sweden, America, Switzerland and Australia (Blomhøj & Kjeldsen, 2006; Lingefjard, 2006; Maaß, 2006; Stillman et al., 2007). In the curriculum applied in England, it is given great importance that mathematical modeling is a part of problem solving (Berry, 2002). In Denmark, one of the three most important elements of the mathematics curriculum since 1988 is mathematical modeling (Blomhøj & Kjeldsen, 2006). It is known that one of the six compulsory competencies in mathematics teaching standards in Germany is mathematical modeling (Blum & Borromeo Ferri, 2009). Similarly, it is emphasized that mathematical modeling activities are one of the important components of mathematics education in the curriculum in Singapore (Ang, 2006), students benefit from modeling while solving problems (Chan, 2010), and modeling, which has been used since 1983, has gained increasing popularity (Cheong, 2002).

Mathematical modeling activities first emerged at the beginning of 1970 (Chamberlin, 2005) and had two main goals. The first of these goals is to encourage students to develop mathematical models so that they can solve complex problems as only applied mathematicians do in real life (Lesh & Doer, 2003). The second is to facilitate researchers in learning students' mathematical thoughts (National Council of Teachers of Mathematics [NCTM], 2000). Mathematical modeling activities can be seen as an important bridge that provides transfer between school and daily life by expressing the mathematics subjects taught in the classroom with daily life situations (Doruk, 2010). It provides students with information about how to use mathematical knowledge in the real world (Sriraman, 2005). For this reason, it is of great importance for teachers and students to have detailed information about mathematical modeling activities.

Tekin Dede and Bukova Güzel (2014) introduced the theoretical structure of mathematical modeling activities. Within the framework of the publications they researched in the literature, they presented the features of mathematical modeling activities as in Figure 1.

Figure 1
Characteristics of Mathematical Modeling Activities

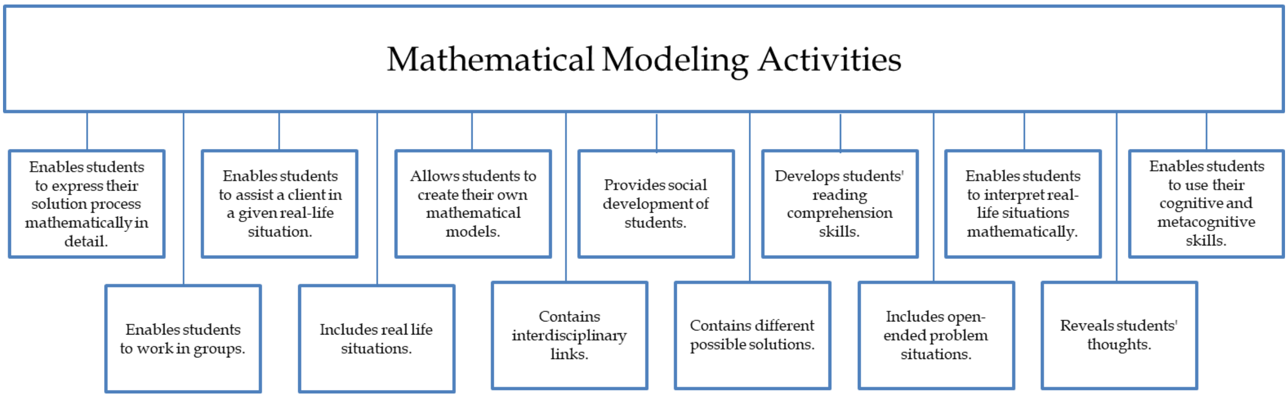

Figure 1 illustrates how modeling activities are open-ended problem situations with several solutions that are created by taking into account real-world situations. Students can solve mathematical modeling problems, explain the problem situation mathematically, and demonstrate their thinking processes with the aid of mathematical modeling exercises. Activities involving mathematical modeling offer the chance to collaborate with a group. As a result, it also contributes to the development of students' social skills.

At every stage of their life, people deal with a variety of problems. These problems might range from minor ones like what to dress tomorrow to major ones like the future profession that will be chosen. Making the appropriate choice in these circumstances is crucial for time management as well as for daily functioning. Making decisions is similar to how mathematicians solve problems. The aim of the mathematics curriculum is to raise individuals who can understand mathematical concepts and use these concepts in their daily lives, who can explain their thoughts using mathematical language correctly, and who can easily express their thoughts and reasoning in the problem solving process (MoNE, 2018). The way to serve this purpose in the most effective way is to develop problem solving skills. Problem solving in mathematics teaching is not only important because it provides a better understanding of the taught subject. Problem solving is a very important skill in terms of its relationship with real life, the confidence it gives when it is process-oriented rather than result-oriented, and students' learning about their mathematical thinking styles (MoNE, 2015).

