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TEACHERS' OPINIONS ON THE APPLICABILITY OF MODEL ELICITING ACTIVITIES

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Abstract

This study aimed to reveal the opinions of mathematics teachers about the applicability of model-eliciting activities after their in-class practices within the scope of mathematical modeling training given to mathematics teachers. The study was based on phenomenological study design, one of the qualitative research methods. A total of 16 mathematics teachers who took the graduate mathematical modeling course in the 2021-2022 academic year at a state university participated in the study. In determining the participants, the criterion sampling method, one of the purposeful sampling types, was used. The data of the study were collected with a semi-structured interview form. A content analysis technique was used to analyse the data. Study findings indicate that most of the teachers think that the applicability of MEA (Model Eliciting Activities) in school programs is limited. Participants emphasized the time-consuming nature of the MEA, curriculum intensity, students' lack of familiarity, the difficulty of application in crowded classrooms, insufficient class hours, and teachers' lack of sufficient knowledge as reasons for this situation. The difficulties that may arise in MEA applications were expressed as classroom management, teaching process, and teaching resources in terms of teacher dimension, and difficulties related to readiness and modeling process in terms of student dimension. Most of the participants had difficulty in selecting MEAs suitable for the level of students for the applications. The mathematical modeling training provided was found to be beneficial academically, professionally, and for the students. After the training, the participants developed positive attitudes toward using MEA in their lessons. Based on the participants' suggestions and the results of the study, some suggestions were made to practitioners and researchers for further application of MEA in schools.

Keywords: Model eliciting activities; mathematical modeling; mathematics teachers

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1. Introduction

One of the main goals of mathematics teaching is to enable students to use their mathematical knowledge and skills to produce solutions to the problems they encounter in life (Blum & Leiβ, 2007). Mathematics courses should therefore include real-life problems so that students can gain experience in the solution processes of such problems (Kaiser, 2007). Mathematical modeling has an important role in including real-life problems in mathematics courses (Kaiser & Schwarz, 2006). The basic aim of mathematical modeling is to make mathematics education engaging and to help students enjoy mathematics not only for their academic achievement but also to discover how they can relate mathematics to real-life situations (Asempapa & Sturgill, 2019). In many countries around the world, teaching and learning mathematical modeling has become an important subject area in terms of mathematics education and educational standards. Many countries include mathematical modeling in their school curricula (Borromeo-Ferri, 2020). Mathematical modeling has a unique place in mathematics curricula as it has the potential to enable students to use mathematics in flexible, creative, and powerful ways (Blum, 2015; Lesh, 2012; Pollak, 2011). Considering the objectives of the mathematics curriculum in Turkey, the emphasis on student's ability to understand mathematical concepts and to use these concepts in daily life is noteworthy (Ministry of National Education [MoNE], 2018). In addition, when the objectives of the curriculum are examined, students are expected to be able to develop mathematical literacy skills and use them effectively (MoNE, 2018). It is stated by researchers that Model Eliciting Activities (MEA) prepare the ground for the acquisition of these competencies (Sole, 2013). As a matter of fact, the Programme for International Student Assessment (PISA, 2018) identifies mathematical modeling as a central aspect of mathematical literacy and emphasizes the role of strategic decisions in the selection of algorithms, concepts, and procedures when seeking mathematical solutions to contextual problems (OECD, 2019). In this context, the mathematical modeling method and MEA also support the development of mathematical literacy skills, which are among the 21st-century skills. These benefits of mathematical modeling will emerge when teachers understand modeling and how to use it in their practice (Asempapa, 2022). Nevertheless, the successful application of mathematical modeling remains a challenge for many mathematics teachers and pre-service teachers (English, 2010). The main reason for this difficulty is teachers' misconceptions about teaching and learning mathematical modeling (Asempapa, Sturgill & Adabor, 2017; Spandaw & Zwaneveld, 2010; Wolfe, 2013). Studies show that most teachers have misconceptions about mathematical modeling and the modeling process (Spandaw & Zwaneveld, 2010; Wolfe, 2013) and lack of knowledge about mathematical modeling practices (Blum, 2015; Borromeo-Ferri, 2018). For the effective application of the mathematical modeling method in classrooms, teachers are expected to create environments that will allow students to identify and interpret their current solution paths as well as to organize and develop these solution paths and their thoughts (Doerr, 2006).

1.1. The role of the teacher in mathematical modeling.

Teachers' attitudes and knowledge toward mathematical modeling instruction greatly influence their students' mathematical modeling learning experiences (Galbraith, 2017). Besides, teachers who will bring MEA into the classroom need to have certain competencies to reflect the mathematical modeling process accurately. Borromeo-Ferri (2014) developed a model explaining the teaching competencies required for mathematical modeling in four dimensions as a result of long-term studies. In this model, the competencies that teachers should have in the mathematical modeling process are classified under the theoretical dimension, activity dimension, instructional dimension, and diagnostic dimension. The first dimension, the theoretical dimension, focuses on the question "What is meant by mathematical modeling?" and how it is interpreted internationally. In this dimension, Borromeo-Ferri (2014) states that teachers should be aware that mathematical modeling is a complex process that can be represented by different modeling cycles that show the transition processes between the real world and mathematics. For this dimension of competence, however, teachers should know at least some of the mathematical modeling cycles. This means that pre-service or in-service teachers should work on a modeling problem (Borromeo-Ferri, 2014). In the second dimension, the activity dimension, teachers should be able to answer the question "What are the characteristics of a good MEA?". Borromeo-Ferri (2014) states that it is important and useful for teachers to design an MEA for the development of this competence. In the teaching dimension, planning the lesson with mathematical modeling problems is at the forefront. The diagnostic dimension finally emphasizes teachers' competencies to recognize difficulties and errors at different stages of the modeling process and suggests that teachers should have the knowledge to address them. Borromeo-Ferri (2014) points out that by training teachers in these competencies, they will have a good foundation on which to fulfill their responsibilities.

The most important task in creating learning environments for students to recognize and apply mathematical modeling and to develop their mathematical modeling competencies falls to teachers. On the other hand, studies show that teachers do not have enough experience in mathematical modeling and rarely include modeling activities in their mathematics lessons (Blum, 2002; Blum & Borromeo-Ferri, 2009; Frejd, 2012). Mathematics teachers' lack of experience in mathematical modeling causes them to think of mathematical modeling method as complex and difficult and not to apply it although it has an important place in the curriculum (Borromeo-Ferri, 2010; İncikabı & Biber, 2020). Blum (1996) divides the difficulties experienced in the mathematical modeling process into three categories: student-induced, teacher-induced, and material-induced, and considers the factors such as teachers' changing curricula, limited class time, time-consuming both the creation and application of mathematical modeling, student profile, and expectations and not seeing mathematical modeling as necessary as teacher-induced difficulties. However, in many studies conducted in Turkey, it was concluded that teachers had difficulties in obtaining MEAs suitable for the lesson; therefore, they could not implement them (Bilgili & Çiltaş, 2019; Deniz & Akgün, 2016; Özgür-Şen, 2020). It is seen that there are few studies examining how to teach mathematical modeling to students, and it is stated that most teachers and pre-service teachers do not have the pedagogy to support effective modeling practices (Borromeo-Ferri, 2018; Gaston & Lawrence, 2015). Teachers should therefore be taught not only what mathematical modeling is, but also how to effectively incorporate it into lessons and how to apply it in their classrooms (Asempapa & Sturgill, 2019; Gaston & Lawrence, 2015). Within this scope, teachers need to gain experience in mathematical modeling applications. In this study, in line with the postgraduate education given to mathematics teachers on mathematical modeling and its applications, it was ensured that the teachers had experience in classroom MEA applications. Then, teachers' opinions about the MEA practices were obtained. The first step for mathematical modeling to be implemented at the desired level in teaching environments and to achieve its purpose is for teachers to have positive views on the use of MEA in the mathematics teaching process (Urhan & Dost, 2016). Therefore, this study aimed to reveal the opinions of mathematics teachers about the applicability of an MEA after their in-class practices within the scope of mathematical modeling training given to mathematics teachers. It is thought that the results to be obtained from the study are important to improve teachers' perspectives on the place and importance of mathematical modeling in mathematics teaching to determine the obstacles to the application of modeling activities in the teaching process and to take measures. In this regard, the study sought an answer to the question "What are the opinions of mathematics teachers about the applicability of an MEA after the in-class applications they made within the scope of the mathematical modeling training they received?".

