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A Mixed Method Research For Improving Mathematical Modelling Skills And Mathematical Resilience Of Preservice Teachers

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***Abstract:** In this study, a 12-hour "Mathematical Modeling Education Program" (MMEP), consisting of theoretical and practical activities was planned to examine its effect on the mathematical modelling knowledge and skills and mathematical resilience perception of preservice mathematics teachers. An embedded experimental mixed method research design was used and both quantitative and qualitative data were collected. The participants were 8 students, who voluntarily attended from 3rd grade students studying in secondary mathematics education department at a medium-sized university in Turkey in 2018-2019 academic year. Mathematical resilience scale, mathematical modeling theoretical knowledge test and mathematical modeling skill tests that prepared in two parallel forms as pre- and post-test were used. The findings showed that twelve hours of mathematical modeling training given to preservice teachers contributed positively to the mathematical modeling skills and mathematical resilience perceptions.*

***Keywords:** Mathematical resilience, mathematical modeling, pre-service teachers.*

I. INTRODUCTION

As a result of the developments in science and technology today, raising individuals who understand the importance of thinking and creativity has become a necessity of the era. In the context of this requirement, mathematics education is very important in raising individuals, who understand thinking and think creatively, to find effective solutions to problems and transfer their knowledge to daily life. As a result of these changes, the curriculum is also effected and the mathematics curricula put into practice in many countries have made arrangements in line with the new requirements. In this context, mathematical modeling has recently become one of the areas of importance, due to its application in the solution of many problems in technology, science and daily life, and it is observed that mathematical modeling has been extensively included in the curriculum (MoNE, 2005; 2018).

Modeling is a complex process consisting of multiple stages. It is important to interpret and process how and when to use which detail. The model occurs at the end of the process with certain modeling skills. Modeling that works in different areas generally refers to the process used to create an example of a real-life situation. In the literature, mathematical modeling is expressed as the process of expressing real life problems with mathematical representations (Blum and Borromeo Ferri, 2009). In this context, "model" is the product that emerges at the end of mathematical process, and "modeling" is the process of constructing a model of a real-life problem with mathematically different representations as a result of the process steps.

In the literature, there are various studies related to the mathematical modeling process and researchers express the processes differently in this regard. (Müller and Witmann, 1984; Mason; 1988; Berry and Houston; 1995; Doerr, 1997; Blum, 1991; Borromeo Ferri, 2006; Maass, 2006). Borromeo Ferri (2006) explains the phases in modeling as real-life situation, mental expression of the situation, real models, mathematical models, mathematical results and accordingly real results. The stages related with transition process between these phases have been expressed as understanding the task, simplification, mathematisation, mathematical work, interpretation and verification.

The emphasis in the new mathematics program emphasizes the importance of mathematical modeling skills as well as the importance of the value given to mathematics, the development of individuals' problem-solving skills and the

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application of these skills in real life problems (MoNE, 2005). One of the important personality trait required by our age for individuals is not to give up when encountered with a problem situation. At this point, the concept of "resilience" comes into focus. The term mathematical resilience that has recently entered the literature is generally defined as the student's willingness to continue struggling and discuss, reflect and research when faced with difficulty (Johnston-Wilder and Lee, 2010). Affective skills, such as positive attitude towards mathematics, the belief that mathematics can be done, and the perception that mathematical knowledge can be improved is directly related to mathematical resilience. Mathematical resilience can also be expressed as the willingness of students to approach mathematics with a successful outcome, to continue struggling against difficulties and to discuss, reflect and research. The perception of mathematical resilience enables the learner to overcome the obstacles that mathematics can provide. Hutauruk and Priatna (2017) stated that the perception of resilience is not static and can be improved or deteriorated. In this context, it has been revealed that the perception of mathematical resilience can be changed with practices.

The perception of mathematical resilience includes four related factors: value, struggle, development, and resilience. The value factor, the first of which is the mathematical resilience factor, states how valuable students find their mathematics lessons in achieving their current or future goals, and that it is related to internal and external motivation and the role of self-regulation (Kooken et al., 2013). The struggle factor means having the belief that the student will have to overcome difficulties in the learning process, since mathematics is a difficult discipline to learn. The development factor of the perception of mathematical resilience expresses the belief that the level of mathematics knowledge has a developable and shapable feature. The fourth and last hypothetical factor, the basis of resilience, is based on the literature on the problem of mathematics learning and psychological resilience defined as a positive response to a serious negativity.