Problem is mostly considered as mathematics problems based on four operations, which are included in primary school mathematics textbooks (Heddens & Speer, 1997 as cited in Altun, 2015). Schoenfeld (1985) defined problems as questions that are difficult to answer or that involve uncertainty and require research and creative thinking. Polya (1997) also defined the problem as the conscious search of actions to achieve the goal in the most appropriate way. According to Blum and Niss (1991), a problem is a situation that has certain open questions, attracts the attention of the individual, and does not have sufficient methodological knowledge to answer these questions. Tallman et al. (1993) defined the problem as the situation that prevents the individual from reaching the desired goal and it is uncertain whether this obstacle can be overcome. This obstacle can be any psychological, interpersonal, social, economic or physical condition. Van de Walle et al. (2014) defined the concept of problem as an event, topic or activity in which there is no memorized rule for solving the situation encountered. Grouws (1996), on the other hand, expressed the problem as a problem that needs to be found or shown, but how to find or show it is not clear at a glance with the available information (as cited in Kayan & Çakıroğlu, 2008). Gelbal's (1991) definition of problem is everything that leads the individual to mental complexity and obscures people's beliefs. The most important thing about the benefits of problem solving is to know how the individual will reach the solution of the problem, to learn new things while solving problems and to apply what they have learned to their life.

When the literature is investigated, it becomes clear that several classifications are created in relation to the different types of problems. Routine and non-routine problem categories will be categorized in this study. Routine problems, according to Polya (1997), are those that can be solved in phases by changing numbers or verbal instructions without introducing a new complicated situation to the original problem. They can be solved by using all or some of the four basic operations. For this reason, it is known as four operation problems in the literature (Polya, 1997). It is generally found in textbooks and encountered in the primary school during education, and it is directed to students so that students can have experience and improve themselves in similar situations (Ramnarain, 2014). Routine problems are not only problems including a few steps that students solve most of the time, but also cognitively interesting and multi-stage problems that require applying formulas or methods that students are accustomed to (Woodward et al., 2012). The skills required to solve non-routine problems can be achieved by adequately solving routine problems. Polya (1997) stated that it is important to work with routine problems for the development of problem solving skills, but it is not enough, and teachers should not focus only routine problems. He emphasizes that in order to develop critical thinking and creativity in students, it is necessary to work with non-routine problems (Polya, 1997). Souviney (1989) defines non-routine problems as problems that require having skills such as organizing data, classifying, seeing relationships, and performing certain actions one after another, beyond four operation skills (as cited in Altun, 2015). Polya (1997) also defined non-routine problems as problems that require more thinking skills than routine problems and for which the method for solving does not seem obvious. Mayer et al. (1995) state that in solving non-routine problems, the ideas and approaches displayed in the solution process are more important than obtaining the right answer (as cited in Bayazıt & Koçyiğit, 2017). Students who try different solutions gain the skills of critical and creative thinking, reasoning and association, which are the most basic skills that mathematics aims to gain. Including non-routine problems during mathematics instruction is very important for students to find solutions to problems they may encounter in real life and to develop positive attitudes towards mathematics.

Different approaches and strategies are utilized to solve different problems. Because every problem has its own solution, it is crucial to comprehend the problem and know what to do.

Through research, specific problem-solving techniques have been established. Polya (1997), who outlined the phases of problem solving in the book "How to Solve?", is the first name that comes to mind when thinking of problem solving steps. The problem solving steps consist of four steps as understanding the problem, devising a plan, carrying out the plan, and looking back (Polya, 1997). This four-step process is supported by models and guided by the questions the teacher asks, rather than being knowledge to be learned directly. The steps of the problem solving process, on the one hand, show the way to be followed during problem solving; on the other hand, it aims to provide students with the scientific thinking method (MoNE, 2015). In the step of understanding the problem, the individual must first be willing and interested in solving the problem. It is expected that the student will be able to distinguish between necessary and unnecessary information by analyzing what is given and what is requested in the problem. If the individual can explain the given problem with his own words, draw the appropriate figure and diagram, and indicate what is given and what is requested, it means that the problem is understood (Baykul, 2020). The most important part of problem solving is to read and understand the problem (Elçi, 2016). In the step of devising a plan, it is aimed to establish a relationship between what is given in the problem and what is requested. A relationship may not be found immediately. In this case, similar problem situations that have been solved before and their solutions are examined. As a result of these attempts, a plan emerges (Altun, 2015). In the step of carrying out the plan, this plan is carried out after the mathematical relations in the problem are established and the operations to be used in the solution are determined (Baykul, 2020). If a solution cannot be reached, the strategy is reviewed by going back to the first or second step, or changed (Altun, 2015). In the step of looking back, the accuracy of the operations used in solving the problem and the compatibility of the result with the prediction are checked (Baykul, 2020). According to Altun (2015), this step is not just for checking the results, it has a broader meaning. At this stage, students evaluate what they have done during the problem situation. They are supposed to look for other solutions or test the usability of the same solution when the conditions of the problem situation change.

Having a positive attitude towards mathematics affects problem solving skills positively (Ma, 1997; Reyes, 1984). When the studies are examined, there are many definitions made on attitude. Attitude is defined as to be affected or not to be affected by the psychological object (Thurstone, 1931). Demirel (1993) expressed attitude as learned tendencies that push the individual to show certain behaviors against certain people, objects and situations. According to Aşkar (1986), attitudes are psychological structures that are included in affective behaviors, cannot be observed directly, are acquired over time, and do not change easily. Attitude is affected by events that occur later and mostly experienced in childhood (Yağmur, 2012). According to İnceoğlu (1993), an individual associates a certain attitude with positive or negative events, gains information by his/her own experiences when faced with an attitude situation, or receives information from outside about the attitude situation. Although the formation of an attitude is generally associated with learning processes, it can be said that factors such as genetic transfer, physiological factors (maturation, old age, etc.), and the process of adaptation to society also have an effect (İnceoğlu, 1993). These factors, which affect the attitudes of individuals, may come to the fore in some periods. According to Morgan (2010), the effect of the family on the attitudes of individuals between the ages of 3-11 is quite high. As individuals grow, this effect leaves its place to social factors such as school and friends. Attitudes of individuals take their final shape between the ages of 12-30 and it is very difficult to change attitudes after this period (Morgan, 2010).

