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Research Article

Mathematical Modeling Competencies and Opinions of Middle School Students in Interdisciplinary Modeling Tasks

Disiplinler Arası Modelleme Etkinliklerinde Ortaokul Öğrencilerinin Matematiksel Modelleme Yeterlikleri ve Görüşleri

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ABSTRACT

The aim of this study is to investigate middle school students' competencies towards mathematical modelling and their views on this process in a learning environment designed with interdisciplinary modelling activities. Embedded experimental mixed design was used in the study. The study lasted 15 weeks with seventh grade students with control and experimental groups, including the application process and pre-test-post-test. The data of the research were obtained from mathematical modeling tasks, pre-opinion, and post-opinion forms for mathematical modeling. In the analysis of quantitative data, Wilcoxon signed ranks test and Mann Whitney U-test; In the qualitative, content analysis and thematic analysis were used. It was determined that there was a significant difference in favour of the post-test in all other competencies except the validating competence in the pre-test-post-test modeling competencies. In the qualitative analysis of the opinions of the experimental group students, it was found that mathematical modeling was efficient in associating mathematics with other disciplines and daily life after the learning process; It has been determined that it contributes positively to their success, understanding, interest and motivation.

Keywords: Modeling competencies, connection with other disciplines, mathematical modeling, middle school students.

ÖZ

Bu çalışmanın amacı, disiplinler arası modelleme etkinlikleri ile tasarlanmış bir öğrenme ortamında ortaokul öğrencilerinin matematiksel modellemeye yönelik yeterliklerini ve bu süreç hakkındaki görüşlerini incelemektir. Araştırmada iç içe deneysel karma desen kullanılmıştır. Çalışma deney ve kontrol gruplu yedinci sınıf öğrencileri ile uygulama süreci ve ön test-son test olmak üzere 15 hafta sürmüştür. Araştırmanın verileri matematiksel modelleme etkinlikleri, matematiksel modellemeye yönelik ön ve son görüş formlarından elde edilmiştir. Nicel verilerin analizinde Wilcoxon işaretli sıralar testi ile Mann Whitney U-testi; nitelde ise betimsel analiz ve içerik analizi kullanılmıştır. Deney grubu öğrencilerinin ön test-son test modelleme yeterliklerinde doğrulama yeterliği hariç diğer tüm yeterliklerde son test lehine anlamlı fark oluştuğu tespit edilmiştir. Deney grubu öğrencilerinin görüşlerine yönelik nitel analizlerde ise öğrenme süreci sonrasında, matematiksel modellemenin öğrencilerin matematiği diğer disiplinler ve günlük hayat ile ilişkilendirmelerinde etkili olduğu; başarı, anlama, ilgi ve motivasyonlarına olumlu katkılar sağladığı belirlenmiştir.

Anahtar Kelimeler: Bilişsel modelleme yeterlikleri, farklı disiplinlerle ilişkilendirme, matematiksel modelleme, ortaokul öğrencileri.

INTRODUCTION

In our age, science and technology are developing rapidly and today's needs are changing accordingly. With the change in needs, the problems that students may encounter in daily life may also differ. In order to keep up with this situation, students should be prepared for the future throughout the education process. As students prepare for the future, it is often emphasized in studies and curricula that studies should be carried out to make students good problem solvers in order to overcome the problems they may encounter (Australia Ministry of Education, 2008; Baki, 2014; Curriculum Planning and Development Division [CPDD], 2012; Ministry of National Education [MoNE], 2013, 2017, 2018a; National Council of Teachers of Mathematics [NCTM], 2000). Mathematical modeling is a powerful tool that helps students better adapt to daily life and develop high-level mathematical ideas and problem-solving processes (English, 2004). Mathematical modeling education should be started at an early age, as mathematical modeling encourages the understanding and development of mathematical concepts in daily life and improves critical thinking and mathematical literacy (Sriraman & Lesh, 2006). Similarly, English (2007) and Maaß (2005) state that the integration of mathematical modeling into the primary school curriculum should not be postponed until middle school and beyond.

Mathematical modeling, whose necessity is emphasized and included in the curriculum and standards for mathematics teaching in different countries (Council of Higher Education [CoHE], 2018; CPDD, 2012; Ministry of National Education [MoNE], 2017, 2018a, 2018b; NCTM, 2000). While it encourages students to solve problems (English, 2004), it also helps students develop high-level mathematical ideas (Biccard & Wessels, 2011). Mathematical modeling reinforces student learning through interaction within a mathematical community, while allowing teachers to guide groups of students by challenging them intellectually and ensuring that each student's ideas contribute to their peers (Suh et al., 2021). It is also an efficient tool in developing students' different mathematical processing skills (proving and making assumptions, etc.) (Borromeo-Ferri, 2006). In addition, it provides the opportunity to explore and apply models in which students can create, combine, and develop their conceptual systems (English, 2006). Modeling problems not only provide students with real-world contexts, but also enable them to use novel problem situations to derive real-world solutions (Blum & Borromeo-Ferri, 2009). Mathematical modeling, which helps to find a strong connection between daily life and mathematics (Doruk & Umay, 2011), is an efficient tool in connecting it with other disciplines (Gürbüz et al., 2018).

There are various definitions in the literature for the mathematical modeling. For example, according to Swetz and Hartzler (1991, as cited in Lingefjärd, 2006), mathematical modeling, which is a mathematical process, involves following a phenomenon, predicting the relations of the phenomenon, applying mathematical analysis (symbolic structures, equations, etc.), drawing mathematical conclusions, and restating the model. García et al. (2010), on the other hand, define mathematical modeling process that allows someone who wants to work with mathematics to critically understand the real world, while at the same time involving various competencies such as communication and problem solving. Similarly, Ang (2010) explains mathematical modeling as the process of representing the effort to find solutions in mathematical terms to problems whose starting point is a real-world situation. Mathematical modeling in the light of definitions in the literature; it can be defined as the cyclical process between mathematics and the real world, which enables students to better understand daily life situations, supports mathematics learning (motivation, comprehension, concept formation, reasoning, mathematizing, problem solving, etc.), helps teach mathematical and other discipline concepts, is tested assumptions, and is predicted results.

There are various theoretical studies on the mathematical modeling approach. The common aspect of these studies is that mathematical modeling has a cyclical structure (Zbiek & Conner, 2006). There is a common consensus that mathematical modeling can be defined as a task that includes moving forth and back between mathematics and reality (Borromeo-Ferri, 2018). The modeling approach addresses the relationship between the real world and mathematics in non-mathematical problems based on model perception. An ideal modeling process begins by (i) taking a real situation as a starting point; (ii) the situation is simplified and structured to create a model. This structure is (iii) transformed into a mathematical model and (iv) the mathematical results are interpreted with respect to the real situation. The adequacy of the results is evaluated, and the process is repeated if not satisfactory (Kaiser, 2005, p. 2).

Mathematical modeling can be classified according to the purpose of use; the approaches used as a teaching tool and the skills aimed to be gained as a result of teaching (Erbaş et al., 2014; Stillman, 2011). There are various studies that address mathematical modeling as skills that need to be developed in relation to mathematics teaching (Blomhøj, 2007; Borromeo-Ferri, 2006; Blum & Borromeo-Ferri, 2009; Lingefjärd, 2006; Maaß, 2006). One of them is Borromeo-Ferri's (2006) 'Modeling Cycle Under Cognitive Perspective'. Borromeo-Ferri (2006), in a project study, defined his own modeling cycle by cognitively restructuring the Blum and Leiß's (2005) modeling cycle. Blum and Leiß (2005) use the transition from the real state to the state model in the modeling cycle. According to the cognitive modeling perspective, the objective is to analyze the learners and teachers' cognitive processes while conducting modeling tasks from a cognitive perspective (Borromeo-Ferri, 2010).

According to Stillman (2011), students gain conscious cognitive or affective experiences that control or regulate cognitive activity through mathematical modeling. By focusing on how students' model and their thinking processes, the cognitive modeling perspective helps to reorganize their ways of modeling (Lehmann, 2024). According to the cognitive perspective, it is important to look at mathematical modeling processes from a cognitive point of view, to teach and learn. The cognitive view assists to deconstruct cognitive obstacles in modeling problems and therefore serves as an essential for identification (Borromeo-Ferri, 2018). Throughout the Modeling Cycle Under Cognitive Perspective, individuals need modeling competencies in parallel with the modeling steps (Borromeo-Ferri, 2010). According to this modeling approach, cognitive modeling competencies are listed as "understanding, simplifying, mathematizing, working mathematically, interpreting, validating" (Borromeo-Ferri, 2006).

Çevikbaş et al. (2022) state that in the literature, modeling competences are divided into two, as global modeling competences and modeling sub-competences. While global modeling competencies include the ability to perform the entire modeling process, solve real-world problems, and question the connections between mathematics and reality, modeling sub-competencies consist of specific skills required to perform each step of the modeling cycle. The concept of competence is a demonstrable set of characteristics that enable an individual to perform effectively, consisting of knowledge, skills, abilities, experiences and behaviours that can be measured and developed through training (Competence, 2024). Mathematical modeling competence can be defined as the ability to perform autonomously and instinctively all aspects of the mathematical modeling process in a given context (Blomhøj & Jensen, 2003). Promoting modeling competence, which refers to the ability to solve real-world problems through mathematics, is considered one of the main goals of mathematics education worldwide if mathematics education is to support responsible citizenship (Kaiser, 2020).

The studies by Borromeo-Ferri (2006, 2010) and Blum and Leiß (2005) defined modeling competencies corresponding to the stages of the modeling cycle. First, understanding competency involves individuals creating a mental representation by making sense of real life problems. Then, simplifying competency involves idealising and simplifying this representation into a real-world model. Mathematising competency is the process of creating a mathematical formulation by moving from this real model to a mathematical model. Subsequently, working mathematically competency enables individuals to achieve mathematical solutions and results by using their mathematical competencies. Interpreting competency refers to the interpretation and evaluation of the mathematical results obtained in the context of real life. Finally, validation competency involves checking the accuracy of mathematical results by comparing them with real-life experiences. These competences detail the stages of the modeling cycle, describing individual cognitive processes and competencies in the modeling process.