The importance of mathematical modeling skills and the development of these skills of individuals and their application to real life has been stressed in mathematics education programs, applied in our country since 2005 (MoNE, 2005, 2013, 2018). In line with the point of view of the program and this perspective, the tasks and interactions of teachers and students have been differentiated, and techniques have been enriched for the changes in the learning environment and the evaluation of mathematical gains. In this context, mathematics teachers working in schools also need to change their practices and plan their teaching according to new approaches.

In the literature, the studies point out the lack of mathematical modeling skills of students and teachers both in Turkey and in other countries (Korkmaz, 2005; Ural, 2014, Urhan and Friends, 2016; Akgün, 2013; Tekin Dede and Yılmaz, 2013; Bilen and Çiltaş, 2015). The results of the studies stated that one of the factors preventing the use of modeling activities in mathematics teaching was the teacher's lack of knowledge of modeling activities. Therefore, many research studies, that focus on improving the difficulties of preservice mathematics teachers in mathematical modeling skills, have been carried out. According to Borromeo Ferri (2014), there are four basic competencies that teachers should have in teaching mathematics based on modeling. These are theoretical dimension, task dimension, instructional dimension and diagnostic dimension. The theoretical dimension covers theoretical information about the mathematical modeling process and scope. The task dimension includes knowing multiple solution approaches and analyzing them in terms of process. The instructional dimension is shaped by thinking about planning, conducting, interfering, and supporting the lesson with mathematical modelling. Finally, the diagnostic dimension includes determining and evaluating what is done at the steps of the modeling process.

When the competencies stated by Borromeo Ferri (2014) are examined, it is worth noting that the dimensions are prerequisite for each other. For this reason, teachers, who are the architects of the learning environment in schools, are expected to be equipped with the theoretical and task dimensions related to the modeling process during their teacher training education. In addition, it is thought that teachers, who have an important role as role models, should give value to mathematics and have a high sense of resilience. It is expected that this will positively affect their students' success. For this reason, in this study, "Mathematical Modeling Education Program" (MMEP), consisting of theoretical and practical activities planned to develop the mathematical modelling knowledge and skills and mathematical resilience perception of preservice teachers was planned and the following research questions were examined:

- ✓ What is the effect of MMEP on preservice teachers' competencies regarding the theoretical knowledge of mathematical modeling?
- ✓ What is the effect of MMEP on preservice teachers' mathematical modeling skills?
- ✓ How do preservice teachers solve a mathematical modelling problem?
- ✓ What is the effect of MMEP on preservice teachers' resilience perception?

II. METHOD

RESEARCH DESIGN

This research is intended to examine the development of mathematical modelling skills and mathematical resiliency of preservice mathematics teachers during a mathematical modelling education program through an embedded experimental mixed method research design. Since the research questions require a combination of qualitative and quantitative methods and it was important to describe the mathematical modelling competencies of preservice teachers in the experimental research, mixed research design was preferred (Creswell and Plano Clark. 2007; Creswell, 2008). The research design of the study can be schematized as in Figure 1.

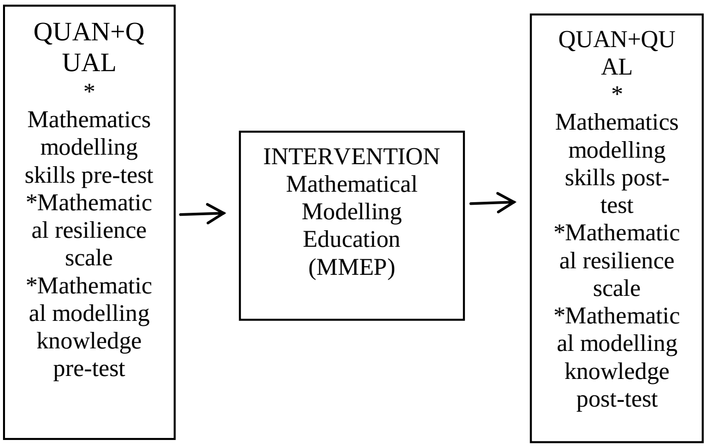

Figure 1: Research design of the study

INTERVENTION - MATHEMATICAL MODELLING EDUCATION PROGRAM (MMEP)