2. Method

2.1. Research Design

This study is a qualitative study that aims to reveal the opinions of mathematics teachers about the applicability of an MEA after their in-class practices within the scope of mathematical modeling training. The study was based on phenomenological study design, one of the qualitative research methods. Phenomenological research is a qualitative research method that allows people to express their understanding, feelings, perspectives, and perceptions about a particular phenomenon or concept and to describe how they experience this phenomenon (Rose, Beeby & Parker, 1995). In the phenomenological approach, it is necessary to examine the phenomenon holistically by considering it with experiences (Van Manen, 2007). In-depth interviews are often preferred in phenomenological design; in fact, this technique is characterized as the main data collection tool in phenomenological research (Eddles-Hirsch, 2015). In phenomenological research, all interviewees must have experienced the phenomenon in question or have established close relationships with people who have experienced this phenomenon (Rolfe, 2006). In this study, mathematics teachers had the experience of selecting and implementing MEA in their classrooms within the scope of the graduate mathematical modeling course. Then, the participants' opinions on the applicability of an MEA were taken. Within this scope, the study adopted a phenomenological approach to reveal the participants' understandings, perspectives, and perceptions about the applicability of MEA, and to describe and understand their experiences.

2.2. Participants

A total of 16 mathematics teachers who took the graduate mathematical modeling course in the 2021-2022 academic year at a state university participated in the study. None of the participants had received mathematical modeling training before. In determining the participants, the criterion sampling method, one of the purposeful sampling types, was preferred. In the criterion sampling method, the group to be studied should have certain qualities suitable for the problem situation (Büyüköztürk, Kılıç- Çakmak, Akgün, Karadeniz & Demirel, 2020). The criteria for determining the sample in this study were that the participants were working in the MoNE, had participated in mathematical modeling training, and had classroom practice experience in MEA. The study group participated in the study voluntarily. The identities of the participants were kept confidential and coded as T1, T2, ..., T16. Information about the participants' professional experience, the grade levels they taught, and the frequency of using MEA in their classes before mathematical modeling education is given in Table 1.

Table 1. Information about the participants

Participants	Years of Professional Experience	Grade Levels Taught	Frequency of MEA Use in Pre-training Classrooms
T1	2	5, 6, 7, 8	Rarely
T2	5	5, 6, 7, 8	Rarely
T3	6	6, 8	Rarely
T4	3	9, 10, 11	Rarely
T5	4	5, 6, 7, 8	Rarely
T6	7	5, 6, 7	Rarely
T7	3	5, 6, 7, 8	Rarely
T8	2	5, 6	Rarely
T9	2	5, 6, 7, 9, 10, 11	Never
T10	2	6, 7, 8	Rarely
T11	9	6, 8	Rarely
T12	8	5, 6, 7, 8	Rarely
T13	3	6	Rarely
T14	3	5, 6, 8	Rarely
T15	5	5, 6, 7, 8	Rarely
T16	3	5, 6, 8	Never

As can be seen in Table 1, the professional experience of the participants varies between 2 and 9 years. Considering the grade levels at which the participants teach, it is seen that they mostly teach at the secondary school level. However, it is seen that T4 gave lessons only at the high school level, while T9 gave lessons at both secondary and high school levels. Considering the frequency of mathematics teachers' use of MEA in their classes before the graduate mathematical modeling course, it is seen that two of the participants (T9, T16) never used MEA in their classes. It is noteworthy that the other 14 participants rarely included MEA in their lessons, but none of the participants included MEA frequently.

2.3. Data collection tools and data collection

In the study, a semi-structured interview form was used as a data collection tool to determine the opinions of mathematics teachers on the applicability of an MEA. The interview questions in the studies of Deniz and Akgün (2017) and Urhan and Dost (2016) were utilized in the creation of the interview form. The prepared interview form consists of 8 questions. The interview questions were examined by two field education experts and the questions were finalized by making the necessary arrangements in line with the opinions of the experts.

The interview questions were administered to the participants online after the completion of the 15-week graduate mathematical modeling course conducted by the researcher. Within the scope of this course, participants received training on the definition of mathematical modeling, the importance of mathematical modeling in mathematics teaching, and mathematical modeling processes, and worked on sample MEA and solutions. Furthermore, they have designed their own MEA by receiving education on the fundamental characteristics that an MEA should possess. The participating mathematics teachers designed a total of three MEAs, one for each week during the lesson. The designed activities were examined by the researcher together with the participants every week and the participants were asked to reorganize the activities by giving feedback about the deficiencies. Moreover, within the scope of the course, the participants examined the current mathematical modeling studies from various perspectives in line with the tasks given by the researcher. Finally, the participants were asked to select an MEA and apply it in their lessons. The participants were emphasized to choose activities suitable for the grade level they would be implementing while determining the MEA and it was stated that they could use the resources recommended by the researcher. For two weeks, the participants practiced MEA in their classrooms, one each week. The practices carried out by the participants were evaluated every week in the lesson given by the researcher and the experiences of the teachers about the practices and the difficulties they experienced, if any, were discussed. Semi-structured interview questions were asked to the teachers in an online environment at the end of the whole process, and their opinions on the applicability of an MEA were obtained.

2.4. Data analysis

To analyse the data obtained from the interviews conducted to determine the opinions of mathematics teachers on the applicability of an MEA, a content analysis technique was used. In the analysis process, the researcher first created a code list for the data. After examining the relationships between the codes obtained, categories covering these codes were reached. The data were classified under these categories and made meaningful for the reader. The categories were grouped, and themes were formed as a result of the analysis of the third research question. The categories and themes determined to increase the reliability of the study were examined by a field education expert other than the researcher, and then the researcher and the field education expert came together and made some arrangements on the categories and themes. The agreement rate between the coders was calculated with Miles and Huberman's (1994) formula to determine the reliability of the analysis. Based on the calculation, the agreement rate between the coders was calculated as 91%. In this case, the results obtained were considered reliable for the research. The codes, categories, and themes are presented in tables in the findings section. The results section includes direct quotations from the participant statements.