From the point of view of cognitive modeling, mathematical modeling should be considered in the context of daily life and other disciplines (Blum & Borromeo-Ferri, 2009), mathematical modeling skills should be identified and learning environments should be prepared for the development of skills (Blomhøj & Kjeldsen, 2006). In addition, Borromeo-Ferri (2018) states that environmental problems that concern our environment, such as gasoline consumption, freshwater consumption, food waste, amount of waste produced, cause critical thinking, thus stating that the concept of 'interdisciplinary' should be an important issue especially for mathematics education and should be more prominent in educational research and practice. In interdisciplinary teaching, by addressing issues in the context of sustainable development around themes such as ‘sustainable consumption, poverty alleviation and climate change’, it makes it possible to learn these issues both from an interdisciplinary perspective and in depth in each discipline (Wiegand & Borromeo-Ferri, 2023). Considering mathematical tasks based on authentic workplace problems in the context of mathematical modeling supports students' understanding of real-world situations from a mathematical perspective (Kohen & Orenstein, 2021). Similarly, English (2015) states that through interdisciplinary studies, problems involving basic concepts from science, society and environmental studies can be addressed to students who can discuss the dynamic nature of environments and how the activities of living and non-living components can change the balance of nature.

Since mathematical thinking is needed to solve real problems today, the products that need to be produced for the problem often require much more than short answers to routine mathematical problems (Sriraman & Lesh, 2006). Therefore, the general idea accepted by mathematics educators today; It is necessary to train individuals who will produce solutions to problems that have the potential to be handled mathematically in daily life, industry, and many other sectors through mathematical modeling (Ural, 2018). Mathematical modeling can be interpreted as an excellent example of mathematical practice and the core competence in mathematics education standards to promote not only modeling competencies, but also interdisciplinary mathematics education in school (Borromeo-Ferri & Mousoulides, 2017). Similarly, it is emphasized in many studies that mathematical modeling is important for interdisciplinary learning (Blomhøj, 2007; English, 2015; Sriraman & Dahl, 2009). Interdisciplinary mathematical modeling is known to support contextual learning and high-level thinking skills such as 21st century skills, creative thinking, reasoning, problem solving, mathematical thinking and scientific literacy (Gürbüz & Çalik, 2021). In fact, it can be observed that students who think that mathematics is not related to different disciplines become aware that mathematics is used in other disciplines and fields thanks to the mathematical modeling process (Duman & Aydoğan Yenmez, 2024).

In studies that deal with mathematical modeling with an interdisciplinary approach, it is generally handled either with science or with a STEM approach (Çavuş Erdem et al., 2021; Güder & Gürbüz, 2018; Gürbüz & Doğan, 2018; Gürbüz et al., 2018; Gürbüz & Çalik, 2021). However, the connection of mathematics with many other disciplines such as art, social studies, economics, sports, and health is ignored. In parallel with this, in the middle school mathematics applications course curriculum (MoNE, 2018b), mathematical modeling tasks; It is stated that problems related to subjects such as savings, tax awareness, healthy and planned life in courses such as science and social studies should be included. Considering that mathematics, which has contributed to the development of many scientific disciplines, has an important place in socio-technical systems and daily life that allows the use of natural resources, the regulation of industrial design, the description and prediction of natural events (Niss, 1994), it can be said that it is important to connect mathematical modeling with other disciplines in mathematics education.

The crucial target of interdisciplinary teaching is to offer students the opportunity to explore relationships and structures that go beyond a specific discipline and unite different aspects of our world in a systematic way (Borich, 2018). On the other hand, research results have shown that organizing and integrating different content areas around a theme can lead to higher-order thinking and meaningful learning (Erickson, 2006). There have been various studies on how to integrate the curricula of different disciplines. Jacobs (1989) explained the interdisciplinary approach by emphasising that combining different disciplines can be the starting point for creating an integrated curriculum. Doğan et al. (2019) proposed the interdisciplinary mathematical modelling (DMM) approach, which can combine STEM disciplines or focus on only two disciplines. In this approach, 'DMM activities' were used, in which mathematics and science are treated together. Similarly, Sezginsoy-Şeker and Dikkartin Övez (2018) investigated the relationship between mathematics and other subjects around a topic within the framework of the 4MAT learning model. However, it is known that modeling is an ideal tool for connecting with other disciplines and should be integrated even into the primary school curriculum (English, 2007) rather than postponing it to middle school and beyond (Maaß, 2005).

Mathematical modeling provides an alternative way of thinking and connecting with real life and mathematics that supports a sustained and internalised learning process by enabling students to actively participate in an open-minded and responsible approach by relating to real-world problems (Spooner, 2022). Research has confirmed that interdisciplinary mathematical modeling activities improve students' mathematical thinking skills (e.g. problem solving, reasoning, higher order thinking tendencies, etc.) and also lead to the positive development of mathematical modeling skills (Özkaya et al., 2023). It is also known that the ability of students to become successful modellers requires the development of mathematical modeling skills through practical modeling activities in the mathematics classroom under the guidance of competent teachers (Frejd & Vos, 2022). Çevikbaş et al. (2022), based on the results of text analysis of internationally renowned articles on mathematical modeling, suggest that it would be beneficial to add qualitative in-depth studies to quantitative studies and turn to mixed methods designs.

For all these reasons, in this study a mixed research was carried out with interdisciplinary mathematical modeling activities, prepared within the framework of Jacobs' (1989: 57) Interdisciplinary Concept Model, focusing on the development of cognitive modeling competencies (understanding, simplifying, mathematizing, working mathematically, interpreting, validating) in Borromeo-Ferri's (2006) study. Çevikbaş et al. (2022), based on the results of text analysis of internationally renowned articles on mathematical modeling, suggest that it would be beneficial to add qualitative in-depth studies to quantitative studies and turn to mixed methods designs. Considering this situation, it is thought that it is a subject that needs to be investigated how the modeling competencies of middle school students change in the learning environment designed with modeling tasks prepared in the context of connecting with other disciplines.

Based on these considerations, the aim of this study is to investigate middle school students' competencies towards mathematical modelling and their views on this process in a learning environment designed with interdisciplinary modelling activities. For this purpose, the research seeks an answer to the problem "What are middle school students' competencies in mathematical modeling and their opinions on the process in a learning environment designed with interdisciplinary modeling activities?". On the other hand, the research focuses on the following sub-problems.

• Is there an important difference between the modeling competencies (understanding, simplifying, mathematizing, working mathematically, interpreting, validating) of the control and experimental groups after the implementation?

• What are the opinions of the experimental group students about the use of modeling tasks after and before the implementation?

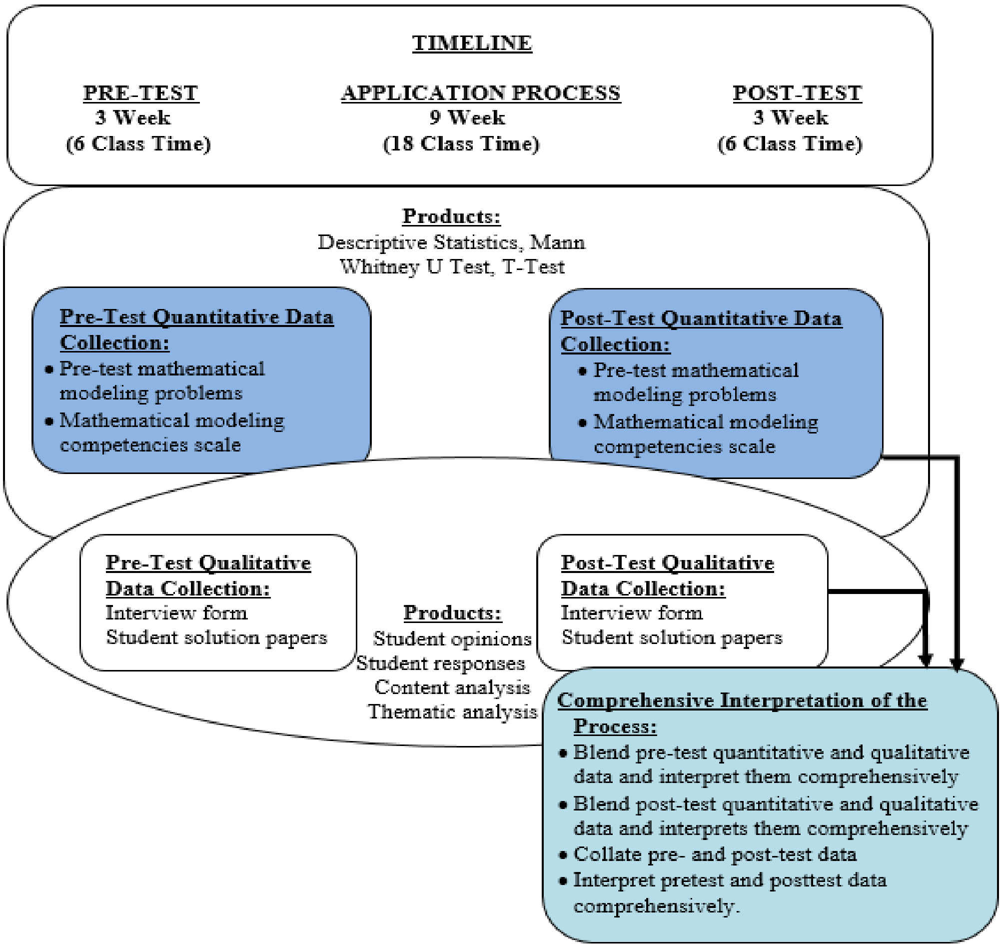
METHOD

This study is mixed research conducted to investigate the competencies of middle school students for mathematical modeling in a learning environment designed with modeling tasks prepared in the context of connection with other disciplines.