It might be argued that attitude and success are positively correlated. According to Neale (1969), success influences attitude, and attitude influences success. The importance of attitude cannot be overlooked in math lessons, as in any lesson. Neale (1969) defined attitude towards mathematics as liking or disliking mathematics, being inclined to engage in mathematical activities or being afraid of them, believing that one is good or bad at mathematics and that mathematics is useful or unnecessary (as cited in Alkan et al., 2004). On the other hand, Nazlıçiçek and Erktin (2002) define mathematics attitude as the attitude that emerges from the students' feelings towards the mathematics lesson. A student's success in mathematics does not only depend on his knowledge. Attitudes should not be ignored when it comes to success in mathematics. Many students think that the mathematics course is difficult. For this reason, students who think that they will not be successful in mathematics lessons develop negative attitudes towards mathematics. This negative attitude they develop starts from the primary school years and continues throughout their education (Baykul, 2020). While the academic success of individuals who develop a positive attitude towards the mathematics course increases, it can be observed that the academic success of individuals who develop a negative attitude decreases (Ma, 1997; Reyes, 1984).

For students to succeed in mathematics, understanding their attitudes towards mathematics is crucial, but it is not sufficient. It's crucial to understand the factors that influence how people feel about math in this regard. Some factors that influence students' views towards mathematics include their personality traits, gender, grade level, the schools they graduated from, and their family environment (Behr, 1973; Duru et al., 2005; Parsons et al., 1982). In addition, it can be said that another important factor affecting the attitude towards mathematics is the teacher (Duru et al., 2005). Teachers' efforts to make students memorize the subjects in a complex and meaningless way without simplifying them cause them to develop negative attitudes towards mathematics (Taşdemir, 2008). In addition, the teaching methods and materials the teacher uses, and the reactions the teacher gives in case of success and failure also play a decisive role in students' attitudes towards mathematics (Küçük et al., 2013). It can be said that the inclusion of mathematical modeling problems in the teaching plans will positively affect the attitude towards mathematics. Considering that teachers can also affect the attitude towards mathematics, it can be stated that it is very important for the pre-service teachers, who will be the teachers of the future, to have a positive attitude towards the mathematics lesson.

Hence, the aim of this research is to reveal the effect of mathematical modeling instruction on the problem-solving skills of PPSTs and their attitudes towards mathematics.

2. Method

2.1. Research Design

A single-group pretest-posttest experimental design was used in this study to investigate the effects of mathematical modeling instruction on PPSTs' problem-solving skills and attitudes. Experimental studies test the effect of researcher-created differences on the dependent variable. The main purpose of the experimental design is to test the cause-effect relationship between the variables (Büyüköztürk et al., 2019). In the one group pre-test post-test experimental design, which is one of the experimental design types, the effect of the experimental procedure is tested with a study on a single group. The measurement tool used in the application process of the pre-test is applied to the same participants as the measurement tool used in the application process of the post-test. In this study, which examines the effect of mathematical modeling activities on the problem solving and attitude of PPSTs, the experimental process can be embodied as in Table 1.

Table 1

Representation of the one group pretest-posttest experimental design

		Pretest	*Treatment*	*Posttest*
		O1	X	O2
Participants	Random Assignment	Scale for Attitudes towards Mathematics Problem Solving Achievement Test	Mathematical Modeling Instruction (Intervention)	Scale for Attitudes towards Mathematics Problem Solving Achievement Test

2.2. Participants

The study group of this research consists of 12 PPSTs who studied mathematical modeling within the scope of Basic Elementary Mathematics course in one of the public universities in the Aegean region of Turkey in 2020-2021 academic year. While creating the sample of the study, the criterion sampling method, which is one of the purposive sampling methods, was used. In purposive sampling, the selection of study-rich situations is ensured (Patton, 2014). Criterion sampling is the study of all situations that meet a predetermined set of criteria. Therefore, in order to determine the problem-solving skills and attitudes of PPSTs towards mathematics with mathematical modeling instruction, the Basic Elementary Mathematics course grades of the PPSTs were chosen as a criterion. The sophomores in the study group participated in the study on a voluntary basis. Information about the participants of the study is given in Table 2.

Table 2
Characteristics of the participants

Variable	*f*	*%*
Gender		
Female	10	83.33
Male	2	16.67
Total	12	100.00
Type of High School Graduated		
Anatolian HS	8	66.67
Vocational Health HS	2	16.67
Basic HS	1	8.33
Social Sciences HS	1	8.33
Total	12	100.00

Note. HS: High School

Table 2 shows that most of the participants were female (83.3%) and graduated from Anatolian high schools (66.7%). The distribution of the participants according to achievement variable is given in Table 3.