3. Results

In this study, mathematics teachers' opinions on the applicability of an MEA after the graduate mathematical modeling education they received were examined. The participants were first asked the question *"What are your thoughts about the contribution of model eliciting activities to mathematics teaching?"*. The results obtained from the analysis of the participant's answers to this question are given in Table 2.

Table 2. Contributions of MEA to mathematics teaching

Category	**Code**	**Participants**	**Frequency**
Cognitive Process	Gaining Association Skills	T1, T3, T4, T5, T7, T10, T11, T12, T16	9
	Gaining Lateral Thinking Skills	T1, T3, T6, T7, T8, T11, T13, T14	8
	Developing Interpretation Skills	T1, T3	2
	Developing Mathematical Literacy Skills	T2, T9	2
	Gaining Mathematical Thinking Skills	T9, T15	2
	Developing Reading Comprehension Skills	T2	1
	Developing Higher Order Thinking Skills	T6	1
	Developing Mathematical Representation Skills	T2	1
	Ensuring Transaction Fluency	T9	1
	Developing Scientific Thinking Skills	T12	1

Learning-Teaching Process	Ensuring Embodiment	T7, T10	2
	Supporting Active Participation	T12, T16	2
	Preparing for New Generation (Skill-Based) Questions	T6, T14	2
	Moving Away from Rote Memorization	T6	1
	Structuring Knowledge	T12	1
	Ensuring Effective and Permanent Learning	T10	1
Affective Process	Developing the Perspective on Mathematics	T1, T13	2
	Removing Prejudice Against Mathematics	T16	1
	Drawing Attention to Mathematics	T4	1

As can be seen in Table 2, three categories were formed as "cognitive process", "learning-teaching process" and "affective process" as a result of the analysis of teachers' opinions on the contributions of MEA to mathematics teaching. Considering Table 2, it is seen that ten codes emerged under the cognitive process category, six codes under the learning-teaching process category, and three codes under the affective process category. Under the category of cognitive process, most of the participants emphasized the aspect of MEA as providing mathematical connection skills and then lateral thinking skills. In addition, two participants each expressed the contributions of an MEA as developing interpretation skills, developing mathematical literacy skills, and gaining mathematical thinking skills. One participant expressed the contributions of an MEA to the development of different skills such as developing reading comprehension skills, developing higher-order thinking skills, developing mathematical representation skills, ensuring fluency in operations, and developing scientific thinking skills. In terms of the learning-teaching process, two participants each emphasized the contributions of an MEA in terms of providing concretization, supporting active participation, and preparing for new-generation (skill-based) questions. One participant expressed the contributions of an MEA as moving away from rote memorization, structuring knowledge, and providing effective and permanent learning. Regarding the contributions of MEA in terms of affective process, two participants mentioned improving their perspective on mathematics, while one participant mentioned its contributions such as eliminating prejudice against mathematics and drawing attention to mathematics. Some of the opinions of the participants regarding the contributions of MEA to mathematics teaching are as follows.

T8: "Students approach math questions and activities with prejudice because they have difficulties in understanding the questions and finding solutions. With the help of modeling, they can express what they understand more easily and can solve questions correctly in different ways. In my opinion, with modeling, students' prejudices against the mathematics course were broken down."

T12: *"Rather than taking information ready*-made, *mathematical modeling is beneficial in terms of enabling students to search for ways to access information, to move from a passive* *position to an active position, to structure their new knowledge on their previous knowledge and experiences, and to associate it with real life.* “The participants were secondly asked the question *"What are your thoughts about the applicability of model eliciting activities in school programs?"*. The results obtained from the analysis of the participant's answers to this question are given in Table 3.

Table 3. Applicability of MEA in school programs

Category	**Code**	**Participants**	**Frequency**
Limited applicability	Activities are time-consuming	T2, T3, T4, T11, T15	5
	Curriculum intensity	T6, T7, T10	3
	Students are unused to it	T3, T7, T13	3
	The difficulty of practicing in crowded classrooms	T8, T15	2
	Inadequacy of course hours	T7, T8	2
	Teachers do not have sufficient knowledge	T3	1
Applicable	If curriculum intensity is reduced	T5, T7, T9	3
	Sufficient class hours and small class size	T7, T8	2
	In elective mathematics applications courses	T14	1
	At some grade levels	T16	1
Rarely applicable	At the end of some topics	T2	1
	Several times a week	T4	1
Should be applied	Activities that are not time-consuming	T1, T11	2
	Because it is suitable for the new exam system	T6	1
	From lower grade levels	T12	1

As can be seen from Table 3, as a result of the analysis of teachers' opinions on the applicability of MEA in school programs, four categories were formed as "limited applicability", "applicable", "rarely applicable" and "should be applied". Participants mostly emphasized the time-consuming nature of the activities under the category of limited applicability. Three participants, however, stated that the applicability of an MEA was limited due to the intensity of the curriculum and students' unfamiliarity with it. Two participants stated that the applicability of an MEA was limited due to the difficulty of application in crowded classrooms and insufficient class hours. One participant stated that the applicability of an MEA is limited because teachers do not have sufficient knowledge. Under the category of feasible, three participants stated that MEA is feasible if the intensity of the curriculum is reduced; two participants stated that MEA is feasible with sufficient class hours and a small class size; and one participant stated that MEA is feasible in elective mathematics applications courses and at some grade levels. One participant stated that MEA is rarely applicable, at the end of some subjects and a few times a week. Under the "should be applied" category, two participants stated that activities that are not time-consuming should be applied, and one participant stated that MEA should be applied from lower grade levels because it is suitable for the new exam system. Some of the opinions of the participants regarding the applicability of MEA in school programs are as follows.

T3: "Even though it is included in the curriculum, teachers' lack of sufficient knowledge on this subject reduces its usability. At the same time, the time-consuming nature of the activities and children's unfamiliarity with the question styles negatively affect their applicability."

T11: "It takes much longer to consider possible outcomes and solutions in a mathematical modeling activity than in solving any other problem. But in my opinion, these activities will be very effective in providing students with different perspectives, especially in questions that require multidimensional thinking, which we call new-generation questions. This is why I think that modeling activities that do not take a lot of time should be included in the lessons."

The participants were thirdly asked the question *"What difficulties may arise in the application of model eliciting activities in lessons?"*. The results obtained from the analysis of the participant's answers to this question are given in Table 4.

Table 4. Challenges that may arise in implementing MEA in lessons

Theme	Category	Code	Participants	Frequency
Teacher dimension	Classroom management	In terms of effective use of time	T1, T3, T4, T7, T12, T15, T16	7
		In terms of class size	T1, T5, T10, T12	4
		In terms of classroom control	T5, T12, T16	3
		In terms of group activities	T3	1
	Teaching process	In terms of activity selection	T8, T11, T12, T14	4
		In terms of teacher guidance	T8, T10	2
		In terms of giving feedback	T3, T8	2
	Teaching resources	In terms of technological infrastructure	T15	1
		In terms of teaching material	T10	1
Student dimension	Readiness	In terms of motivation	T6, T7	2
		In terms of experience	T6, T10	2
		In terms of attitude	T6	1
		In terms of procedural knowledge	T5	1
		In terms of basic mathematical skills	T6	1
	Modeling Process	In terms of understanding the problem	T3, T9	2
		In terms of mathematical communication	T2	1
		In terms of strategy selection	T2	1

*T14 stated that "I do not think there will be any difficulties".