Creswell & Plano Clark (2018) state that a qualitative stage can be attached to a quantitative work, such as an experimental study, by researchers. In this case, also called the embedded experimental mixed-method design (Creswell & Plano Clark, 2018, p. 98), researchers use qualitative data to answer middle problems within the study to support the more dominant quantitative data and to improve the original data with additional data. Figure 1 shows the flow chart of the embedded experimental mixed method the study's design

Figure 1

Embedded Experimental Mixed Method Design (adapted from Creswell & Plano Clark, 2018, p. 78)



Data analysis methods, data collection tools, timeline and flowchart used in the qualitative and quantitative parts of the research are given. As can be seen from the flowchart, qualitative and quantitative data were collected and analysed at the same time. In this study, quantitative data and qualitative data were blended by focusing on quantitative data. In the study, it was aimed to balance the limitations of both qualitative and quantitative data by mutual validating with qualitative and quantitative findings. In addition, qualitative and quantitative data were blended in the study, as well as post- and pre-test data were blended and commented together.

2.1. Participants

This study was performed with seventh class students studying in a public school found in the centre of one of the metropolitan cities of our country. The study group was primarily selected from the school where the researcher worked, with easily accessible case sampling (Yıldırım & Şimşek, 2005). Since it was not possible to randomly distribute the students to the control and experimental groups, the two classes with the closest averages of the previous semester were selected by the researcher by using the group matching design (Büyüköztürk et al., 2019). In addition, in accordance with the embedded sample relationship (Johnson & Christensen, 2014), all control and experimental groups consisting of a sum of 61 students were selected in the quantitative part of the study, and only experimental group students consisting of 34 students were selected in the qualitative part of the research. Since the real names of the students were not wanted to be given the experimental group students were "E1, E2, E3, E4, ..." and the control group students were "C1, C2, C3, C4, ..." it is coded as.

Mathematics achievement grades of the students in the control and experimental groups were obtained from the MoNE e-School system. It was determined that the students' number in the range of 70-100 points in the groups was equal and 14. Similarly, in the experimental group the percentage of students with a grade point average of 55 and above was 55.9%; In the control group, it was 62.9%. According to these values, it can be said that the control and experimental group students are similar with regard to mathematics achievement.

2.2. Data Collection Tools

2.2.1. Mathematical Modeling Tasks

Model Building Activities are described as problem-solving tasks in which students generate models and clarify, test, and make necessary adjustments and corrections using their mathematical thinking to enable students to take advantage of mathematical modeling in complicated real-life problems (Eric, 2008). In this study, while mathematical modeling tasks were developed; It has been tried to pay attention to the curriculum, the achievements of mathematics and other disciplines, connecting with other disciplines, developing modeling skills, setting up different models, the readiness and interest of the students, their usefulness in the classroom environment, the simplicity of the language, and the appropriateness of the visuals.

In this study, a framework was created for the general characteristics of the activities by considering the principles of event design and implementation (Kerpiç & Bozkurt, 2011). These features are purpose, flexibility, time use, classroom organization, student and teacher roles, inclusivity, student challenge, assessment and evaluation, student readiness, multiple starting points, appropriateness of the materials used and inclusivity. In addition, while preparing the modeling tasks, the characteristics of the mathematical modeling tasks created by Tekin Dede and Bukova Güzel (2014, p.98) within the framework of the literature and the principles of modeling tasks expressed by Lesh et al. (2003, p.43) were taken care. In other respects, taking into account the basic components of the modeling tasks (Chamberlin & Moon, 2005), the activities were divided into stages as introductory essay, readiness questions, problem situation and presentation of solutions.

While designing the activities, the role of the student and the teacher were determined during the two lesson hours at the time of activity implementation. In addition, arrangements have been made in conformity with the study's the purpose, such as the materials to be used, classroom organization, time use, measurement, and evaluation. Figure 2 shows the interdisciplinary concept model of the Hevsel Gardens Activity [Appendix-1] given in the appendix. This model has been developed using Jacobs' (1989) interdisciplinary conceptual model.

While preparing the activities, a concept model was used in which mathematics and one or more other disciplines were connected around a theme. In conformity with the aim of the mathematics applications course, these themes are determined in accordance with social values and in accordance with mathematics and other disciplines, and interdisciplinary connections have been established. As can be seen in the concept model in Figure 2, it is aimed for students to establish connections between mathematics and social studies courses with the theme of "protecting cultural heritage". For example, since the article given to the students in this activity talks about the history of Anatolia and Mesopotamia, it has a relationship with the social studies lesson. Nonetheless, students are expected to realize the importance of our cultural values.

Figure 2

Sample Interdisciplinary Concept Model: Hevsel Gardens Task

The purpose of this modeling problem is to enable students to understand the importance of our agricultural lands in the social studies lesson and to connect the subject of maps and scales in the social studies lesson with the ratio-proportion and area topics in the mathematics lesson. The aim of giving it as a modeling problem is for the student to assume the area of an irregular region as a regular shape and to produce a solution to the problem. Thus, the student is expected to realize that the approximate value of the area can be calculated by converting irregular shapes into regular shapes.

In the first stage of the activity development process, post-test and pre-test modeling problems and application process activities were prepared by connecting the mathematics course with the achievements of other disciplines (science, social studies, visual arts, physical education, information technologies) within the framework of the main theme. After the activities were prepared, the branch teachers of other disciplines were asked to examine the activities in terms of the appropriateness of the achievements, language expression and content, and necessary arrangements were made together with the researcher in cooperation with the branch teachers. Then, the Activity Evaluation Form, which includes topics such as suitability of achievements, language expression, tables/graphics and visuals, connection with other disciplines, mathematical modeling, suitability for the achievements of other disciplines, was prepared, and evaluations were received from five academicians and three graduate students who are experts in their fields, and necessary arrangements were made. After the necessary arrangements were made in the activities, the pilot study was performed with 8 students during extracurricular times. Considering the feedback from the students, the activity development process was completed.

2.2.2. Opinion Forms

Opinion forms containing structured questions were prepared by the researcher in order to specify the students' the opinions on mathematical modeling and mathematical connection and mutual connection of mathematics with other disciplines throughout the study process. In this study, only opinions on mathematical modeling are included. A "Preliminary Opinion Form"

[Appendix-2] was prepared for the pre-implementation and a "Final Opinion Form" [Appendix-3] was prepared for the post-application. From these forms, there are two open-ended opinion questions in the preliminary opinion form and six open-ended opinion questions in the final opinion form for mathematical modeling. So as to decide whether the questions in the opinion form are appropriate to determine the students' opinions on mathematical modeling, opinions were taken from academicians who experts in their fields are. Then, in order to determine whether the questions are understandable, the opinions of the students who will not participate in the research are taken and the necessary arrangements are made, and the forms are finalized.

2.3. Data Analysis

In this study, the quantitative data is based on data obtained from mathematical modeling tasks. In determining mathematical modeling competencies, successful completion and evaluation of the modeling process is envisaged. For this reason, the "Modeling Competencies Assessment Rubric" developed by Tekin Dede and Bukova Güzel (2018), which deals with modeling competencies more comprehensively, was used. In the analysis of the data obtained with rubrics, Shapiro Wilk test was used since the number of students in the control and experimental groups was less than 50. It was determined that the data regarding the modeling competencies of the groups did not show normal distribution. Therefore, the Wilcoxon signed rank test and the Mann Whitney U-test, which are alternative tests used in cases where the normality assumption is not met, were used.

Modeling Competencies in the Evaluation Rubric, modeling competencies include five levels of understanding the problem, simplifying four levels, mathematizing five levels, working mathematically five levels, interpreting five levels, and validating competencies seven levels. Using rubrics, equal scoring was made so that the highest 12 points that students could get from each of the modeling competencies were made. The quantitative data of the study were evaluated with pre- and post-tests administered individually. The modelling activities were carried out as group work during the implementation process, but the group work process was not included in the scoring; only the individual test results were scored. In terms of the reliability of the scoring process before and after the implementation of the study, each activity was scored twice by the first author at different times and 75% agreement was achieved between the scores. This rate meets the reliability criterion suggested by Miles and Huberman (1994) (70% agreement rate). The discrepant ratings were discussed with the second author and the appropriate ratings were decided.

The study’s the qualitative data were obtained by using preliminary and post-opinion forms from data collection tools. These opinions were analysed using content analysis and thematic analysis of qualitative analysis methods. Content analysis involved organising student responses, creating codes and categories by identifying concepts and relationships in the data, and interpreting the data through these structures. In cases where student responses could not be conceptualised through content analysis, thematic analysis, which is a more superficial method, was applied and direct quotes were included in order to represent individual opinions more impressively (Çepni, 2012). In order to ensure coding reliability, the data were coded twice by the first author. In order to ensure the safety of the coding process and the appropriateness of the codes and themes, evaluations were made with the second author and an academic expert in the field of qualitative analysis and necessary arrangements were made. The table below shows an example content analysis table.

Table 1

An example content analysis table

Category	Subcategories	Codes	Example Phrases	f
The Importance of Mathematical Modeling	Increasing Interest-Motivation	Interest, Motivation, Attention	D22: Actually, yes, it wasn't nice before. But then I got used to it and it seemed easy and beautiful to me...	2
	Contribution to Success	Procedural Skill, Success, Development, Self-Control	D1: It is important. Because I saw questions in this class that we had not seen before. It has improved me... D18: It's very important. Because I'm testing myself. I'm learning how to deal with unambiguous questions.	2
	Developing Comprehension and Thinking Skills	Understanding, Thinking, Connecting	D14: Important. Because it increases our ability to think. D33: It's important to me. Because when we make our own assumptions, we can solve them in more ways.	4
	Contribution to Connecting with Different Disciplines	Connection, Related Course Contents, Support	D2: I repeat some of the topics because they come up in both mathematics and science. D19: It’ s important because if we don't know mathematics, we can't know some of the topics of other subjects. For example, science, social studies, visual arts.	4
	Comprehending the Importance of Mathematics	Importance, Basic Discipline	D6: Mathematics is very important. It can happen at any time. If we know the mathematics lesson well, we know almost all the lessons well. D24: Since every lesson is related to mathematics, it is very important to solve.	3
	Solving Daily Life Problems	Daily Life, Problem Solving	D17: yes because it makes it easier for us to answer questions in our daily lives. **D29:** Important. Because it can occur in daily life, such as finding the area of a place easily.	9

2.4. Application Process

The study lasted a total of fifteen weeks, including three weeks for the pre-test, nine weeks for the intervention and three weeks for the post-test. The same modelling activities were used in both the pre-test and the post-test. The first task related the mathematical concepts of equality and equations to the concepts of weight and mass in science. The second activity linked the mathematical concepts of measuring length and ratio to the concept of speed in science. The third activity linked the mathematical concept of volume measurement to the concept of natural resources in social studies. The students were asked to complete these modelling activities individually within 40 minutes.