Table 3
Distribution of participants according to course grades and GPA

Participants	*Basic Elementary Mathematics Course Grade*	*Basic Elementary Mathematics Letter Grade*	*GPA*
S1	76	BB	2.88
S2	79	BA	3.40
S3	56	CC	3.51
S4	98	AA	3.67
S5	72	BB	3.42
S6	62	CB	3.18
S7	88	AA	3.58
S8	69	BB	3.55
S9	54	CC	3.41
S10	89	AA	3.09
S11	52	DC	3.75
S12	83	BA	3.28

Table 3 presents that half of the participants have AA and BB as letter grades (25.00% each), four of the participants have BA and CC as letter grades (16.67% each), and two of the participants have CB and DC as letter grades (8.33% each). When the grade point averages (GPA) obtained by the PPSTs in the 1st, 2nd and 3rd semesters are examined, it is seen that all of the participants except one have GPAs greater than 3.00 and the highest GPA is 3.75.

2.3. Data Collection Tools

The data of this study were collected using five data collection tools, which are the Attitudes towards Mathematics Scale, Mathematical Modeling Activities selected from the literature, Modeling Competencies Assessment Rubric, Problem Solving Achievement Test (PSAT) prepared by the researcher, and the Problem Solving Assessment Rubric prepared by the researcher.

2.3.1. Scale for Attitudes towards Mathematics (SATM)

This four-factor scale which is developed by Alkan et al. (2004) consists of 42 items in 5-point-Likert type as "Never, Rarely, Occasionally, Usually, Always". The reliability coefficient (Croanbach alpha) of the scale is .95. Factors were named considering the item contents as affective, cognitive, application area of mathematics, and belief.

The first of the determined factors explains 23.02% of the total variance, the second 8.32%, the third 6.88%, and the fourth 6.05% of the total variance. The common variance explained by the four factors with the items varies between 23.02% and 44.2%. After factor rotation, it was determined that the first factor of the scale consisted of 22 items, the second factor consisted of 8 items, the third factor consisted of 7 items, and the fourth factor consisted of 5 items (Alkan et al., 2004).

SATM was employed to PPSTs as a pre-test before starting the study and as a post-test at the end of the study. After the application, the relationship between the pre-test and post-test scores of the PPSTs was examined.

2.3.2. Mathematical Modeling Activities

This scale which was used during the treatment included selected problems from the literature. The order of Mathematical Modeling Activities for the implementation is given in Table 4.

Table 4
Order of implementation for mathematical modeling activities

Week	*Mathematical Modeling Activities*
1. Week Warm-up	Big Foot Problem (Tekin Dede & Bukova Güzel, 2011) Apple Pie Problem (adapted by Tekin Dede, 2015 from Schukajlow et al., 2012)
2. Week	Tooth Brushing Problem (Mischo & Maaß, 2013) Uncle Tailor Hikmet Problem (Kal, 2013) Team Ranking Problem (Carmona & Greenstein, 2010)
3. Week	Apartment Problem (adapted by Tekin Dede, 2015 from Maaß ve Mischo, 2011) Eiffel Tower Problem (Kal, 2013) Whitewash Problem (Tekin Dede, 2017)
4. Week	Highway Problem (Jahnke, 1997; Maaß, 2006) Paper Planes Problem (English & Watters, 2005) Weather Report Problem (adapted by İnan Tutkun & Didiş Kabar, 2018 from Doerr & English, 2003)

Within the scope of mathematical modeling instruction, Big Foot Problem and Apple Pie Problem were solved together with the pre-service teachers as a warm-up exercise. Afterwards, the problems stated in Table 4 were studied in the form of group work as three problems for each week.

2.3.3. Rubric for Assessment of the Modeling Skills (RAMS)

RAMS is an analytical scoring rubric developed by Tekin Dede and Bukova Güzel (2014) to evaluate the cognitive modeling competencies of students working on modeling problems in order to examine their solution approaches when they work individually or in groups (Tekin Dede, 2015).

RAMS has 6 sub-dimensions: understanding the problem, simplification, mathematization, working mathematically, interpretation and verification. Understanding the problem sub-dimension has 5 levels, the simplification sub-dimension has 4 levels, the mathematization sub-dimension has 4 levels, the working mathematically sub-dimension has 5 levels, the interpretation dimension has 5 levels, and the verification dimension has 7 levels. While scoring in RAMS, Level 1 is assigned 0 points and other levels are assigned 1, 2, 3, 4, 5 and 6 points, respectively. In light of this information, a maximum of 25 points and a minimum of 0 points can be obtained from RAMS. In line with the scores obtained as a result of RAMS analysis, the competency levels are categorized as follows:

- 0-6 points: Does not have modeling competence
- 7-12 points: Has some modeling competence
- 13-21 points: Acceptable modeling competence
- 22-25 points: Have a high level of modeling competence

As a result of validity and reliability studies, the percentage of agreement was calculated as 73.3% (Tekin Dede, 2015).

While making evaluations with RAMS, the mathematical modeling activities of the groups were examined. The existence of each sub-dimension was questioned and their levels were determined during the examinations. After determining the levels for all dimensions, the total scores of the groups were calculated.