Mathematical Modelling Education Program (MMEP) is a 12-hour program that consists of theoretical and practical activities for the development of mathematical modeling skills of preservice mathematics teachers. Mathematical modeling theoretical part includes presentations that focused on what mathematical modeling is and the processes it contains, why it matters and where it is encountered in daily life. This part was planned in an active learning environment. Practical part includes examples of mathematical modeling activities. The activities were carried out in pairs and discussed in whole group.

PARTICIPANTS

The participants were 8 students, who voluntarily attended from 3rd grade students studying in secondary mathematics education department at a medium-sized university in 2018-2019 academic year. The students in the study group completed their courses in general education in the field of mathematics and pedagogical courses, and in the period of study, they were taking pedagogical content knowledge training courses such as Teaching Mathematics. preservice teachers in the study group had not taken a course before in mathematical modeling.

III. DATA COLLECTION TOOLS

In the study; mathematical resilience scale, mathematical modeling theoretical knowledge test and mathematical modeling skill tests that prepared in two parallel forms as pre- and post-test were used.

MATHEMATICAL RESILIENCE SCALE

Mathematical Resilience Scale was applied to determine the change in preservice mathematics teachers' perception of mathematical resilience before and after the application. The Mathematical Resilience Scale, which was created by Kooken, Welsh, Mccoach, Johnson-Wilder and Lee (2016) and adapted from English to Turkish by Gürefe and Akçakın (2018), was used in the study. The scale consists of 19 items including the values, struggle, development sub-dimensions. The Cronbach Alpha reliability coefficient of the scale was found to be .92, .80, .76 and .87, respectively for the value, struggle and development sub-dimensions and the entire scale.

MATHEMATICAL MODELING THEORETICAL KNOWLEDGE TEST

In order to determine the change in the mathematical modelling theoretical knowledge level of preservice mathematics teachers about mathematical modeling skills before and after the application, a test consisting of 5 open-ended questions was created and this form was applied before and after MMEP. The questions were determined by expert opinion and were evaluated by two raters. The open-ended questions in the test were as follows:1-What is a model? Make the definition.; 2-What is mathematical modeling?; 3-What are the steps of mathematical modeling?; 4-What are the features of mathematical modeling problems?; and 5-Are there any qualifications required for mathematical modeling? If there are, what are they?

MATHEMATICAL MODELING SKILL TESTS

In order to measure the mathematical modeling skills of preservice teachers participating in the research, two parallel skill tests consisting of three questions were prepared. The test questions were selected among the modeling questions (Bukova Güzel, 2016) that were previously applied, and the questions that exist in the two tests were chosen in parallel with each other by taking the expert opinion.

IV. DATA ANALYSIS

Quantitative and qualitative analysis were done in the study. Descriptive and inferential statistics for quantitative data was performed with SPSS 21.0.

In the analysis of Mathematical Modeling Theoretical Knowledge Test, each question was coded by two different experts. They were scored as 0 points for "Empty or completely wrong answer"; 1 point for "Partially correct answer" and 2 points for "Completely correct answer" and total score of each participant was calculated.

Consistency of scores between two coders was calculated as r = 0.87 and r = 0.91 for pretest and posttest. The difference between the pretest and posttest mean scores was examined by Non-parametric Wilcoxon Signed Ranks Test.

The score of each preservice teacher was found by using the Mathematics Modelling Performance Rubric for the analysis of preservice teachers' modeling skill tests. The mathematical modeling problems in the tests used to determine the skill levels of the participants related to mathematical modeling were coded with the rubric used by Korkmaz (2010). This scoring key includes the stages of Borremeo Ferri's (2006) modeling process which are simplifying, mathematizing, working mathematically, interpreting and validating stages. The coders completed their scoring by giving separate points to each stage of the mathematical modeling process between 1-4 according to the levels specified in the scoring key according to the performances of the preservice teachers. For example, the levels determined for the simplifying step are as follows:

Simplifying:

- ✓ Level 1: The student does not show a sign that s/he understands the real life problem and has failed to form an opinion that s/he understands the simplified version of the situation.
- ✓ Level 2: Despite failing to take into account the impact of one or more of the major components, s/he shows a sign of understanding the real-world problem to a lesser extent.
- ✓ Level 3: It shows that s/he understands the real world problem and can handle all the basic components related to the problem correctly.
- ✓ Level 4: It can refer to all of the features that show that the problem situation is comprehended in depth and comprehensively.