During the experimental group's application phase, various mathematical modelling activities, previously prepared by the researcher, were carried out over a period of nine weeks. These activities aimed to link mathematical concepts with learning outcomes in other disciplines, including science, social studies, visual arts, physical education, sport and information technology. The activities covered mathematical concepts such as ratio and proportion, measuring length, equations, measuring volume, percentage, pie charts and whole numbers. At the same time, links were made to topics such as natural resources, national economy, history, map lines and scales in social studies; force, mixtures and speed in science; perspective in visual arts; healthy living in physical education; and data storage in information technology.

Each modelling activity in the experimental phase was carried out according to a constructivist approach, consisting of preparation, application and evaluation phases. The experimental group was divided into heterogeneous trios. Prior to each activity, the students were presented with previous assignments, presentations and research tasks, followed by presentations of these activities in the classroom. The teacher then showed appropriate videos, presentations or computer applications related to the task and asked preparatory questions about the problem situation. Clear role definitions for both teacher and students before each activity minimised the teacher's role and created a collaborative learning environment with increased student participation. As part of the constructivist approach, the teacher minimised direct instruction and encouraged students to engage in discussion to solve the activities. After the application phase, one or two groups presented their solutions to the class and a collective solution was reached. Finally, after each activity, the proposed solutions were discussed, encouraging different perspectives in a constructive evaluation environment. This process helped students to develop a deeper understanding of the links between mathematics and other disciplines. An example of a task and the daily programme of the experimental phase are given in Appendix 1.

2.5. Research Ethics

For the research, permission was obtained from Dicle University Educational Sciences Ethics Committee with the decision number 90871155-044 dated 03/01/2018 and Directorate of National Education. While conducting this research, attention was paid to the "Higher Education Institutions Scientific Research and Publication Ethics Directive".

RESULTS

Under this heading, the findings of the question "What are the modeling competencies of the students before and after the learning process designed with modeling tasks?", which is the problem of the research, are presented.

3.1. Findings of the First Sub-Problem

In the context of the research problem, first, an answer to the first sub-problem "Is there a meaningful difference between the modeling competencies of the control and experimental groups at the end of the application?" was sought.

As can be seen in Table 2, there was no statistically meaningful difference between the mathematical modeling competencies of the control and experimental groups before the implementation ($U=343.50$, $p>0.05$). When the rank averages are examined, the mathematical modeling competency scores of the control group students are lower than the experimental group students. However, statistically, this difference is not meaningful. Based on this, it can be said that the modeling pre-test scores of the groups are parallel to each other. When each of the pre-test modeling competencies of the control and experimental groups was examined respectively, no statistically meaningful difference was found in any of the problems of understanding the problem ($U=345.00$; p0.05), simplifying ($U=351.50$; $p>0.05$), mathematizing ($U=364.50$; $p>0.05$), mathematical working ($U=338.00$; $p>0.05$), interpreting ($U=417.50$; $p>0.05$), validating ($U=442.50$; $p>0.05$). When the order mean values of the modeling competencies are looked at separately, it is seen that the control group values have lower values than the experimental group values. However, this difference is not statistically remarkable. According to these statistical values, when each of the pre-test modeling competencies of the control group and the experimental group students is examined separately, it can be said that the groups have similar characteristics in terms of modeling competencies. Similarly, it is possible to see this situation in the solution sheets of the students.

Table 2

Mann Whitney U-Test Results Regarding Pre-Test Mathematical Modeling Competency Scores of Control and Experimental Group Students

Modeling Competencies	Group	n	Rank average	Rank Sum	U	p
Understanding	Experiment	4	34.35	1168.00	345.00	084
	Control	7	26.78	723.00		
Simplifying	Experiment	4	34.16	1161.50	351.50	.112
	Control	27	27.02	729.50		
Mathematizing	Experiment	34	33.78	1148.50	364.50	.157
	Control	27	27.50	742.50		
Working Mathematically	Experiment	34	34.56	1175.00	338.00	.065
	Control	27	26.52	716.00		
Interpreting	Experiment	34	32.22	1095.50	417.50	.443
	Control	27	29.46	795.50		
Validating	Experiment	34	31.49	1070.50	442.50	.766
	Control	27	30.39	820.50		
Modeling Competencies Total Scores	Experiment	34	34.40	1169.50	343.50	.093
	Control	27	26.72	721.50		

In order to show that the answers of the students in the control and experimental groups to the modeling competencies in the pre-test modeling problems are similar, an example of the answers of different students in the control and experimental groups to understanding, simplifying and mathematizing the modeling competencies is given and explained in Table 3.

Table 3

Responses of Different Students in the Control and Experimental Groups to Pre-Test Modeling Competencies

Citation	Explanation
[1) Interpret what is given to you and what is asked of you by expressing the problem in your own words. C16: He gave us the distance of Mr. Ahmet to the Ten Eyed Bridge. He wants how many minutes it will take for Mr. Ahmed and the object to arrive.]	1) Interpret what is given to you and what is asked of you by expressing the problem in your own words.Since it was seen that the C16 student used expressions showing that he understood the problem to some extent and did not establish a relationship between what was given and what was requested, the student's ability to understand the problem remained at the 2nd level.
[E17: There is 2 km between the Tigris river and the Ten-Eyed Bridge. How many minutes can it take to reach the Tigris river and the Ten-Eyed Bridge.]	Since it was seen that the E17 student used expressions showing that he understood the problem to some extent and did not establish a relationship between what was given and what was requested, the student's ability to understand the problem remained at the 2nd level.
[2) Make up your own assumptions about the problem. C15: That the water from the tap falls in five seconds, the sides of the container are 10 cm and 15 cm, and the drop is 4 mm.]	While determining the necessary variables for the Water Drop problem, the C15 student made a mistake with the expression "Assuming that a drop falls per second" in the problem, but the student made a mistake with the expression "Assuming that a drop of water falls from the tap every 5 seconds" and made wrong assumptions, so it was determined that the simplifying competence was at level 2.
[E15: If a drop flows in 1 second, it becomes 3600 in 1 hour. I'll figure it out based on that.]	For the Water Drop problem, the E15 student determined the necessary variables to some extent with the expression "If 1 drop of water flows in one second". However, since he did not make assumptions about the size of the water droplet, the simplifying adequacy remained at level 2.
[3) Explain how you will follow a mathematical path in solving the problem. C27: For example, if you put 3 kg of metal on the right pan of the scale and rice on the left pan, the rice is 3 kg.]	For the Grocer's Apprentice problem, the C27 student created a verbal model of one of two types of assumptions, which is to leave brass weights on one side of the scale and metal weights on the other. However, he did not mention that metal weights could be left on the balance together. For this reason, the competence of mathematizing remained at level 2 because it created an incomplete mathematical model based on an acceptable assumption to some extent.
[E27: Adding each metal, it will form a non-identical number of metals, thus creating a path.]	For the Grocer's Apprentice problem, student E27 created a verbal model of one of two types of assumptions, which is to leave brass weights on one side of the scale and metal weights on the other. However, while he established a model to leave the sum of the weights to a pan, he did not create a model to leave the metal weights alone. Therefore, the student remained at level 2 because he or she had created an incomplete mathematical model based on some acceptable assumption.

According to the qualitative and quantitative data of the pre-test, it was seen that the control and experimental group students were close to each other in terms of mathematical modeling competencies. On the other hand, descriptive statistical calculations were made regarding the modeling competencies obtained from the groups' the post-test data. In the analysis of the total scores of the groups' the post-test modeling competencies, the average of the total scores of the mathematical modeling competencies of control group students were 27.18, while the experimental group students were 103.41. The Mann Whitney U-test in Table 4 was performed to specify whether this difference between the sum scores of the modeling competencies of the groups and the sum scores of each of the modeling competencies was statistically remarkable.

Table 4

Mann Whitney U Test Results Regarding Post-Test Mathematical Modeling Competency Scores of Control and Experimental Group Students

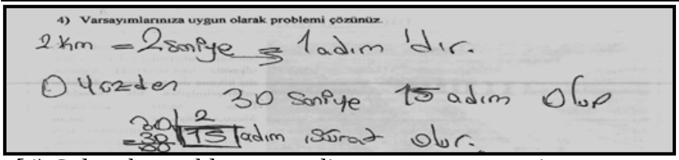
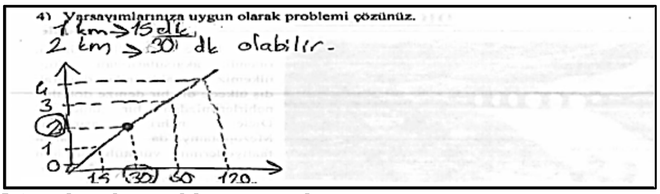
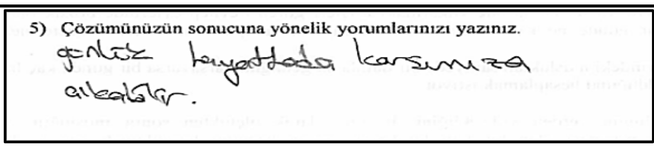
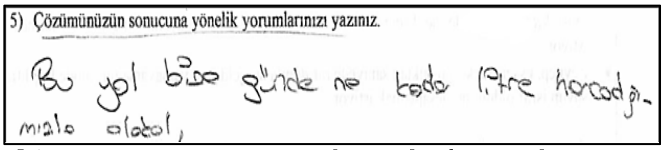
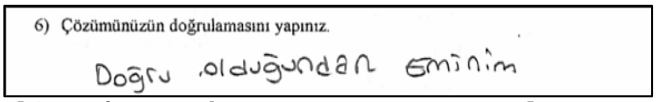
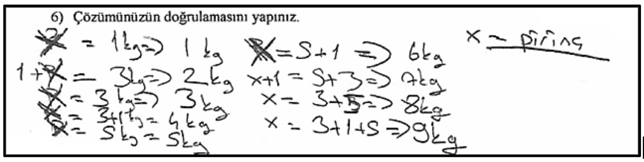
Modeling Competencies	Group	**n**	**Rank average**	**Rank Sum**	**U**	**p**
Understanding	Experiment	34	42.03	1429.00	84.00	.00
	Control	27	17.11	462.00		
Simplifying	Experiment	34	42.74	1453.00	60.00	.00
	Control	27	16.22	438.00		
Mathematizing	Experiment	34	42.32	1439.00	74.00	.00
	Control	27	16.74	452.00		
Working Mathematically	Experiment	34	40.71	1384.00	129.00	.00
	Control	27	18.78	507.00		
Interpreting	Experiment	34	38.53	1310.00	203.00	.00
	Control	27	21.52	581.00		
Validating	Experiment	34	40.03	1361.00	152.00	.00
	Control	27	19.63	530.00		
Modeling Competencies Total Scores	Experiment	34	42.57	1147.50	65.50	.00
	Control	27	16.43	443.50		