2.3.4. Problem Solving Achievement Test (PSAT)

PSAT was developed by the researchers to be used within the scope of the study. While preparing PSAT, the primary school teaching curriculum (Higher Education Council [HEC], 2018) was taken as the basis and the subjects covered in primary school were included. PSAT consists of 20 open-ended questions covering the set of natural numbers, digit value, addition, subtraction, multiplication, division, four operation problems, consecutive numbers, odd and even numbers, pattern and motion problem. Two routine problems and two non-routine problems were written for each topic. After PSAT was prepared, it was sent to 1 faculty member working in the field of primary school education, 3 faculty members working in the field of mathematics education, 2 teachers working in public schools and 3 teachers working in private schools to obtain expert opinions. Required corrections were made according to the feedback from the expert opinions and one from the routine and one from the non-routine problems were selected for each topic.

2.3.5. Problem Solving Evaluation Rubric (PSER)

The rubric developed by the researcher during the study. Polya's problem solving steps were taken as basis while preparing the PSER. It consists of 4 sub-dimensions: understanding the problem, devising a plan, carrying out the plan, and looking back. Each dimension is scored as 0, 1 and 2 points. Based on this information, a maximum of 8 points and a minimum of 0 points can be obtained from PSER.

While making the evaluation with the PSER, the answers given by the PPSTs to the PSAT were examined. During the examinations, the existence of each dimension was questioned and scores were assigned. After scoring for all dimensions, the total scores of the pre-service teachers were calculated. The relationship between the scores for the pre-tests by the two experts is shown in Table 5.

Table 5
The relationship between Expert 1 and Expert 2's PSAT pretest scores

	Expert 1	
Expert 2	*r*	.97
	p	.000**
	N	12

Note. **p<.01

The correlation analysis showed a positive, high level and significant relationship between Expert 1 pre-test and Expert 2 PSAT pre-test scores ($r = .97, p < .01$) and post-test scores

($r = .87, p < .01$), which is a proof of high reliability. Therefore, the students' problem solving skills test scores were calculated by taking the average of the scores assigned by two experts.

2.4. Data Collection Process

Necessary permissions were obtained for the data collection tools to be used in the research. In order to carry out the research, an application was made to the Social and Human Sciences Scientific Publication Ethics Committee on 12.10.2020 and it was decided that the research was ethically appropriate. After obtaining the necessary permissions, no identification information was requested from the participants during the research, apart from the personal information within the scope of the research.

The data collection process was carried out online with Microsoft Teams due to the COVID-19 pandemic conditions. In the first week of MMA, which consists of six weeks, the SATM and PSAT pre-tests were employed to the PPSTs. PPSTs were told not to get help while solving the PSAT and to solve it in a way that primary school students can understand without setting up equations. Afterwards, there was a four-week implementation period in which mathematical modeling activities were introduced and implemented. Before starting the application, the participants were divided into groups of three. These groups were created by the researcher based on the course grades in the Basic Elementary Mathematics course.

Table 6
Characteristics of the participant groups

Groups	*Participant*	*Basic Elementary Mathematics Course Grade*
Group 1	S1	76
	S2	79
	S3	56
Group 2	S4	98
	S5	72
	S6	62
Group 3	S7	88
	S8	69
	S9	54
Group 4	S10	89
	S11	52
	S12	83

In the second week of the application process, model and modeling, model building activities and the importance of modeling in primary school were explained within the scope of mathematical modeling instruction. Afterwards, the groups were asked to go to the Discussion Rooms in Microsoft Teams and they were asked to solve the "Big Foot Problem" and "Apple Pie Problem" as part of the warm-up activities. PPSTs solved mathematical modeling problems in groups. They were told to use all kinds of materials in the solution process. After all the groups finished their work, they came together at the main meeting and discussed their solutions. The researcher created a discussion environment with the questions they asked and offered the opportunity to prove their solutions.

The role of the teacher in mathematical modeling activities was explained in the third week of the study. The groups participated to the discussion rooms and solved the "Tooth Brushing Problem", "Uncle Tailor Hikmet Problem" and "Team Ranking Problem". After all the groups finished their work, they came together at the main meeting and shared their ideas about the problem situation.

In the fourth week of the study, the importance of group work in mathematical modeling activities and how many students the groups could include were explained. Afterwards, the groups went to the Discussion Rooms and solved the "Apartment Problem", "Eiffel Tower Problem" and the "Whitewash Problem". In the Whitewash Problem, which is one of the mathematical modeling activities, unlike the other problems, pre-service teachers were asked to prepare a poster. As in solving other problems, pre-service teachers were left unconstrained for the use of material and program to solve this problem. Pre-service teachers were given one week to prepare their posters. The groups that finished the other problems came together at the main meeting and explained the answers they gave to the problems to their other groupmates.

The challenges that could be faced during mathematical modeling activities were explained in the fifth week of the program. In the discussion rooms that followed, the groups worked together to find solutions to the "Weather Report Problem," "Paper Planes Problem," and "Highway Problem". When the groups were finished, they came to the main meeting and shared their thoughts on the issues. In this way, pre-service teachers defended their own ideas when there were opposing viewpoints and explained the solutions of their groups to peers in the other groups.

SATM and PSAT were used as the post-tests in the study's sixth and final week. Participants were encouraged once more not to ask for help when completing the PSAT, to do so in a manner that elementary school pupils might understand without using equations, and to do so without consulting their pre-test responses. The participants all fully completed the data collection tools.