Then, the sum of sub-dimension scores were calculated and the performance score of the preservice teacher was calculated. Two coders determined the performance scores, and the consistency of the scoring of the coders was examined for the reliability of the study. There was a r = 0.97 relationship between the coder scores of the mathematical modeling skill pre-test, and r = 0.91 between the coder scores of the mathematical modeling skill post-test. The mean difference between the pre-test and post-test to evaluate the participants' development was examined with the Non-parametric Wilcoxon Signed Ranks Test.

In order to examine the effect of MME with only quantitative data, it would not be sufficient to examine it with open-ended questions in mathematical modeling skill tests, Borromeo Ferri's (2006) mathematical modeling steps, and descriptive analysis was obtained by the coders.

V. RESULTS

In this section, results related to the research questions mentioned above have been presented.

QUANTITATIVE RESULTS RELATED WITH THEORETICAL KNOWLEDGE ABOUT MATHEMATICAL MODELLING

A Wilcoxon Signed Rank test showed that there was a significant difference (Z = -2,539, p< 0.05) between scores given for the pre-test compared to the post-test knowledge scale in favor of post-test scores. The mean score for the pre-test was 3,38 compared to 13,12 for post-test of mathematical modelling knowledge test.

QUANTITATIVE RESULTS RELATED WITH MATHEMATICAL RESILIENCE OF PRESERVICE TEACHERS

The result of Wilcoxon Signed Rank test to compare the pre- and post- applications of mathematical resilience showed that there was a significant difference (Z = -2.527, p<0.05) in the mean scores. The mean score of preservice teachers increased from 112.75 to 119,75. For the sub-dimensions of the mathematical resilience scale, the results of mean scores and the z value for the Wilcoxon signed rank test were obtained as in following Table 1. There was a significant difference between pre- and post-applications of the scale in growth subdimension. The difference was not statistically significant for value and struggle subdimensions.

	Mean score Pre-test	Mean score Post-test	Z value
Value	51,75	52,00	-0,271 (p>0.05)
Struggle	37,87	37,75	-0,345 (p>0.05)
Growth	23,62	28,62	-2,117 (p<0,05)

Table 1: Quantitative results related with mathematical modelling skills of preservice teachers

The result of Wilcoxon Signed Rank test to compare the pre- and post-tests of mathematical modelling skills test showed that there was a significant difference (Z = -2.524, p< 0.05). The mean scores of participants for pre- and post-test were 35,12 and 58,12, respectively. For each subdimension, mean scores and z value for the Wilcoxon signed rank test for pre- and post-test are presented in Table 2.

	Mean score Pre-test	Mean score Post-test	Z value
Simplifying	7,7500	12,0000	-2,529 (p< 0.05)
Mathematizing	6,7500	12,0000	-2,545 (p< 0.05)
Working mathematically	6,8750	12,0000	-2,526 (p< 0.05)
Interpreting	7,3750	12,0000	-2,529 (p< 0.05)
Validating	6,3750	10,1250	-2,536 (p< 0.05)

Table 2: Qualitative results related with mathematical modeling skills of preservice teachers

When the responses of preservice teachers to the mathematical modeling skills pre-test are analyzed in terms of modeling steps, the expressions of the thinking processes required for the simplifying, mathematizing, working mathematically, interpreting and validating steps were not observed. For example, it is understood that by drawing a triangle on the picture in order to create a simpler mathematical representation that will lead to a better understanding of the problem addressed in the student simplifying step, the participant P6 attempts to fulfill the requirements of the mathematizing step even if it is not stated.