As can be seen in Table 4, at the end of the application, it was seen that there was a remarkable difference between the groups in favour of the experimental group in terms of mathematical modeling competencies ($U=65.50$, $p<0.05$). This finding can be said that the mathematical modeling activity process connected with other disciplines contributes positively to the total scores of the modeling competencies of the experimental group students. Similarly, the Mann Whitney U test was performed for each of the mathematical modeling competencies between the groups and is given in Table 4. According to these statistical values, the values in the table were obtained for each of the understanding ($U=84.00$; $p<0.05$), simplifying ($U=60.00$; $p<0.05$), mathematizing ($U=74.00$; $p<0.05$), mathematical working ($U=129.00$; $p<0.05$), interpreting ($U=203.00$; $p<0.05$) and validating ($U=152.00$; $p<0.05$) competencies. According to these values, statistically it shows that there is a meaningful difference between the control and experimental groups for each of the modeling competencies. These findings show that the experimental group students' the modeling competencies to whom the mathematical modeling application process was applied improved on behalf of the experimental group compared to the control group students.

In order to better understand this developmental difference, it is explained in Table 5 with an example of the answers of different students in the control group and the experimental group for mathematically working, interpreting and validating post-test modeling competencies from modeling competencies.

Table 5

Responses of Different Students in the Control and Experimental Groups to Posttest Modeling Competency

Citation	Explanation
 [4) Solve the problem according to your assumptions. C9: 2km = 2 seconds = 1 step. Therefore, 30 seconds is 15 steps and 30/2=15 steps is speed.]	For the Tigris River problem, the C9 student remained at the 1st level because he tried to solve the wrong mathematical model by equalizing the distance, time and number of steps with expressions such as "2 km = 2 seconds = 1 step" in his mathematical competence.
 [4) Solve the problem according to your assumptions. E24: 1 km can be 15 min, 2km can be 30 min.]	It was decided that the E24 student was at the 5th level because he created a correct model based on realistic assumptions for the speed of the object by first drawing a graph with the assumption of "1km-15 minutes" in his ability to work mathematically for the problem called Tigris River.
 [5) Write your comments on the result of your solution. C6: It can be encountered in daily life.]	The C6 student for the problem called Water Drop remained at level 1 because he did not interpret the mathematical solution obtained in the interpreting competency in the real-life context.
 [5) Write your comments on the result of your solution. E13: It's about how many liters we spend per day.]	In the interpreting competence of the E13 student for the problem called Water Drop, it was decided that he was at the 5th level because he correctly interpreted the expression "This way is related to how many liters of water we spend per day" in the real-life context of how much water is wasted on average.
 [6) Verify your solution. C3: I'm sure it's true.]	The C3 student for the problem called Grocer's Apprentice remained at level 1 because he did not have a validating approach in his validating competency.
 [6) Verify your solution. E23: x=rice and student's solution]	For the problem called Grocer's Apprentice, student E23 demonstrated all the weights that can be created by using an algebraic validating approach in the validating competency. Therefore, it was determined that he was at level 7. This shows that the student's validating competency is at a high level.

In order to reveal the meaningful difference between the sum scores of the modeling competencies of the post-test and pre-test and the total scores of each of the post-test and pre-test modeling competencies of the control group students, the Wilcoxon signed ranks test was performed and the results obtained are presented in Table 6. Similarly, when the sum scores of the post-test and pre-test modeling competencies of the control group students were looked at, the analysis values in the table were obtained for each of the pre-test and post-test simplifying (z=.53, p>.05), understanding (z=1.41, p>.05), mathematizing (z=.95, p>.05), working mathematically (z=1.34, p>.05), validating (z=.00, p>.05) and interpreting (z=.81, p>.05) competencies. This shows that no meaningful difference is found between the post-test and pre-test modeling competencies of the control group.

Table 6

Results of Wilcoxon Signed Ranks Test of Pre-Test and Post-Test Modeling Competency Scores of Control Group Students

Modeling Competencies	Post-test-Pre-test	n	Rank average	Rank Sum	Z	p
	Negative Rank	0	.00	.00		
Understanding	Positive Rank	2	1.50	3.00	-1.41*	.15
	Equal	25				
	Negative Rank	1	2.00	2.00		
Simplifying	Positive Rank	2	2.00	4.00	-.53*	.59
	Equal	24				
	Negative Rank	5	3.00	15.00		
Mathematizing	Positive Rank	1	6.00	6.00	-.95**	.33
	Equal	21				
	Negative Rank	2	1.50	3.00		
Working Mathematically	Positive Rank	0	.00	.00	-1.34**	.18
	Equal	25				
	Negative Rank	1	1.50	1.50		
Interpreting	Positive Rank	2	2.25	4.50	-.81*	.414
	Equal	24				
	Negative Rank	1	1.50	1.50		
Validating	Positive Rank	1	1.50	1.50	-.00***	1.00
	Equal	25				
	Negative Rank	7	4.43	31.00		
Modeling Competencies Total	Positive Rank	3	8.00	24.00	-.358**	.720
	Equal	17				

**Based on Negative Sequences* ***Based on Positive Sequences* ****Based on equal ranks*

When the rank means and totals of each of the modeling competencies are viewed, it is seen that the post-test and pre-test scores based on equal ranks, do not have a meaningful difference. In parallel with these test results, it was observed that the changes in the total mean scores of the pre-test-post-test modeling competencies (understanding [10,13-10,56]; simplifying [8,15-8,37]; mathematizing [3,78-3,41]; working mathematically [2,89-2,70]; interpreting [1,11-1,33]; validating [0,81-0,81]) obtained by descriptive statistical calculations were also similar. According to all these data, it can be said that the application process does not acquire a significant act upon improving the control group students' the modeling competencies.

In order to reveal the significant difference between the experimental group students' the total scores of the post-test and pre-test modeling competencies and the sum scores of each of the post-test and pre-test modeling competencies, Wilcoxon signed rank test was performed and the results obtained are presented in Table 7. Accordingly, the modeling competencies of the experimental group students show that there is a meaningful difference between the post-test and pre-test results (z=5.04, p<.05). Considering the rank mean and sums of these difference scores, it is observed that this difference is on behalf of positive ranks, that is, the post-test scores of the experimental group students. In addition, the mean scores of the total scores of modeling competencies were 103.41 in the post-test and 37.02 in the pre-test.

Table 7

Wilcoxon Signed Ranks Test Results of Post-Test and Pre-Test Modeling Competency Scores of Experimental Group Students

Modeling Competencies	Post-test-Pre-test	n	Rank average	Rank Sum	z	p
Understanding	Negative	1	3.50	3.50		
	Positive	32	17.42	557.50	-4.96*	.00
	Equal	1				
Simplifying	Negative	0	.00	.00		
	Positive	33	17.00	561.00	-5.03*	.00
	Equal	1				
Mathematizing	Negative	1	2.50	2.50		
	Positive	30	16.45	493.50	-4.82*	.00
	Equal	3				
Working Mathematically	Negative	2	2.50	5.00		
	Positive	26	15.42	401.00	-4.52*	.00
	Equal	6				
Interpreting	Negative	1	2.00	2.00		
	Positive	22	12.45	274.00	-4.14*	.00
	Equal	11				
Validating	Negative	1	4.43	31.00		
	Positive	26	8.00	24.00	-.358*	.72
	Equal	7				
Modeling Competencies Total	Negative	1	2.50	2.50		
	Positive ank	33	17.95	592.50	-5.04*	.00
	Equal	0				

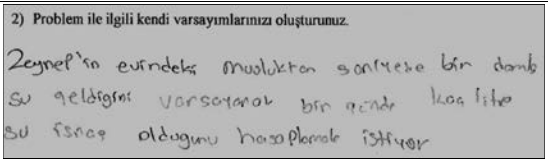
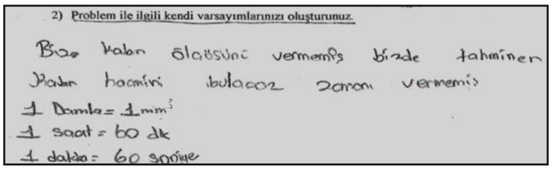
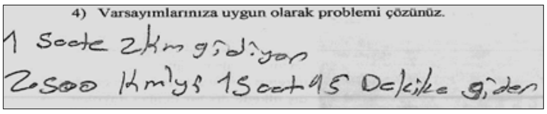
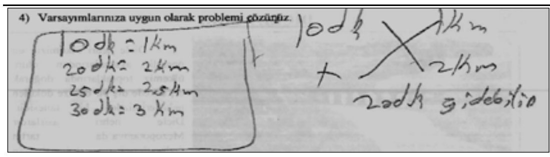
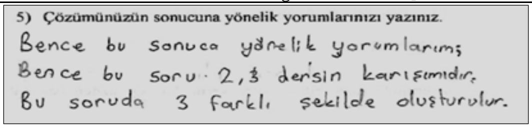
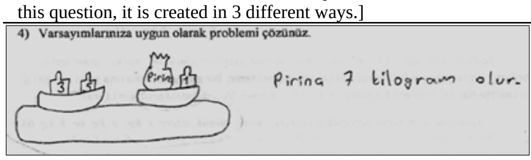
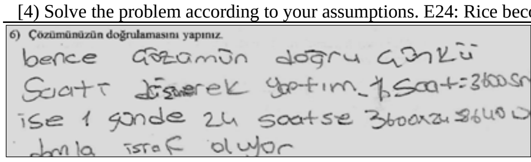
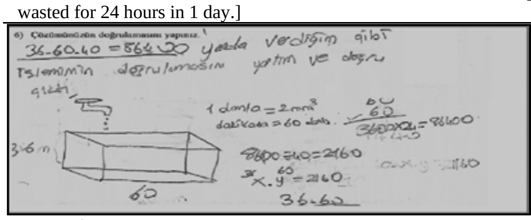
** Based on Positive Ranks*

It can be said that the mathematical modeling activity process connected with different disciplines, which is applied according to the values in the table, has an important act upon the development of the modeling competencies of the experimental group students. The analysis values in the table were obtained for each of the pre-test and post-test simplifying (z=5.03, p<.05), understanding (z=4.96, p<.05), working mathematically (z=4.52, p<.05), mathematizing (z=4.82, p<.05), validating (z=-.358, p>.05) and interpreting (z=4.14, p<.05) competencies of the experimental group students. This situation shows that there is a meaningful difference between the post-test and pre-test understanding, simplifying, mathematizing, mathematical work and interpreting competencies of the experimental group students; It shows that there is no important difference between validating competencies.