2.5. Data Analysis

Statistical package program was used for the analysis of the data and the findings were interpreted by giving tables. The normality tests were conducted to see whether the pre-test and pos-test scores of SATM and PSAT met the normality assumption. Based on the findings, dependent samples *t*-test and simple linear correlation test were carried out when the data were normally distributed, while Wilcoxon signed ranks test, Spearman's rank difference correlation, Mann Whitney-U and Kruskal Wallis tests were carried out accordingly when the data were not normally distributed.

3. Findings

3.1. Findings Regarding the First Sub-Problem

The dependent samples t-test results, which were conducted to determine whether mathematical modeling instruction has an effect on the skills of problem solving, understanding the problem and carrying out the plan, are presented in Table 7.

Table 7

Dependent samples t-test results on the effect of mathematical modeling instruction on the skills of problem solving, understanding the problem and carrying out the plan

	Test	*N*	$\bar{X}$	*SD*	*df*	*t*	*p*
PSAT	Pre-test	12	65.79	14.87	11	-2.692	.021*
	Post-test	12	76.92	13.23			
Understanding the problem	Pre-test	12	25.88	5.84	11	-3.271	.007*
	Post-test	12	31.08	4.37			
Carrying out the plan	Pre-test	12	19.46	4.40	11	-3.140	.009*
	Post-test	12	23.21	3.99			

Note. *$p < .05$

As a result of the dependent samples t-test performed to determine whether there is a difference between the PSAT pre-test and post-test scores, a statistically significant difference [$t_{(11)} = -2.692$, $p < .05$] has been found between the mean pre-test scores ($\bar{X}_{\mathrm{PreTest}}$ = 65.79) and post-test scores ($\bar{X}_{\mathrm{PostTest}}$ = 76.92). The effect size calculated as a result of the test (d=0.8) shows that the level of the difference is high. In addition, there was a significant difference between the pre-test ($\bar{X}_{\mathrm{PreTest}}$ = 25.88) and post-test ($\bar{X}_{\mathrm{PostTest}}$ = 31.08) scores of understanding the problem [$t_{(11)} = -3.271$, $p < .05$]. There was a significant difference between the pre-test ($\bar{X}_{\mathrm{PreTest}}$ = 19.46) and post-test ($\bar{X}_{\mathrm{PostTest}}$ = 23.21) scores of the ability to carry out the plan [$t_{(11)} = -3.140$, $p < .05$]. The effect size calculated for both subscales (d=0.9) shows that the levels of the differences are high. These results show that mathematical modeling instruction has a significant effect on pre-service teachers' skills of problem solving, understanding the problem and carrying out the plan. Mathematical modeling instruction improves the problem solving skills of PPSTs in a positive way.

The Wilcoxon signed rank test results, which were conducted to determine whether mathematical modeling instruction has an effect on the skills of devising a plan and looking back, are presented in Table 8.

Table 8
Wilcoxon Signed Rank Test results on the effect of mathematical modeling instruction on the skills of devising a plan and looking back

	PreTest-PostTest	*N*	*Mean rank*	*Sum of Ranks*	*z*	*p*
Devising a plan	Negative ranks	4	3.88	15.50		
	Positive ranks	6	6.58	39.50	−1.227	.220
	Ties	2				
Looking back	Negative ranks	2	1.75	3.50		
	Positive ranks	1	2.50	2.50	−.272	.785
	Ties	9				

As a result of Wilcoxon signed rank test, statistically significant difference has not been found between devising a plan pretest-posttest scores [$z = -1.227$, $p > .05$] and looking back pretest-posttest scores [$z = -.272$ $p > .05$]. This situation shows that mathematical modeling instruction does not have a significant effect on pre-service teachers' skills of devising a plan and looking back.

The Dependent Samples t-Test results, which were conducted to determine whether the mathematical modeling instruction had an effect on the routine problem solving skills of PPSTs, are presented in Table 9.

Table 9
Dependent samples t-test results on the effect of mathematical modeling instruction on routine problem solving skills

	Test	*N*	$\bar{X}$	*SD*	*df*	*t*	*p*
Routine problem solving	Pre-test	12	41.00	6.82	11	−2.225	.048*
	Post-test	12	45.83	6.48			
Understanding the problem	Pre-test	12	15.50	2.46	11	−2.847	.016*
	Post-test	12	17.62	1.95			
Devising a plan	Pre-test	12	12.33	2.09	11	−1.374	.197
	Post-test	12	13.29	2.81			
Carrying out the plan	Pre-test	12	12.92	2.54	11	−2.640	.023*
	Post-test	12	14.75	1.92			

Note. *$p < .05$

As a result of the dependent samples t-test performed to determine whether there is a difference between the routine problems pre-test and post-test scores in the PSAT, a statistically significant difference [$t_{(11)} = -2.225$, $p < .05$] has been found between the mean pre-test scores ($\bar{X}_{\text{PreTest}} = 41.00$) and the post-test scores ($\bar{X}_{\text{PostTest}} = 45.83$). The effect size calculated as a result of the test (d=0.6) shows that the level of the difference is moderate.