As can be seen from Table 4, two themes, namely "teacher dimension" and "student dimension", were formed as a result of the analysis of the teachers' opinions on the difficulties that may arise in the application of MEA in the lessons. Under the teacher dimension, three categories were obtained: classroom management, teaching process, and teaching resources. Under the category of classroom management, the participants stated that the most difficulties in the application of an MEA in the lessons may arise in terms of effective use of time. Subsequently, four participants stated that there could be difficulties in terms of class size, three participants stated that there could be difficulties in terms of classroom control and one participant stated that there could be difficulties in terms of group activities. Under the category of the teaching process, the participants stated that the most difficulties in the application of an MEA in the lessons could be experienced in terms of activity selection, while two participants stated that there could be difficulties in terms of teacher guidance and feedback. Regarding teaching resources, one participant stated that there may be difficulties in terms of technological infrastructure and teaching materials. Student difficulties were grouped under two categories: readiness and modeling process. Regarding the difficulties that may be experienced in terms of readiness, two participants stated that there may be difficulties in MEA applications in terms of students' motivation and experience, while one participant stated that there may be difficulties in terms of students' attitudes towards MEA, procedural knowledge and basic mathematical skills. Regarding the modeling process, the participants stated that students may experience difficulties in terms of understanding the problem, mathematical communication, and strategy selection. T14 stated that he/she did not think that there would be any difficulty in the application of MEA in the lessons. Some opinions of the participants regarding the difficulties that may arise in the application of MEA in the lessons are given below.

T5: "In classrooms with large class sizes, difficulties may arise in terms of application and classroom management. Many students come from primary school before they can read and write, or who do not know the multiplication tables or the four operations. In my opinion, I cannot involve such students in mathematical modeling activities."

T8: "The large number of students in the classrooms prevents giving feedback to all students and guiding them through the process. The feedback that is not given to the students promptly and sometimes the teacher's unintentional misdirection of the child cause the activity not to fulfill its purpose. The limitations in applying the activity include the fact that the academic achievement and readiness of the students in the class are different and that the activity does not appeal to all students."

T10: "Overcrowded classrooms pose great difficulties in implementing modeling activities. Because of the large number of students, it is not possible to pay much attention to each student in a 40-minute lesson and there is a lot of noise. At the same time, the cost of preparing the material is quite high due to the high number of students. Sometimes the *children do not understand the questions, so the teachers try to explain them one by one in detail, giving hints. Students reach the answers effortlessly.”*

In response to the question *"Did you have any difficulties in choosing activities for the MEA application you made to your students in your class within the scope of the graduate course? Explain."*, five of the participants (T5, T6, T7, T11, T13) stated that they had no difficulty, while 11 participants stated that they had difficulty. The results obtained from the participants' answers to this question are given in Table 5.

Table 5. Difficulty in selecting an MEA

Experiencing difficulties	Reason	Participants	Frequency
Yes	Selection of activities suitable for student level	T1, T2, T3, T4, T8, T10, T12, T14, T15	9
	Limited resources	T9, T14, T16	3
	Fewer question types	T9	1
	The questions do not reflect the mathematical modeling process sufficiently	T10	1
No	Mathematics applications books	T6, T7, T11, T13	4
	Theses and articles on the subject	T5, T13	2

As can be seen from Table 5, the participants who stated that they had difficulties in selecting MEA in classroom practices had the most difficulties in selecting activities appropriate to the student level. Three participants stated that they had difficulties due to the limited resources for MEA, while one participant stated that they had difficulty in choosing activities because the MEA question types were few and the questions did not reflect the mathematical modeling process sufficiently. Meanwhile, the participants who stated that they did not have any difficulty in selecting MEAs stated that they benefited from mathematics practice books and related theses and articles. Some of the opinions of the participants regarding the difficulties in selecting an MEA are given below.

T14: “Modeling books and activities were not very accessible. Therefore, I found it difficult to find an activity suitable for the level of the students.”

T10: “Yes, I had difficulties. Because mathematical modeling activities usually have more for the high school level. Since we are middle school teachers, the questions do not exactly match the level of the children. At the same time, the questions that match do not fully reflect the concept of mathematical modeling. I had difficulties in choosing questions.”

T5: “I had no difficulties. I found the mathematical modeling activities I wanted to implement very easily by researching the theses related to the subject".

T6: "I selected activities from the book of mathematics applications that I thought were appropriate for the level of my students and applied them. It was not difficult for me to find the kind of activity I was looking for."

The results obtained from the analysis of the answers given to the *"Did you have any difficulties during the MEA application process you did with your students? If yes, what kind of difficulties did you experience?"* questions asked to the participants are given in Table 6.

Table 6. Difficulties in MEA application

Experiencing difficulties	**Reason**	**Participants**	**Frequency**
	Classroom management	T2, T3, T14, T15	4
	Being a guide	T3, T8, T10,	3
Yes	Giving feedback	T7, T10	2
	Inadequate readiness level of students	T9, T12	2
	Selection of activities that are not appropriate for the level	T12	1
	Time management	T15	1
No	-	T1, T4, T5, T6, T11, T13, T16	7

As can be seen from Table 6, seven participants stated that they did not experience any difficulties in the application of MEA. Considering the answers of the participants who had difficulties in the application of MEA, it was determined that four participants had difficulties in terms of classroom management, three participants had difficulties in terms of being a guide in the process, two participants had difficulties due to giving feedback and students' insufficient readiness level, and one participant had difficulties in terms of choosing activities that were not suitable for the level and time management. Some opinions of the participants regarding the difficulties experienced in the application for an MEA are given below.

T12: "The lack of sufficient level of readiness of my students about the modeling activity caused me to have difficulties in the application of the activity. Besides, the difficulties I had in choosing questions reduced the applicability of the activity."

T15: "Yes, I had difficulties in practice. Since there are 40 students in the classes and they are small in age, it is not possible to dominate and train them on time, I experienced such a difficulty."

T11: "I did not have any problems because I conducted the practice with a class with high academic achievement. Since these students are also good at solving new generation questions, they adapted to the process more quickly."

T4: "Since the modeling activities were interesting to me, I had no difficulty in practicing them. It just takes longer to make the solutions."

It was determined that all participants answered yes to the *"Did the graduate mathematical modeling course contribute to you? If yes, how did it contribute?"* question asked the participants. The results obtained from the participants' explanations about the contributions of the graduate mathematical modeling course are given in Table 7.