Looking the rank mean and totals of each of the modeling competencies, it is seen that this difference is in favour of positive ranks, that is, the experimental group students' the post-test scores. In parallel with these test results, it is seen that the changes in the total mean scores (understanding [11.47-22.50]; simplifying [11.06-23.65]; mathematizing [6.00-18.18]; working mathematically [5.74-16.50]; interpreting [1.27-9.71]; validating [1.53-12.88]) obtained by descriptive statistical calculations, respectively, are similar. When the total scores of the modeling competencies are taken into account, the post-test's the total scores increase in all competencies compared to the pre-test's the total scores. Although the difference in the increase in each of the competencies varied, the least increase was in the competency of interpreting. With these results, it can be said that the mathematical modeling activity process connected with other disciplines has an important act upon the development of the modeling competencies of the experimental group students. In parallel with the data in Table 7, in order to show this developmental difference between the experimental group's post-test and pre-test modeling competencies, it was endeavoured to be described in Table 8 by giving an example of the answers of different students in the experimental group for each modeling competencies of simplifying, mathematical working, interpreting and validating.

Table 8

Experimental Group Students' Responses to Pre-Test-Post-Test Modeling Competencies

Citation	Explanation
 2) Problem ile ilgili kendi varsayımlarınızı oluşturunuz. Zeynep'in evindeki musluktan saniyede bir damla su geldigini varsayarak bir günde kaç litre su israf oldugunu hesaplamak istiyor [2) Make up your own assumptions about the problem. E17: If one drop of water comes from the tap in her house per second, Zeynep wants to calculate how many liters of water are wasted in a day.]	In the pre-test simplifying competency, the E17 student determined the necessary variables with the statement "Assuming that one drop of water comes from the tap in Zeynep's house per second, she wants to calculate how many liters of water are wasted in a day", but she remained at level 1 because she did not assume suitable for the problem.
 2) Problem ile ilgili kendi varsayımlarınızı oluşturunuz. Boş kabın ölçüsünü vermemiş biz de tahminen kabın hacmini bulacaz zamanı vermemiş 1 Damla = 1 mm³ 1 saat = 60 dk 1 dakika = 60 saniye [2) Make up your own assumptions about the problem. E17: He did not give the size of the empty container, and we will probably find the volume. He didn't give the time. 1 drop=1 mm^3, 1 hour= 60 min, 1 min= 60 sec.]	For the problem called Water Drop, the E17 student determined the necessary variables with the expressions "1 minute = 60 seconds,1 hour = 60 minutes " and "He did not give the dimensions of the container, we will find the volume of the container by guessing" in the post-test simplifying competency, and it was determined that he was at the 4th level, that is, at a high level, since he made realistic assumptions with the expression "1 drop of water = 1 mm3".
 4) Varsayımlarınıza uygun olarak problemi çözünüz. 1 Saate 2km gidiyor 2500 km'yi 15 saat 15 Dakika gider [4) Solve the problem according to your assumptions. E10: It goes 2 km in 1 hour. It travels 2500 km in 15 hours and 15 minutes.]	The E10 student for the problem called Tigris River remained at the 1st level because he solved the wrong mathematical model incorrectly with expressions such as "He travels 2 km in 1 hour, travels 2500 kilometers in 1 hour and 15 minutes" in the pre-test mathematically study competency.
 4) Varsayımlarınıza uygun olarak problemi çözünüz. 10 dk = 1km 20 dk = 2km 25 dk = 2,5 km 30 dk = 3 km 10 dk 1km, x 2km, 20 dk gidebilir [4) Solve the problem according to your assumptions. E10: 10 min 1km; for x, 2km. He can go in 20 minutes.]	The E10 student created a realistic hypothetical model for the velocity of the object by using the assumption of "1 km in 10 minutes, 2 km in x minute, x = 20 minutes" with the assumption of "1 km in 10 minutes" in the post-test mathematically working competency in the post-test test. However, since the student reached the correct mathematical solution using the mathematical models he created, it was decided that he was at the 5th level.
 5) Çözümünüzün sonucuna yönelik yorumlarınızı yazınız. Bence bu sonuca yönelik yorumlarım; Bence bu soru 2,3 dersin karışımıdır. Bu soruda 3 farklı şekilde oluşturulur. [5) Write your comments on the result of your solution. E24: I think my comments on this result are. I think this question is a mixture of 2-3 lessons. In this question, it is created in 3 different ways.]	The E24 student for the problem called Grocer's Apprentice remained at level 1 because he did not interpret the mathematical solution obtained in the pre-test interpreting competency in a real-life context.
 4) Varsayımlarınıza uygun olarak problemi çözünüz. Pirinç 7 kilogram olur. [4) Solve the problem according to your assumptions. E24: Rice becomes 7 kg.]	In the post-test interpreting competency, the E24 student tried to explain that weighing can be done with the difference of weights by leaving metal weights on both pans of the equal-arm scale on the figure. With this figure, he made a correct interpreting in the real-life context for the use of the equal-arm scale. For this reason, it was decided that the student's interpreting competency was at level 5.
 6) Çözümünüzün doğrulamasını yapınız. bence çözümün doğru çünkü Saati düşünerek yaptım 1 saat = 3600 sn ise 1 günde 24 saatse 3600x24 = 86400 damla israf oluyor [6) Verify your solution. E16: I think the solution is right because I did it with the clock in mind. 1 hour: If it is 3600 seconds, 3600x24=86400 drops are wasted for 24 hours in 1 day.]	For the problem called Water Drop, the E16 student did the same solution for the validating competency as he did for the pre-test validating competency as he did for the mathematical working competency. The student found the amount of wasted water in drops, but not in liters. Although there was such a shortcoming, he did not make a correction. Although it has a validating approach to some extent, it has remained at level 2 because it does not correct the errors.
 6) Çözümünüzün doğrulamasını yapınız. 36.60.40 = 86400 1 damla = 2 mm³ [6) Verify your solution. E16: 6.60.40=86400 ; 1 drop = 2mm^3 , 60 drops per minute.]	In the post-test validation competency of the E16 student for the problem called Water Drop, he found the number of water drops wasted by assuming "1 drop of water = 2 mm3", but did not convert the amount of water into liters. In addition, he tried to show the accuracy of the dimensions of the container in an algebraic way by accepting the volume of the container as the volume of the drops. It was determined that the student was at level 5 because he took the validating approach and corrected the identified errors to some extent.

When the data in Table 7 and the student responses in Table 8 were viewed, it was seen that there was a meaningful difference between the modeling competencies of the experimental group in favor of the posttest. In order to determine whether this change in the modeling competencies of the experimental group was reflected in the opinions of the students, the opinions of the students gained from the post-test and pre-test interview forms were examined with a qualitative approach by thematic and content analysis.

3.2. Findings of the Second Sub-Problem

Under this heading, the findings of the sub-problem of the research "What are the experimental group students' the opinions on the use of modeling tasks before and after the application?" are included.

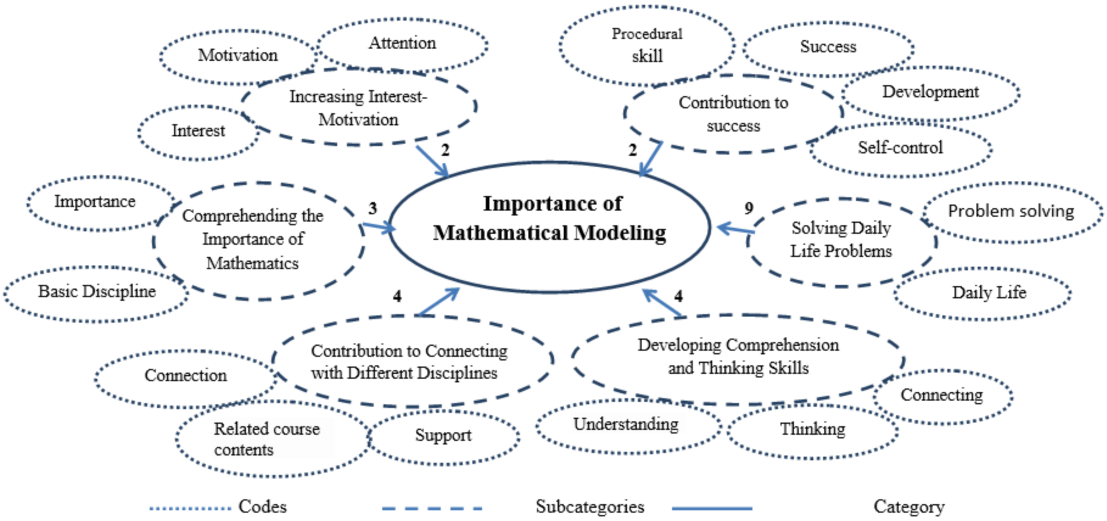
In the preliminary opinion form, "Have you solved problems in your mathematics classes that can be solved according to your assumptions, some of which are not given? If you have solved it, explain it with concrete examples." was analyzed thematically with a qualitative approach. The students' answers to the question in the pre-interview form about whether they solve problems in mathematics lessons on the basis of their assumptions and without some information were thematically analyzed. Two students did not answer this question, 28 students said that they did not encounter such problems in class and 1 student said yes but did not give any explanation. Student E7 used the expression "equation with unknown numbers" and confused the modelling problem with equations with first order unknowns. Similarly, Student E9 referred to the modelling problem with the statement "I found a way and solved it that way, not the way the teacher said", but did not provide any information about the content of these problems. Student E18 said: "Yes, in maths. I couldn't solve it because I didn't understand it" and explained that he didn't understand the problem and couldn't give a solution. It was observed that the students associated the expression "problems based on their assumptions" with the subject of equations with unknowns and thought that modelling problems and equations with unknowns were the same thing. This shows that students were not exposed to modelling problems prior to the use of modelling tasks and that such problems were not used by teachers.