In addition, there was a significant difference between the pre-test ($\bar{X}_{\text{PreTest}} = 15.50$) and post-test ($\bar{X}_{\text{PostTest}} = 17.62$) scores of understanding the problem [$t_{(11)} = -2.847$, $p < .05$]. There was also a significant difference between the pre-test ($\bar{X}_{\text{PreTest}} = 12.92$) and post-test ($\bar{X}_{\text{PostTest}} = 14.75$) scores of the ability to implement the plan [$t_{(11)} = -2.640$, $p < .05$]. The effect size calculated for both subscales (d=0.8) shows that the levels of these differences are high. These results show that mathematical modeling instruction has a significant effect on pre-service teachers' ability to solve routine problems, understand the problem and carry out the plan. On the other hand, no significant difference has been found between pre-test ($\bar{X}_{\text{PreTest}} = 12.33$) and post-test ($\bar{X}_{\text{PostTest}} = 13.29$) scores of devising a plan [$t_{(11)} = -1.374$, $p > .05$]. This shows that mathematical modeling instruction does not have an effect on the pre-service teachers' ability to plan in routine problem solving.

The results of Wilcoxon signed rank test, which was conducted to determine whether mathematical modeling instruction has an effect on pre-service teachers' ability to look back in routine problems, are presented in Table 10.

Table 10
Wilcoxon Signed Rank Test results on the effect of mathematical modeling instruction on the skill of looking back in routine problems

PreTest-PostTest	*N*	*Mean Ranks*	*Sum of Ranks*	*z*	*p*
Negative ranks	2	1.75	3.50		
Positive ranks	1	2.50	2.50	−.272	.785
Ties	9				

As a result of the Wilcoxon signed rank test, it was determined that there was no statistically significant difference between the pre-test and post-test scores of the ability to look back for routine problems [$z = -.272$, $p > .05$]. This shows that mathematical modeling instruction has no effect on pre-service teachers' ability to look back for routine problems.

The dependent samples t-test results, which were conducted to determine whether mathematical modeling instruction has an effect on the non-routine problem solving skills of PPSTs, are presented in Table 11.

Table 11
Dependent samples t-test results on the effect of mathematical modeling instruction on non-routine problem solving skills

	Test	*N*	$\bar{X}$	*SD*	*df*	*t*	*p*
Non-routine problem solving	Pre-test	12	24.79	9.37	11	−2.435	.033*
	Post-test	12	31.08	7.46			
Understanding the problem	Pre-test	12	10.38	3.80	11	−2.784	.018*
	Post-test	12	13.46	2.88			
Devising a plan	Pre-test	12	7.88	3.26	11	−1.603	.137
	Post-test	12	9.17	2.69			
Carrying out the plan	Pre-test	12	6.54	2.51	11	−2.471	.031*
	Post-test	12	8.46	2.36			

Note. $^*p < .05$

As a result of the dependent samples t-test performed to determine whether there is a difference between the pretest and posttest scores of non-routine problems in the PSAT, a statistically significant difference [$t_{(11)} = -2.435$, $p < .05$] has been found between the mean pre-test scores ($\bar{X}_{\text{PreTest}} = 24.79$) and post-test scores ($\bar{X}_{\text{PostTest}} = 31.08$). The effect size calculated as a result of the test (d=0.7) shows that the level of the difference is moderate.

In addition, there was a significant difference between the pre-test ($\bar{X}_{\text{PreTest}} = 10.38$) and post-test ($\bar{X}_{\text{PostTest}} = 13.46$) scores of understanding the problem [$t_{(11)} = -2.784$, $p < .05$]. There was also a significant difference between the pre-test ($\bar{X}_{\text{PreTest}} = 6.54$) and post-test ($\bar{X}_{\text{PostTest}} = 8.46$) scores of the ability to carry out the plan [$t_{(11)} = -2.471$, $p < .05$]. The effect sizes calculated for both subscales show that the level of the difference in problem understanding skill is high (d=0.8), while it is moderate (d=0.7) in carrying out the plan. These results show that mathematical modeling instruction has a significant effect on pre-service teachers' ability to solve non-routine problems, understand the problem and carry out the plan. On the other hand, no significant difference has been found between pre-test ($\bar{X}_{\text{PreTest}} = 7.88$) and post-test ($\bar{X}_{\text{PostTest}} = 9.17$) scores of devising a plan [$t_{(11)} = -1.603$, $p > .05$]. This shows that mathematical modeling instruction does not have an effect on the pre-service teachers' ability to devise a plan in non-routine problem solving. Mathematical modeling instruction has no effect on pre-service teachers' ability to look back for non-routine problems.

3.2. Findings Regarding the Second Sub-Problem

The dependent samples t-test results, which were conducted to determine whether the mathematical modeling instruction has an effect on the PPSTs' attitudes towards mathematics, are presented in Table 17.

Table 17
Dependent samples t-test results on the effect of mathematical modeling instruction on attitudes towards mathematics

Test	*N*	$\bar{X}$	*SD*	*df*	*t*	*p*
Pre-test	12	169.33	15.84	11	.287	.779
Post-test	12	168.08	19.40			

As a result of the dependent samples t-test performed to determine whether there is a significant difference between the pre-test and post-test scores of attitudes towards mathematics, non-significant difference [$t_{(11)}$= .287, $p > .05$] has been found between the pre-test scores ($\bar{X}_{\text{PreTest}}$ = 169.33) and the post-test scores ($\bar{X}_{\text{PostTest}}$ = 168.08). This shows that mathematical modeling instruction does not have a significant effect on pre-service teachers' attitudes towards mathematics.