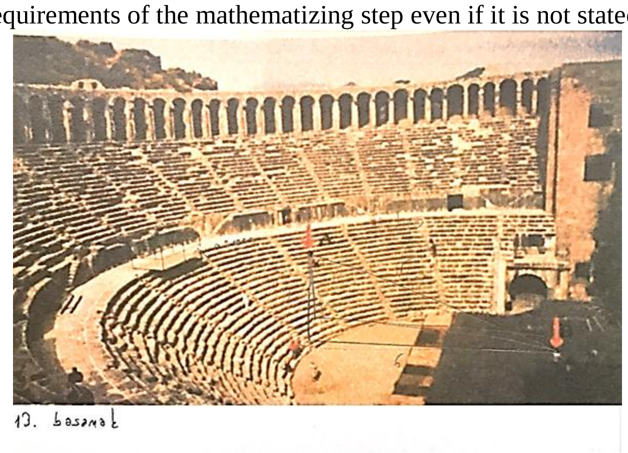

Figure 2: The solution presented by P6 in mathematical modelling skills pre-test

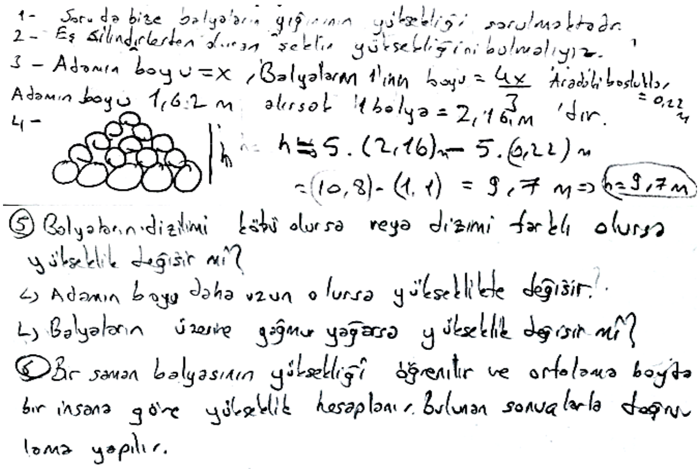

Figure 3: The solution presented by P6 in mathematical modelling skills post-test

The same participants' solution in the post-test for the similar problemis given in figure 3. When the given answer is examined in terms of modeling steps, the expression of the thinking processes required for the simplifying, mathematizing, working mathematically, interpreting and validating steps are clearly seen. He showed that he understood the real-world problem in the simplifying step and was able to transfer to the mathematizing step by correctly addressing the basic components related to the problem. He was able to perform operations with the model in a mathematically valid manner and was able to come up with a solution for the mathematical form of the problem. Considering the simplified form of the problem, he was able to interpret the solution. He was able to provide a justified solution for the simplified form of the problem, and reflect it on an inner insight gained by the problem under consideration.

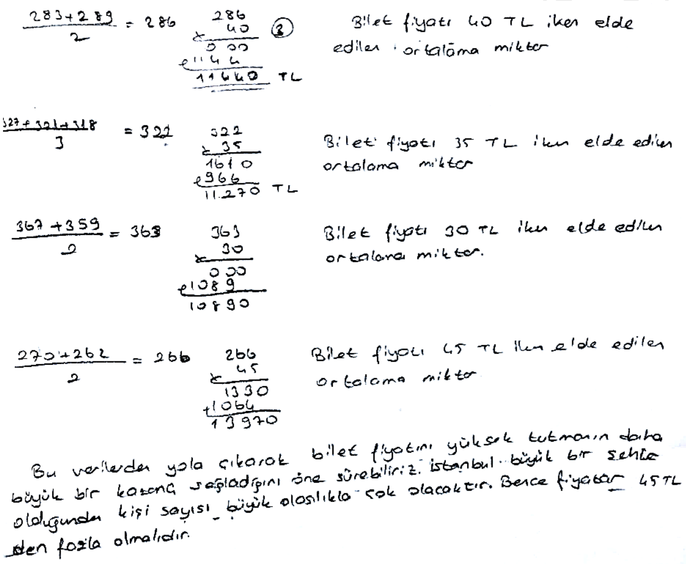

Figure 4: The solution presented by P8 in mathematical modelling skills pre-test

The answer given by the participant named P8 to the problem in modeling skill test pre-test is given above in figure 4. When the given answer is examined in terms of modeling steps, the expressions of the thinking processes required for the steps of simplifying, mathematizing, working mathematically, interpreting and validating are partially seen.