Table 7. Contributions to the graduate mathematical modeling course

Category	**Code**	**Participants**	**Frequency**
Academically	Providing knowledge about mathematical modeling	T3, T7, T9, T10, T11, T12, T14, T15, T16	9
	Developing lateral thinking skills	T4, T6, T12, T13	4
	Developing MEA evaluation skills	T1, T5, T10	3
	Developing MEA designing skills	T1, T5	2
Vocationally	Developing MEA selection and application skills	T1, T3, T4, T5	4
	Ensuring to start using MEA in lessons	T2, T3, T7	3
	Developing a positive attitude towards using MEA in lessons	T6, T7, T16	3
	Developing students' ability to evaluate mathematical modeling skills	T5	1
In terms of students	Developing lateral thinking skills	T3, T10, T12, T14	4
	Developing mathematical connection skills	T7, T8, T16	3
	Supporting active participation	T10, T16	2
	Developing self-confidence in mathematics	T8	1

As can be seen in Table 7, according to the opinions of the participants, the contributions of the graduate mathematical modeling course are grouped under three categories: academically, professionally, and from the perspective of students. From an academic perspective, the participants stated that the graduate mathematical modeling course provided the most knowledge about mathematical modeling. According to the participants, the mathematical modeling training they received improved their lateral thinking skills. In addition, they stated that the graduate course they took improved their MEA evaluation skills and MEA design skills. Regarding the professional contributions of the graduate mathematical modeling course, the participants stated that it improved their ability to select and apply MEA, they started to use MEA in their courses, they developed positive attitudes towards using MEA in their courses, and it improved their ability to evaluate students' mathematical modeling skills. Besides, teachers mentioned that the graduate mathematical modeling course also contributed to their students. As a result of the practices carried out within the scope of the course, she stated that students' lateral thinking skills and mathematical connection skills improved, the activities supported students' active participation in the lesson, and improved their self-confidence in mathematics. Some of the participants' opinions about the contributions of the graduate mathematical modeling course are as follows.

T7: "Of course, the mathematical modeling course helped. Even the first benefit was to learn the concept of "modeling", which is also in the name of the course. As I became familiar with the modeling questions, what I realized was that unless I exposed students to these questions, they might not understand where the information I was teaching could be used in real life. I decided to include more mathematical modeling examples in my lessons despite the concerns of curriculum development and preparing students for the exam, and I started to implement them."

T10: "Yes, it helped. I learned the definitions of mathematical models and modeling concepts. I learned what criteria a question should meet for me to call it a modeling activity. I learned that sometimes I can bring such modeling questions to the children and make them participate more actively in the lesson, have fun, and at the same time observe their different perspectives."

All participants answered yes to the *"Do you plan to use modeling activities in your lessons in the future? Explain."* question asked to the participants. Table 8 presents the results obtained from the analysis of the participants' opinions on using MEA in their lessons after mathematical modeling training.

Table 8. Teachers' opinions on using MEA in their lessons after mathematical modeling training

Frequency of use	**Method of use**	**Participants**	**Frequency**
Frequently	From lower grade levels	T1, T2, T6, T7, T11, T16	6
	In the form of group work	T8	1
	At the end of a topic	T14	1
As much as possible	Depending on curriculum intensity	T3, T4, T5, T12, T13	5
	In difficult-to-understand outcomes	T10	1
	In uncrowded classrooms	T15	1
	Students with high academic success	T9	1

Table 8 shows that after the mathematical modeling training, half of the 16 participants stated that they would frequently use MEA in their lessons, while the other half stated that they would use MEA in their lessons whenever possible. A large proportion of the teachers who stated that they would use it frequently stated that they would use MEA from the lower grade levels onwards. However, one participant stated that he/she would frequently apply the activities as group work and at the end of the subject. Those participants who stated that they would use MEA whenever possible mostly stated that they would try to implement the activities depending on the intensity of the curriculum. One participant stated that he/she would use the activities as much as possible in difficult-to-understand acquisitions, in uncrowded classes, and with students with high academic achievement levels. Some of the opinions of the participants about using an MEA in their lessons after mathematical modeling training are as follows.

T8: "Yes, I think I will use it often. I plan to implement mathematical modeling activities as group work."

T10: "I think I can use it differently from topic to topic. I will take care to use modeling activities as much as possible in acquisitions that are difficult for students to understand."

T11: "Yes, I think I will use it frequently, especially in mathematics applications courses, starting from lower grade levels."

T12: "As long as the curriculum allows, I will try to use modeling activities in my lessons as much as possible and integrate them into my lessons as much as I can, even if there are application difficulties."

The results obtained from the analysis of the answers given to the last *"What are your suggestions for further application of model eliciting activities in lessons?"* question asked to the participants are given in Table 9.

Table 9. Suggestions for more effective application of MEA in lessons

Category	**Code**	**Participants**	**Frequency**
Recommendations for Practitioners	Can be applied in mathematics applications course	T3, T5, T6, T11, T15	5
	Applicable from lower grade levels	T6, T9, T11, T12	4
	Can be applied in one class hour each week	T3	1
	Level groups can be created	T8	1
	Classes can be divided into groups	T2	1
	Can be given as homework	T2	1
Recommendations for Education Policymakers	Sourcebooks can be prepared	T6, T10, T13, T16	4
	In-service training can be provided to teachers	T7, T12, T13	3
	Elective mathematical modeling courses can be opened	T1, T4, T14	3
Recommendations for Program Developers	The intensity of the curriculum can be reduced	T4, T5, T7, T8, T16	5
	The curriculum can be organized to include mathematical modeling method	T9, T13	2

Table 9 shows that the suggestions of the participants for a more effective application of MEA in the lessons were grouped under three categories: suggestions for practitioners, suggestions for education policymakers, and suggestions for curriculum developers. When the suggestions of the participants for practitioners are examined, it is seen that they stated that MEA can be applied mostly in the mathematics applications course. Nevertheless, participants emphasized that MEA can be implemented from lower grade levels. One participant stated that MEA can be implemented in one class hour every week, it can be implemented by forming level groups, it can be given as homework and classes can be divided into groups during the applications. Regarding the participants' suggestions for education policymakers, it is seen that they mostly made suggestions for the preparation of resource books. In addition, three participants suggested that in-service mathematical modeling training could be provided to teachers and an elective mathematical modeling course could be offered. Teachers made the most frequent suggestion under the category of suggestions for curriculum developers to reduce the intensity of the curriculum. Two participants, however, suggested that the curriculum could be organized to include the mathematical modeling method. Participants' suggestions for a more effective application of the MEA in the lessons are given below.

T2: "In this context, if we divide the class into groups if only one person from each group answers, the class size may naturally decrease, or students can be given modeling activities as homework and discuss their answers during the lessons."

T7: "First of all, teachers should be introduced to modeling activities. When I started my master's degree, I did not know modeling. I thought of modeling as concrete materials, but when I took the course, I realized that it was not. Many mathematics teachers received their undergraduate education at the same faculty as me, and maybe even graduated from other faculties, but they are not aware of this issue. Teachers should be made aware of this issue through in-service training or courses and seminars. Afterward, appropriate course hours and programs should be prepared by the Ministry of National Education for us mathematics teachers so that we can use these activities in our lessons without worrying about time."

T9: "It can be part of the curriculum. The curriculum can be organized to include mathematical modeling. The modeling questions are like preparation for LGS (High School Transition System) new generation math questions. That is why it can be spread and implemented in the curriculum starting from the lower grades."