4. Discussion, Conclusion and Suggestions

According to the findings obtained from the first sub-problem, in which the effect of mathematical modeling instruction on the problem solving skills of PPSTs was investigated, it was observed that there was an increase in the scores of PPSTs when their pre-test and post-test scores were compared. Therefore, it can be concluded that teaching mathematical modeling has a significant effect on PPSTs' ability to solve problems.

Kertil (2008) stated that even a short three-week study on mathematical modeling activities improved the problem-solving skills. Similar to this result, Bakırcı's (2016) study exploring the relationship between middle school students' involvement in mathematical modeling activities and PISA mathematics achievement level found that the experimental group's pre-test and post-test PISA mathematics scores were higher than the control group as a result of teaching with mathematical modeling activities. Cinislioğlu (2017) concluded that the problem solving skills of the experimental group were higher in the lessons taught with mathematical modeling activities in his study with middle school third grade students. In the study of Çavuş Erdem and Gürbüz (2018), which aimed to reveal the area measurement skills of seventh grade students in learning environments where mathematical modeling activities were used, they concluded that mathematical modeling activities positively affected students' learning about the subject. Çiltaş and Zihar (2018) stated that after the implementation of mathematical modeling activities, there was an increase in the post-test achievement scores of the students, so that the mathematical modeling activities provided a positive change in the learning of the subject of exponential expressions. Kurt (2019) also stated in his study with fifth grade students that the academic achievement of the students in the experimental group was significantly higher than the students in the control group.

The answers given to PSAT were analyzed by considering the problem solving steps of Polya. The problem solving steps of Polya (1997) consist of four steps. In the textbooks used in the classrooms, the solutions of the problems are provided in accordance with the problem solving steps of Polya. Primary school students use Polya's problem solving steps, but the PPSTs, who are the participants of our study, first learnt this subject in the Basic Elementary Mathematics course during their undergraduate education. As a result of the analyses, while mathematical modeling instruction has a positive effect on understanding the problem and carrying out the plan, it has no effect on devising the plan and looking back. Due to the examination system in Turkey, students have become good problem solvers by encountering many types of problems. It can be said that this is the reason why they are successful in understanding the problem. It is seen that they do not show the expected success in the planning step because they focus on the result of the problem, not the solution process. In the problem solving process, the solution should be checked not only at the end of the process but also at the previous steps. However, it was observed that the pre-service teachers did not control their solutions due to the anxiety of reaching the solution quickly. This hasty attitude was also reflected in the reporting process of mathematical modeling activities. Although they put forward good thoughts about the problem situation in the group, it was seen that they did not reflect the majority of the thoughts they put forward in the reporting process due to their hasty attitude.

Similarly, mathematical modeling instruction has a positive effect on routine problem solving and non-routine problem solving. While routine and non-routine problem solving skills had a positive effect on understanding the problem and carrying out the plan, it was seen that it had no effect on planning and looking back. The reason why the same results are seen in both problem types can be shown as that the pre-service teachers do not study enough with non-routine problems. Unlike other studies, this study associated PSAT with routine and non-routine problems and tried to reveal the deficiencies of students in these subjects.

As a result of the findings obtained from the second sub-problem in which the effect of mathematical modeling instruction on the attitudes of PPSTs towards mathematics was examined, it was seen that mathematical modeling instruction did not have a significant effect on the attitudes of PPSTs towards mathematics. Unlike this result, Korkmaz (2010) stated that there was a positive change in attitude scores in his study with primary school mathematics and PPSTs on mathematical modeling activities. Kal (2013) stated that mathematical modeling activities improved the students' attitudes towards solving mathematical problems in his study with 6th grade students. There are other studies showing that students' attitudes towards mathematics change positively when working with mathematical modeling activities rather than traditional problems (Blum, 2011; Bonotto, 2007; Bracke & Geiger, 2011; Kim & Kim, 2010; Maaß, 2011; Yu & Chang, 2009). Morgan (2010) stated that the attitude takes its final shape between the ages of 12-30 and it will be very difficult to change the attitudes after these ages. In this study, it is thought that the reason why the attitude did not change is due to the short time allocated for the implementation.

This study aims to shed light on the impact of mathematical modeling instruction on PPSTs' problem-solving skills and attitudes towards mathematics. It was noted that PPSTs found it very challenging to complete the PSAT without using equations. Even though they were aware that they had to complete the PSAT without creating an equation, some of the pre-service instructors chose to do so. PPSTs are required to be able to solve problems without using equations because primary school students are not taught how to set up equations.

It is incredibly challenging to alter one's attitude. When it comes to achieving success in mathematics, attitudes should not be disregarded. The majority of students form a negative attitude about mathematics, believing that the subject is challenging and that they will not be able to succeed in the subject. This unfavorable mindset first appears in elementary school and gets worse as students progress through their education (Baykul, 2020). Because of this, scientists who want to carry out a similar study can change people's attitudes toward math by extending the application period.

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