The preservice teacher showed that an understanding of the real-world problem in the simplifying step, and he was able to move to the mathematizing step by correctly addressing the basic components related to the problem. He was able to perform operations mathematically and come up with a solution for the mathematical form of the problem. In the interpreting step, he was in an effort to interpret the solution put forward. However, although he did not make an inaccurate inference and did not clearly establish the link between the problem under study and the simplified form, he made an effort to develop a justified solution for the simplified version of the problem.

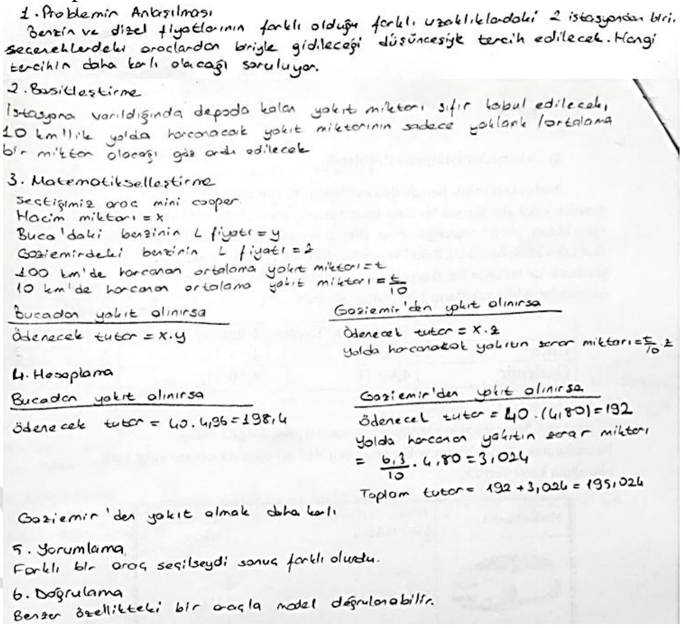

Figure 5: The solution presented by P8 in mathematical modelling skills post-test

The answer given by the participant named P8 to the problem in mathematical modeling skills post-test is given above in figure 5. When the given answer is analyzed in terms of modeling steps, the expression of the thinking processes required for the simplifying, mathematizing, working mathematically, interpreting and validating steps are quite clearly seen. In the simplifying step, he showed in detail that he understood the real-world problem and was able to make transition to the mathematizing step by correctly addressing the basic components related to the problem. He was able to perform operations in a mathematically valid manner and came up with a solution. Considering the simplified form of the problem, he was able to interpret the solution. He was able to present the solution of the problem and reflect it for validation of the problem.

VI. DISCUSSION

The "Mathematical Modeling Education Program" (MMEP), consisting of theoretical and practical activities, was planned in the study to improve the theoretical knowledge of preservice mathematics teachers about mathematical modeling and the competencies of the modeling modeling and to examine the change of resilience perception. At this stage, the findings showed that twelve hours of mathematical modeling training given to preservice teachers contributed positively to the mentioned mathematical modeling and mathematical resilience perceptions. Preservice mathematics teachers who attended the training had not taken a course on mathematical modeling before. For this reason, it is expected that preservice teachers to score low in theoretical knowledge pretest related to mathematical modeling. The fact that there was a statistically significant result between before and after the education showed that the preservice teachers achieved the goals related to MMEP. In the pretest, it was recorded that preservice teachers had some inaccurate opinions about modeling definition, steps and requirements. In the mathematical modeling theoretical knowledge post-test, it was noted that preservice teacher wrote the definition of mathematical modeling correctly and that they had some correct views with their own expressions regarding mathematical modeling steps and requirements. Making inferences and using different examples with their own expressions was interpreted as an indicator of their internalization