4. Discussion and Conclusions

This study aimed to reveal the opinions of mathematics teachers about the applicability of an MEA after their in-class practices within the scope of mathematical modeling training given to mathematics teachers. The findings of the study show that teachers who did not receive any training in mathematical modeling at the beginning of the study think that MEA has many contributions to mathematics teaching after the training they received. These contributions listed by the teachers were analyzed in terms of cognitive, affective, and learning-teaching process dimensions. In terms of cognitive aspects, the participants emphasized the cognitive aspects of an MEA as providing mathematical connection skills and lateral thinking skills. In addition, the participants expressed the contributions of an MEA to the development of different skills such as developing interpretation skills, developing mathematical literacy skills, developing mathematical thinking skills, developing reading comprehension skills, developing higher order thinking skills, developing mathematical representation skills, developing fluency in operations, and developing scientific thinking skills. When the literature is examined, it is seen that MEA improves many skills such as mathematical connection skills (Anhalt & Cortez, 2016; Doruk & Umay, 2011), mathematical literacy skills (Ata-Baran, 2019), mathematical thinking skills (Eker, 2019; English & Watters, 2004), higher-order thinking skills (Doruk & Umay 2011; İncikabı & Biber, 2020), mathematical processing skills (Eker, 2019) and supports the development of different perspectives (Eker, 2019; İncikabı & Biber, 2020). Besides, in terms of the learning-teaching process, the participants emphasized the contributions of an MEA in terms of providing concretization, supporting active participation, moving away from rote learning, structuring knowledge, and ensuring effective and permanent learning. Parallel to this result, in İncikabı and Biber's (2020) study, it wamengis also stated by the participants that MEA provides pedagogical opportunities such as motivation, qualified and permanent learning. In terms of affective process, the contributions of an MEA were expressed as improving the perspective on mathematics, eliminating prejudice against mathematics, and drawing attention to mathematics. Ata-Baran (2019) conducted a teaching experiment based on the mathematical modeling approach and observed positive improvements in students' cognitive skills as well as affective characteristics such as mathematics self-efficacy, mathematics anxiety, openness to problem-solving, and mathematical motivation. Similarly, it is among the results reached by the researchers that MEA has positive contributions to the affective characteristics of students (İncikabı & Biber, 2020).

Regarding the applicability of an MEA in school programs, which is the main focus of the research, most of teachers think that its applicability is limited. Participants emphasized the time-consuming nature of the MEA, curriculum intensity, students' lack of familiarity, the difficulty of application in crowded classrooms, insufficient class hours, and teachers' lack of sufficient knowledge as reasons for this situation. These statements are similar to the results of many studies (Bilgili & Çiltaş, 2019; Deniz & Akgün, 2017; Urhan & Dost, 2016). On the other hand, the participants stated that if the intensity of the curriculum is reduced, with sufficient class hours and small class sizes, MEA can be applied in elective mathematics practice courses and at some grade levels. The intensity of curricula and the time-consuming nature of an MEA are among the barriers expressed by teachers in many studies (Borromeo-Ferri 2014; Deniz & Akgün, 2017; Gaston & Lawrence 2015; Urhan & Dost, 2016). Gaston and Lawrence (2015) reported that teachers with little mathematical modeling experience may find these practices too challenging as they require significant time and effort, and even teachers with more modeling experience may be reluctant to use modeling activities due to the level of difficulty or the demands on class time. To overcome this obstacle, English (2010) suggests that modeling experiences should not be understood as an additional burden on teachers in an intensive curriculum and should be integrated into existing practices.

From the opinions of the teachers, the difficulties that may arise in the application of an MEA in the lessons were discussed in three categories: classroom management, teaching process, and teaching resources in terms of teacher dimension. As mentioned above, the participants stated that the most difficulties in classroom management may arise in terms of effective use of time, followed by difficulties in class control in terms of class size and group activities. Regarding the teaching process, the participants stated that the most difficulties could be experienced in terms of activity selection, while there were also teachers who stated that difficulties could be experienced in terms of the teacher's guidance and giving feedback. In Turkey, despite the emphasis on mathematical modeling in the mathematics curriculum, it is seen that MEA is not sufficiently included in textbooks and supplementary resources and the activities do not reflect the mathematical modeling process sufficiently (Çavuş-Erdem, Doğan, Gürbüz & Şahin, 2017; Saka & Alkan, 2022). Hence, teachers are likely to have difficulties in selecting activities despite the training they receive. In terms of the student dimension, it was stated that there may be difficulties in terms of students' motivation and experience, students' attitude towards MEA, procedural knowledge, and basic mathematical skills, while in terms of the modeling process, it was stated that students may experience difficulties in terms of understanding the problem, mathematical communication and strategy selection. In parallel with these results, it is among the frequently reached results that there are problems arising from the fact that students are not used to mathematical modeling method applications or that students' readiness levels are not sufficient (Urhan & Dost, 2016). The results obtained from the study are thought to be largely parallel to the difficulties that may arise in the mathematical modeling process categorized by Blum (1996) but offer a more detailed perspective. As a matter of fact, Blum (1996), while explaining teacher-related difficulties, also addressed the factors that teachers do not see mathematical modeling as necessary. This study concluded that the participants found mathematical modeling useful to a great extent and had a positive opinion that it should be implemented in classrooms.

Another result obtained from the study was that most of the participants had difficulty in selecting MEAs suitable for student-level for in-class applications. Participants cited the limited resources for the MEA, the low number of MEA questions, and the fact that the questions did not reflect the mathematical modeling process sufficiently as reasons for this. In some studies, conducted in Turkey, it was stated that teachers had difficulties in obtaining MEAs suitable for the lesson; therefore, they could not implement them (Bilgili & Çiltaş, 2019; Deniz & Akgün, 2017). This result suggests that more resources reflecting the mathematical modeling process should be prepared for each grade level. On the other hand, the difficulties experienced by the participants during the in-class applications were as follows: classroom management, being a guide in the process, giving feedback, inadequate readiness level of the students, inappropriate activity selection, and time management. The difficulties experienced by teachers in providing guidance and feedback during the application process stem from overcrowded classrooms, insufficient class time, and teachers' unintentional misguidance of students. In studies focusing on teachers' MEA applications, it is among the results that teachers experience hesitations and difficulties about where and how to intervene (Sağıroğlu & Karataş, 2018; Şahin, Doğan, & Gürbüz, 2022). The limitation of this study is that the practices that the teachers carried out with their students after the training covered a period of two weeks. Nevertheless, as Blum and Borromeo Ferri (2009) point out, even experienced teachers have difficulties in making appropriate interventions during the application process for MEA. Interventions by the teacher during the modeling process should be adaptive interventions that provide a balance between students' independent work and the teacher's guidance (Borromeo-Ferri, 2018). Interventions by the teacher during the modeling process should be adaptive interventions that provide a balance between students' independent work and the teacher's guidance. Leiß (2007) defines adaptive interventions as *"those types of assistance provided by the teacher to the student that minimally supports the student's individual learning and problem-solving process so that students can continue to work at a maximum level of independence"* (p. 65). According to Blum (2015), strategic interventions such as *"Read the text carefully!", "Create a solution plan!", "What data do you need?"* are adaptive interventions necessary for a student-centered learning environment.