In the preliminary opinion form, the students were asked, "If you were given problems in your mathematics lessons that could be solved according to your assumptions, some of which were not given, how would you solve them? Explain your thinking with concrete examples." an open-ended question was asked, and the answers of the students were analyzed descriptively with a qualitative approach, different tendencies were observed. Some students stated that they had not encountered such problems before and that they would have difficulties. For example, student E10 said, "I have never solved problems like this before. I would have difficulties", while student E27 said: "I would have difficulties if it was a question I had never solved before". Some students stated that they would try to solve the problems they encountered with their existing mathematical knowledge. Student E18 said: "I try to solve by looking at other mathematics subjects. Because mathematics subjects are related to each other". On the other hand, some students stated that they could make connections with different subjects, for example, student E7 said, "I solve by making connections with different subjects. For example, if there is a question in maths, I connect it to science". Only a few students emphasized the tendency to make assumptions and student E13 said, "I make assumptions using information". These statements show that students do not have sufficient knowledge about modelling problems and lack guidance about the stages of the process.

In the Final Opinion Form, open-ended questions were used to determine the students‘ opinions about the importance of mathematical modelling activities in the mathematics applications course and the students' responses were analyzed by content analysis.

Figure 3

Students' Opinions on the Importance of Mathematical Modeling in the Final Opinion Form

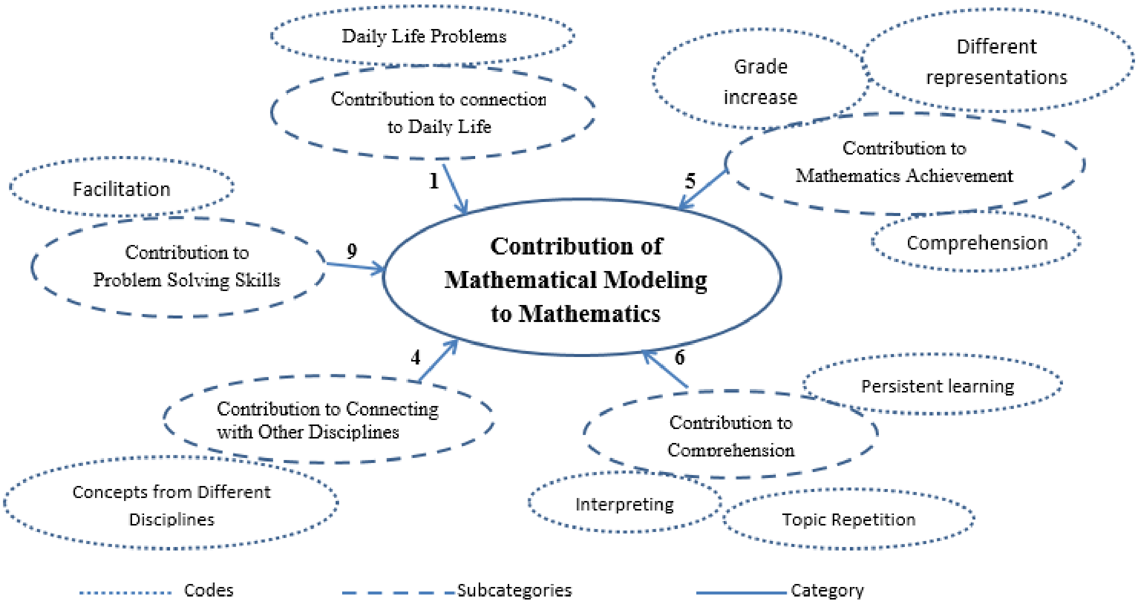


The findings are presented in Figure 3 with the codes and subcategories created under the main category of ‘Importance of Mathematical Modelling’. Based on the students' responses, the importance of mathematical modelling was grouped under five main subcategories: increasing interest and motivation, contributing to mathematics achievement, understanding the importance of mathematics, making connections with other disciplines, and developing understanding and thinking skills. When the responses of the students are detailed, positive opinions were reported especially about the contribution of modelling activities to motivation and interest. The student coded E22 stated that his interest in modelling increased with the statement ‘I did not like it at first, but then I got used to it and it was easy and beautiful...’. In the subcategory of contribution to mathematical achievement, the student coded E1 stated that modelling activities contributed to mathematical achievement by saying ‘In this lesson, I saw questions that we had not seen before, it improved me...’. In the subcategory of contribution to the development of understanding and thinking skills, students coded E7 and E14 stated that modelling improved their understanding and thinking skills. For example, E14 said, ‘It is important. Because it increases our thinking skills.’ and emphasised that modelling activities improve thinking skills. In addition, some of the students stated that modelling activities contributed to making connections with other disciplines. The student coded E19 said, ‘It is important, because if we do not know mathematics, we cannot know some of the subjects of other courses. For example, science, social studies, visual arts.’ and stated that modelling facilitated them to make connections with the concepts in other courses. Finally, it was observed that students also expressed opinions about their ability to make connections with daily life. For example, student coded E17 said, ‘Yes, it makes it easier for us to answer questions in our daily lives.’ and emphasised that modelling activities provide preparation for situations that can be encountered in real life. These findings provide strong evidence that mathematical modelling activities increase students' interest and motivation, contribute to mathematics achievement, comprehension and thinking skills, and are effective in making connections with other disciplines and daily life.

In the final opinion form, the responses of the students to the open-ended question about whether the mathematical modelling activities in the mathematics applications course contributed to the mathematics course were analysed by content analysis and the findings are presented in Figure 4 with codes and categories.

Figure 4

Students' Opinions on the Contributions of Mathematical Modeling Tasks



While three students stated that they did not contribute, 31 students stated that they contributed; five of them emphasised the contribution without explanation and 26 of them emphasised the contribution with explanation. In the explanations of the students, contribution to mathematics achievement, contribution to problem solving skills, contribution to comprehension skills, contribution making connections with other disciplines and daily life applications came to the fore. When students' views on the contribution of modelling activities to the mathematics course were analysed, it was found that the majority believed that these activities had positive effects (Figure 4). In the category of contribution to mathematical achievement, some students stated that modelling activities contributed to the use of different representations (tables, graphs, equations) and indirectly to achievement. For example, student E22 emphasised this by saying: "We do things like tables, graphs, equations, that contributes to our lesson". In the category of contribution to problem solving skills, students stated that modelling activities helped them to solve complex problems more easily. Student E23 expressed the improvement in problem solving skills with the statement "I can solve complex problems more easily".

In the category of contribution to comprehension skills, four students stated that their interpretation and comprehension skills improved thanks to the modelling activities; student E34 expressed this contribution with the statement "Yes, I can interpret better". In addition, some students stated that modelling activities contributed to their ability to make connections with other disciplines and apply them to real life. These findings provide evidence that modelling activities have a positive impact on students' achievement, ability to make connections, problem solving skills and sustainable learning.

In the final opinion form, "Would you like the problems given in the form of activities in the mathematics applications course to be used in your lessons? Explain your opinion with justifications. Give concrete examples." was analysed thematically with a qualitative approach. In this question, which was not answered by two students, 17 students stated an affirmative opinion on the use of modeling tasks in the lessons, while 13 students stated that they did not want them to be used and expressed a negative opinion. 1 student states that he is undecided about whether it should be used or not. One of the students who wanted the activities to be used, the student with the code E7 said, "Yes. My grades would have improved in my other courses as well", while the student with the code E28 said, "Yes, I would. Because I can understand other courses better", emphasizing the contribution of modeling tasks to other disciplines, they stated that they wanted the activities to be used in the lessons. Similarly, the student with the code E9 said, "Yes. Because I always want to be successful in my classes", while the student with the code E12 said, "Yes. Because solving those papers in mathematics improves me", they stated that modeling tasks contribute to success and that they want modeling tasks to be used in lessons. The student with the code E15 said, "Yes. Because it was beneficial for us", and the student with the code E26 stated that it would be beneficial to use modeling tasks with the phrase "Yes, it is very good, it is beneficial". The E14 student said, "Yes. Because we have an interest in thinking about problems specifically", it can be said that he emphasizes his contribution to higher-order thinking. When the opinions of the students are looked at, it can be said that they express the significance of using modeling tasks by stating that modeling tasks will contribute to mathematics success and other course achievements, and that problem solving skills will improve. In addition, when the responses of the students who want the activities to be used in the lessons are examined, it can be said that they express opinions parallel to the characteristics of modeling tasks such as course success, problem solving skills, contribution to other disciplines, and daily life, which are the general characteristics of modeling tasks.

Students E1, E11 and E23 who stated that they did not want modeling tasks to be used in the lessons complained that the activities were long with expressions similar to the phrase "No. Because it is a bit long." The E4 student used the phrase "No. Because it is exceedingly difficult, I have difficulty in doing it", and the students with the codes E17, E18 and E27 used expressions similar to the expression of the E4 student. These four students state that modeling tasks are difficult. It can be said that this situation is since students mainly encounter multiple-choice questions in the lessons. The E33 student said, "It should be used. Because we should not get used to test questions" supports this idea. It can be said that the students who expressed negative opinions were not aware of the importance of modeling tasks in terms of daily life and connecting them with other disciplines.