When the mathematical resilience scale, applied before and after MMEP, was examined, it was concluded that the preservice teachers' mathematical resilience perceptions were positively affected. In the analyzes conducted to examine the change in the views on the sub-dimensions related to resilience perception, a significant difference was found for the development stages, while no significant improvement was observed in the value and struggle step. It is thought that this study group is the third year students of mathematics education as the reason why there was no difference between preservice teachers' findings before and after the application in terms of value and struggle sub-factor, which is one of the sub-factors of mathematical resilience scale. Because an individual who has chosen mathematics teaching as a profession is probably aware of the value of mathematics, its importance, benefit and necessity in life and has an effort to solve mathematical problems. Thus, there was no difference in the opinions of the preservice teachers regarding the sub-factors of the value and struggle that they had also a high score in the pretest. In terms of development sub-dimension, it is thought that the 12-hour MMEP given was the reason for a positive development between the findings of preservice teachers before and after the application. In the examples and studies studied during MME, everyone can have difficulties in mathematics, if he / she works correctly and tries, he can be successful in mathematics, making mistakes in mathematics will improve people, every student can do mathematics, math skills are not innate, everyone, not only smart people, can be successful in mathematics and fail in mathematics. It is emphasized that there are many ways to foster someone to be successful in mathematics. At this stage, it is thought that MMEP given to preservice teachers contributes to mathematical perceptions of resilience. In the literature, it is also pointed out that mathematical resilience can be developed in learning environments by appropriate methods of learning mathematics (Johnston-Wilder et al., 2015).

Post-test scores of modeling skills of preservice teachers after MMEP application showed a positive difference compared to pre-test scores. Regarding mathematical modeling activities, preservice mathematics teachers were found to have difficulty in organizing the information given in the problem. During dealing with the activities, preservice teachers stated that the information given in the problem was not sufficient for the solution of the problem. The preservice teachers had a low score in the pre-test of mathematical modeling skill test in terms of the average score due to the lack of knowledge about modeling and mathematical modeling process. However, as a result of MMEP, as a result of informing preservice teachers related to mathematical modeling, the average score of the post mathematical modelling skill test increased. Studies in the literature indicate that preservice mathematics teachers’ mathematical modelling skills and mathematical perceptions can be improved through mathematical modelling hands-on activities (Akgün, 2013; Eraslan, 2012; English, 2006). It was observed that preservice teachers who could not reach the solution of the questions in the pre-test succeeded in solving the modeling activities as a result of the application and were able to reach and explain the results. Along with the modeling process, students have the opportunity to produce and develop original mathematical ideas in accordance with the problems. At this point, modeling is a learning process that nurtures and encourages curiosity so that learners can learn more. It is thought that individuals who are aware of the mathematical modeling process increase their mathematical modeling skills. It has been revealed that having proficiency in terms of mathematical modeling would have a positive impact on one’s academic achievement and mathematics achievement of students who have been educated with mathematical modeling have been increased and also structured teaching with mathematical modeling activities is very effective in increasing mathematical success (Özturan Sağırlı, Kırmacı and Bulut, 2010; Çiltaş and Işık, 2012; Yıldırım and Işık, 2013).

VII. CONCLUSION AND SUGGESTIONS

The inclusion of mathematical modeling in the curriculum, which has become important in the developing world, requires importance in teacher education. It was concluded that preservice teachers who received a training planned according to new teaching approaches in mathematical modeling developed their knowledge on mathematical modeling as well as their mathematical modeling skills. Modeling problems, instead of solving the problem in a traditional way, allows students to develop their understanding of mathematics in various directions. Therefore, it is seen that the ability to create a mathematical model will make positive contributions to mathematics teaching.

As a result of the education given in the study, the mathematical resilience perceptions of preservice teachers was also improved. There was no difference in terms of the values and struggle sub-factors of mathematical resilience in terms of preservice teacher who had already understood the value of mathematics and stated that it could be challenged in mathematics, but the belief that everyone could do mathematics emerged with post-test findings. This is the result of their knowledge about mathematical modeling and their perception that the mathematics program goal is within the framework of "anyone can do mathematics."

As a result, it is thought that the students, who experience the mathematical modeling process and the development of mathematical modeling skills appropriately, understand the value of mathematics and be active in making mathematics without giving up in the face of difficulty.

According to the results of this study; learning environments can be tailored to mathematical modeling. In preservice or in-service teachers' education, mathematical modeling can be experienced with sample applications. All teachers can be informed about what mathematical resilience is, its importance and how to use it effectively can be informed in teacher training. The scope of the teaching mathematics methods courses can be extended to include mathematical modeling. In order to create awareness in terms of mathematical resilience, it should be given importance starting from preschool.

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