The mathematical modeling training provided was found to be beneficial academically, professionally, and for the students. The participants stated that the training they received mostly provided them with knowledge about mathematical modeling, developed their lateral thinking skills, and improved their ability to select, implement, evaluate, and design MEAs. Moreover, he/she stated that the activities supported students' active participation in the lesson and improved their self-confidence in mathematics. The participants also stated that after the training they received, they developed positive attitudes towards using MEA in their lessons and started to use MEA in their lessons. Some of the participants stated that they would use MEA frequently from the lower grade levels, in the form of group work and at the end of the subjects, while others stated that they would use it as much as possible depending on the intensity of the curriculum, in difficult-to-understand acquisitions, and uncrowded classes. According to this result of the study, mathematical modeling training has positive contributions for both teachers and their students. This positive attitude towards mathematical modeling applications is a desirable result even though none of the teachers participating in the study had received mathematical modeling training before. In Deniz and Akgün's (2017) study in which secondary mathematics teachers were trained on mathematical modeling and their opinions were taken, the number of teachers who used MEA in their lessons before the application increased after the application. On the other hand, some teachers stated that they did not think of using this method in their lessons because it was too time-consuming. Teachers in Urhan and Dost's (2016) study also stated that unless questions based on modeling are included in the transition to higher education exam, MEA cannot be used effectively in lessons. Although the participants in this study did not express a negative opinion against

MEA applications, they stated that they would apply it as much as possible depending on the intensity of the curriculum, as in the studies.

When the suggestions of the participants for practitioners for the application of MEA in the lessons more effectively were examined, it was emphasized that MEA could be applied mostly in mathematics applications lessons and from lower grade levels. In addition, it was suggested that MEA could be implemented in one class hour each week that it could be implemented by forming level groups, that it could be given as homework, and that classes could be divided into groups during the applications. Regarding the participants' suggestions for education policymakers, it is seen that they mostly made suggestions for the preparation of resource books. In addition, participants suggested that in-service mathematical modeling training could be provided to teachers and an elective mathematical modeling course could be offered. Considering the suggestions for curriculum developers, it was mostly emphasized to reduce the intensity of the curriculum and it was also suggested that the curriculum could be arranged to include the mathematical modeling method. Based on the participants' suggestions for further application of MEA in schools and the results of the study, suggestions for practitioners and researchers are presented below.

5. Suggestions

The participants in this study, after the training given to the teachers, thought that MEA had many contributions in terms of cognitive, affective, and learning-teaching processes, but they thought that the applicability of the activities in school programs was limited. To disseminate MEA practices in the teaching process, teachers need to plan their lessons in a way to allocate space for MEA to avoid time constraints (Tekin-Dede & Bukova-Güzel, 2013). It is recommended that in-service training, workshops, or seminars be organized for teachers to prepare appropriate lesson plans that include MEA.

As teachers emphasized in their suggestions, MEA can be implemented in elective courses such as mathematics applications or in one class hour each week. In crowded classrooms, students can be divided into groups for the application. Due to the limited resources for in-class applications, the low number of questions, and the fact that the questions did not reflect the mathematical modeling process sufficiently, teachers had difficulties in selecting MEAs appropriate for the level of students. As emphasized by the teachers in their suggestions, there is a need for the preparation of sourcebooks containing MEA that fully reflect the mathematical modeling process. For this purpose, MEAs can be prepared for students at different levels and shared in a way that facilitates access by teachers and students. In this study, although the mathematical modeling training given to the teachers was a 15-week process, the MEA practices of the teachers with their students were limited to two weeks. Some of the teachers experienced difficulties in terms of classroom management, time management, being a guide, and giving feedback during the practices. In future studies, the application process can be spread over a longer period and it can be investigated whether similar difficulties will arise if teachers have more application experience.

In Turkey, with the mathematics teaching undergraduate program updated in 2018, the modeling course in mathematics teaching started to be taught as a compulsory course. Therefore, the number of graduate teachers trained in mathematical modeling is still quite small. Therefore, in-service training on mathematical modeling should be continued for teachers who did not receive this training at the undergraduate level. In this way, more teachers can be reached and teachers can be informed about the mathematical modeling method and their development towards MEA applications can be ensured.

Declaration of Conflicting Interests and Ethics

The author declare no conflict of interest.

References

Anhalt, C. O., & Cortez, R. (2016). Developing understanding of mathematical modeling in secondary teacher preparation. *Journal of Mathematics Teacher Education*, *19*, 523-545. https://doi.org/10.1007/s10857-015-9309-8

Asempapa, R. S. & Sturgill, D. J. (2019). Mathematical modeling: Issues and challenges in mathematics education and teaching. *Journal of Mathematics Research, 11*(5), 71-78. https://doi.org/10.5539/jmr.v11n5p71

Asempapa, R. S. (2022). Examining practicing teachers' knowledge and attitudes toward mathematical modeling. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 10*(2), 272-292. https://doi.org/10.46328/ijemst.2136

Asempapa, R. S., Sturgill, D. J., & Adabor, J. K. (2017). Mathematical modeling: A teaching and learning strategy in school mathematics. *Pennsylvania Teacher Educator*, *16*, 66-75.

Ata-Baran, A. (2019). *Matematiksel modellemeye dayalı bir öğretim deneyinde sekizinci sınıf öğrencilerinin matematiksel iletişim becerilerinin, matematik okuryazarlıklarının ve duyuşsal özelliklerinin incelenmesi* [Yayınlanmamış doktora tezi]. Anadolu Üniversitesi, Eskişehir.

Bilgili, S., & Çiltaş, A. (2019). Similarity and differences in visuals in mathematical modelling of primary and secondary mathematics teachers. *International Journal of Eurasia Social Sciences. 10*(35), 334-353.

Blum, W. (1996). Anwendungsbezüge im mathematikunterricht. Trends und perspektiven. *Schriftenreihe Didaktik der Mathematik, 23*, 15-38.

Blum, W. (2002). ICMI 14 study: Applications and modeling in mathematics education. A discussion document. *Educational Studies in Mathematics, 51*, 149–171.

Blum, W. (2015). Quality teaching of mathematical modelling: What do we know, what can we do?. In *The proceedings of the 12th international congress on mathematical education: Intellectual and attitudinal challenges* (pp. 73-96). Springer International Publishing.

Blum, W., & Borromeo Ferri, R. (2009). Mathematical modeling: Can it be taught and learnt? *Journal of Mathematical Modeling and Applications, 1*(1), 45–58.

Blum, W., & Leiss, D. (2007). How do students and teachers deal with modelling problems? In C. Haines, P. Galbraith, W. Blum & S. Khan (Eds.), *Mathematical modelling (ICTMA 12): Educatio*n, engineering *and economics* (pp. 222-231). Horwood.

Borromeo Ferri, R. (2010). On the influence of mathematical thinking styles on learners' modeling behavior. *Journal für Mathematik-Didaktik*, *31*(1), 99-118.

Borromeo Ferri, R. (2014). Mathematical modelling – The teachers' responsibility. In A. Sanfratello & B. Dickman (Eds.), *Proceedings of conference on mathematical modelling at Teachers College of Columbia University* (pp. 26–31). New York. https://doi.org/10.7916/jmetc.v0i0.660

Borromeo Ferri, R. (2018). Key competencies for teaching mathematical modeling. In *Learning how to teach mathematical modeling in school and teacher education* (pp. 1-12). Cham: Springer.

Borromeo Ferri, R. (2020). Make mathematical modeling marvelous! Follow teacher Mr. K. for your lesson tomorrow. *The New Jersey Mathematics Teacher*, *78*(1), 44-53.

Büyüköztürk, Ş., Kılıç-Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2020). *Bilimsel araştırma yöntemleri* (28. Baskı). Ankara: Pegem Yayınları.

Çavuş-Erdem, Z., Doğan, M. F., Gürbüz, R., & Şahin, S. (2017). Matematiksel modellemenin öğretim araçlarına yansımaları: Ders kitabı analizi. *Adıyaman Üniversitesi Eğitim Bilimleri Dergisi*, *7*(1), 61-86

Deniz, D., & Akgün, L. (2017). The sufficiency of high school mathematics teachers to design activities appropriate to model eliciting activities design principles. *Karaelmas Journal of Educational Sciences, 4*(1), 1-14.

Doerr, H. M. (2006). Examining the tasks of teaching when using students' mathematical thinking. *Educational Studies in Mathematics, 62*(1), 3–24.

Doruk, B. K. & Umay, A. (2011). Matematiği günlük yaşama transfer etmede matematiksel modellemenin etkisi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 41*, 124–135.

Eddles-Hirsch, K. (2015). Phenomenology and educational research. *International Journal of Advanced Research, 3*(8), 251–260.

Eker, T. (2019). *Matematik öğretmenlerinin matematiksel modelleme etkinliklerinde karşılaştıkları güçlükler* [Yayınlanmamış yüksek lisans tezi]. Mersin Üniversitesi, Eğitim Bilimleri Enstitüsü, Mersin.

English, L. D. (2010). Modeling with Complex Data in the Primary School. In R. Lesh, P. Galbraith, C. Haines, & A. Hurford (Eds.), *Modeling students' mathematical modeling competencies.* ICTMA 13 (pp. 287-299). Springer.

English, L. D., & Watters, J. J. (2004). Mathematical modelling with young children. In M. Johnsen Hoines & A. Berit Fuglestad (Eds.), *Proceedings of the 28th International PME Conference* (pp. 335-342). Norway: Bergen University College.

Frejd, P. (2012). Teachers' conceptions of mathematical modelling at Swedish upper secondary school. *Journal of Mathematical Modelling and Application*, *1*(5), 17-40.

Galbraith, P. (2017). Forty years on: Mathematical modelling in and for education. In A. Downton, S. Livy, & J. Hall (Eds.), *40 Years on: We are still learning! Proceedings of the 40th annual conference of the Mathematics Education Research Group of Australasia [MERGA]* (pp. 47-50). MERGA.

Gaston, J. L., & Lawrence, B. A. (2015). Supporting teachers' learning about mathematical modeling. *Journal of Mathematics Research, 7(*4), 1-11. https://doi.org/10.5539/jmr.v7n4p1

İncikabı, S., & Biber, A. Ç. (2020). Ortaokul matematik öğretmen adaylarının matematiksel modelleme farkındalıklarının araştırılması. *Türk Akademik Yayınlar Dergis*i, *4*(1), 55-72.

Kaiser, G. (2007). Modeling and modeling competencies in school. In C. Haines, P. Galbraith, W. Blum, & S. Khan (Eds.), *Mathematical modeling (ICTMA 12): Education, engineering and economics* (pp. 110–119). Horwood.

Kaiser, G., & Schwarz, B. (2006). Mathematics modelling as bridge between school and university. *Zentralblatt für Didaktik der Mathematik, 38*(2), 196-208. https://doi.org/10.1007/BF02655889

Leiß, D. (2007). Hilf mir es selbst zu tun: Lehrerinterventionen beim mathematischen modellieren [Help me to do it myself. Teachers' interventions in mathematical modelling processes]. Hildesheim: Franzbecker.

Lesh, R (2012). Research on models & modeling and implications for common core state curriculum standards. In R. Mayes, L. Hatfield, & S. Belbase, (Eds.), *WISDOMe Monograph: Quantitative reasoning and mathematical modeling: A driver for STEM integrated education and teaching in context,* (Vol. 2, pp. 197–203). University of Wyoming.

Ministry of National Education [MoNE]. (2018). *Mathematics lesson curriculum program (Primary and Middle School Grades 1, 2, 3, 4, 5, 6, 7 and 8).* Ankara, Turkey.

Organisation for Economic Co-operation and Development [OECD]. (2019). PISA 2018 Assessment and analytical framework. Paris: OECD Publishing.

Özgür-Şen, E. (2020). Öğretmen adaylarının tasarladıkları matematiksel modelleme problemleri ve tasarlama sürecine ilişkin görüşleri. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi*, *21*(3), 1530-1560.

Pollak, H. O. (2011). What is mathematical modeling? *Journal of Mathematics Education at Teachers College*, *2*(1), 64-72.

Rolfe, G. (2006). Validity, trustworthiness and rigour: Quality and the idea of qualitative research. *Journal of Advanced Nursing*, *53*(3), 304-310.

Rose, P., Beeby, J., & Parker, D. (1995). Academic rigour in the lived experience of researchers using phenomenological methods in nursing in nursing. *Journal of Advanced Nursing*, *21*(6), 1123-1129.

Sağıroğlu, D., & Karataş, İ. (2018). Matematik öğretmenlerinin matematiksel modelleme yöntemine yönelik etkinlik oluşturma ve uygulama süreçlerinin incelenmesi. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi*, *12*(2), 102-135.

Saka, E., & Alkan, S. (2022). Examining the secondary school mathematics practices course books in Turkey according to the principles of the model eliciting activity design. *International Journal of Curriculum and Instruction*, *14*(1), 523-542.

Sole, M. (2013). A primer for mathematical modeling. *Journal of Mathematics Education at Teachers College*. *4*, 44-49.

Spandaw, J., & Zwaneveld, B. (2010). Modelling in mathematics' teachers' professional development. In *Proceedings of the sixth Congress of the European Society for Research in Mathematics Education–Working group* (Vol. 11, pp. 2076-2085). INRP.

Şahin, S., Doğan, M. F., & Gürbüz, R. (2022). Examining teacher interventions in teaching mathematical modeling: A case of middle school teacher. *International Journal of Scholars in Education*, *5*(2), 60-79.

Tekin-Dede, A., & Bukova Güzel, E. (2013). Matematik öğretmenlerinin model oluşturma etkinliği tasarım süreçleri ve etkinliklere yönelik görüşleri. *Bartın Üniversitesi Eğitim Fakültesi Dergisi, 2*(1), 300-322.

Urhan, S., & Dost, Ş. (2016). The use of mathematical modelling activities in courses: Teacher perspectives. *Electronic Journal of Social Sciences*, *15*(59), 1279-1295.

Van Manen, M. (2007). Phenomenology of practice. *Phenomenology & Practice. 1*(1), 11-30. https://doi.org/10.29173/pandpr19803

Wolfe, N. B. (2013). *Teachers' understanding of and concerns about mathematical modeling in the common core standards* (Doctoral dissertation). The Claremont Graduate University.