In the final opinion form, "Do you think there are negative aspects to these problems? If so, what are they? Explain your opinion with justifications. Give concrete examples." was analysed thematically with a qualitative approach. While 4 of the students mentioned the existence of negative aspects of modeling tasks, 30 students stated that modeling tasks did not have negative aspects, on the contrary, they had positive aspects. The student with the code E1 expressed the same thought with the phrase "Too many unknowns and steps" and the student with the code E23 expressed the same thought with the phrase "There are too many unknowns and steps, so it is negative". While the student with the code E4 stated that "Yes, there was, I was having a hard time", the student with the code E22 said, "... but it's a bit boring." Looking at the responses of the students who gave negative opinions, it can be said that modeling problems, unlike the multiple-choice questions used in the courses, require a longer process for the solution and this process is in steps. However, the majority of the students in the group did not adopt these negative opinions about modeling problems. 30 of the students stated that modeling problems have positive aspects as opposed to negative aspects. For example, a student with the code E9 "... My mathematics written grades have increased one more notch", while talking about the contribution of modeling tasks to success, the E19 coded student said, "... I can understand it better. For example, I can solve complex issues more easily", referring to its contribution to understanding and problem-solving skills. Similarly, the student with the code E32 "... I connect mathematics with other courses." while talking about the contribution of modeling tasks to connecting with other disciplines, the student with the code E15 said, "... Now I can solve the questions I will encounter in daily life" and shared his thoughts on the contribution of modeling tasks to daily life situations. Overall, when the students' answers in the final opinion form were taken into account, the majority of the students expressed positive thoughts such as modeling problems that contributed to their interest in mathematics, helping them with course success, contributing to their interpretation and problem-solving skills, connection with other disciplines daily life and, and improving their understanding. Thanks to the implementation process, it can be said that in parallel with the modeling competency scores of the students, it has increased the positive opinions of the students towards modeling.

In the final opinion form, "What are the similarities and differences between these problems and the problems you have seen before? Explain your opinion with justifications. Give concrete examples." was analysed thematically with a qualitative approach. While three of the students did not answer the question appropriately, 11 of them stated that the modeling problems were not similar to other problems used in mathematics lessons, but they did not explain their reasons. 20 of the students emphasized many different aspects of modeling problems with other problems. Illustrating the differences of the modeling problems, 10 of the students emphasized the stages of the modeling problems, five emphasized the connection aspect of the modeling problems, and five emphasized the modeling problems in the form of activities. For example, student E10 "... gradual, etc.", with the E34 student "... A stepwise solution is required", emphasizing the existence of sub-steps for the solution of modeling problems. Some students said that the E18 student "... We are asked to express the problem in our own words." while emphasizing the understanding step with similar opinions, some students also emphasized the understanding step with the E15 student's "Too much is not given..." They directly emphasized the simplifying step by emphasizing the necessity of creating assumptions with expressions similar to the statement. Similarly, the students who used expressions similar to the E12 student's statement "The problems I have seen before are different from this problem are that they are tests, and our thoughts are not shared", directly emphasized the interpreting step of the modeling problems. Emphasizing the connection aspect of modeling problems, student E7 said, "Yes, there are different aspects. I encounter it in daily life", emphasizing that modeling problems provide connection with daily life, while the E13 student said, "Different. Because I have never had a problem with every course before", the students emphasized the importance of modeling problems in connecting with other disciplines. Other students, who emphasized different aspects of modeling problems, stated that modeling problems were in the form of activities, while other problems were in the form of tests. The E14 student said, "While solving tests in other problems, it is necessary to think and solve these problems specifically.", while the E33 student said, "There are different aspects because they are test questions, and these are activities. We think more at the event." In general, when we look at the opinions of the students who explain the difference between modeling problems and other problems with their justifications, it can be said that solving modeling problems in steps makes a positive contribution to students' thinking, problem solving and connection skills. The E19 student exemplifies the importance of the connection aspect of modeling problems with the statement, "I think they are more successful in the connection aspect."

In the last opinion form, "When you encounter similar problems in daily life or in your lessons, do you believe that you can solve the problems by applying the sub-steps given in the problems? (Will you follow the steps in the problems given in the form of activities in the math applications course? How?). Explain your opinion with justifications. Give concrete examples." was analysed thematically with a qualitative approach. While four of the students did not answer the question appropriately, seven of them stated that they would not use the sub-steps given if they encountered similar problems. While six of the students who stated that they would not use it did not give a reason, the E33 student said, "No, I will not use it. Because it takes longer." Twenty-three of the students pointed out that if they came across similar problems, they would solve them by applying the lower steps. For example, the E17 student said, "I do what I am given and what is asked of me. I can do it with assumptions. I write reviews. I will do it if it is related to some courses.", and the E19 student said, "In mathematics problems, I first make assumptions, then interpret, solve, validate and make connections". Some of the students who used expressions similar to those of these students additionally stated that they would solve it using different mathematical models. For example, the E14 student would use the phrase "Yes with assumptions, verbal, mathematical graphs, ratio proportions, tables, coordinates" and the E4 student with the statement "Yes, I would use it. Table, proportion proportion..." They emphasized that they would solve problems with different mathematical models. When the students' opinions were looked at, the majority of the students stated that they would use the sub-steps of the modeling tasks applied during the application process in the problems they would encounter in daily life. For example, the E24 student supports this opinion with the statement "I can contribute to solving similar problems in daily life and solve them easily". It is desirable for students to approach the problems they will encounter in daily life by using modeling steps. In general, when the students' opinions were looked at, it can be said that the fact that they will use modeling in daily life reveals the positive effects of the application process.

When the findings are considered in general, at the end of the application, it was specified that the modeling competencies of the experimental group students improved in favour of the experimental group compared to the control group students. In addition to these findings, when the quantitative data of the experimental group were looked at, it was determined that the modeling competencies scores increased significantly after the implementation compared to the pre-implementation. When the experimental group students' responses to the post-test and pre-test modeling problems were assessed, it was observed that the answers they gave to the post-test modeling problems in parallel with the quantitative data showed an important positive improvement compared to the answers they gave to the pre-test problems. In parallel with the quantitative data, when the responses of the experimental group students to the preliminary and final opinion forms were examined, it was seen that there were significant differences in the opinions of the experimental group students about the modeling problems. In the final opinion form, it can be said that students have more positive thoughts, modeling tasks contribute positively to their understanding, success, interest, and motivation, help them better understand the significance of mathematics in terms of other disciplines and daily life, and there are positive developments in connection and problem-solving skills. It can be said that the data gained from both quantitative and qualitative findings and the application process carried out with modeling tasks connected with other disciplines have positive effects on the experimental group students' the modeling competencies.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

In this study, middle school students' the competencies and opinions towards mathematical modeling were examined in the learning environment designed with modeling tasks prepared in the context of connected with other disciplines.

When the data obtained from the pre-test modeling problems applied before the learning process are examined; It was observed that there was no significant difference between the total scores of the mathematical modeling competencies of the experimental group students and the control group students and the scores of each modeling competence scores, and they were similar and low. Similar results have been reported in the literature with both middle school students (Biccard & Wessels, 2011; Şeker, 2019) and pre-service teachers (Çakmak Gürel, 2018; Karacı, 2016). For example, Biccard and Wessels (2011), in their study with middle school students, found that all modeling competencies of the students were at a low level before the application; Çakmak Gürel (2018), on the other hand, in his qualitative study with pre-service teachers, found that pre-service teachers had problems in all modeling competencies before the learning process. In general, it can be said that the mathematical modeling competencies of the participants remain at a low level before a certain teaching process is implemented. In order to overcome this situation, students should be exposed to more modeling problem situations; Studies that will contribute to the development of modeling competencies should be included.

The data obtained from the student responses to the question about whether the modeling tasks were used in mathematics lessons in the preliminary opinion form of the experimental group students were examined. According to these data, it can be said that students have never encountered modeling problems before the learning process, modeling problems have never been used by teachers, and students do not have knowledge about mathematical modeling and problems. When examined in the literature, similar results are encountered. For example, in different studies conducted with pre-service teachers (Çiltaş & Işık, 2013; Özer Keskin, 2008) it was observed that pre-service teachers did not have idea about mathematical modeling and problems. Kaiser and Schwarz (2006), on the other hand, conducted a study with middle and undergraduate students, and it was specified that most of the students had undeveloped, ordinary opinions about mathematics. In order to eliminate this situation, it was stated by the students that modeling examples should be included in ordinary mathematics teaching. In the study conducted by Sarı and Sağırlı (2021) with middle school mathematics teachers, they found that teachers did not have sufficient knowledge about mathematical modeling. The researchers concluded that teachers confuse the concept of mathematical modeling and representation with modeling. When we look at the studies in general, it can be said that both the modeling competencies of the students and their opinions on modeling are insufficient before the application. It can be said that the most important reason for this situation is that mathematical modeling is not included enough in mathematics lessons.

When the findings obtained from the modeling problems applied after the learning process are examined, it is seen that there is a meaningful difference between the control group students and the experimental group students with regards to the total scores of mathematical modeling competencies. When the total scores of the post-test-pre-test the control group students' modeling competencies are looked, it is seen that there is no important difference. Similarly, it shows that there is no meaningful difference between the total scores of the post-test-pre-test the control group students' modeling competency. However, when the total scores of the post-test and pre-test the experimental group students' modeling competencies are looked, it is seen that there is an important difference, and it shows an improvement on behalf of the post-test scores. According to these findings, learning process carried out with mathematical modeling tasks contributed positively to the total scores of the modeling competencies of the experimental group students. Similar results have been obtained in studies conducted at different teaching levels in the literature. For example, Özdemir (2014) determined that as a result of his mixed research with middle school students, the modeling competencies of the students participating in the application developed at 94% medium and above levels. In another study conducted with middle school students with control and experimental groups (Şeker, 2019), it was determined that the experimental group's the students who were taught with modeling as a result of the application showed a significant improvement in their modeling competencies, while there was no meaningful improvement in the modeling competencies in the control group where the courses suitable for the curriculum were taught. In the study to evaluate the learning process with 13-week modeling with pre-service teachers (Karacı, 2016), it was found that the participants' the post-test modeling competency scores heightened compared to the pre-test modeling scores. Similarly, Özer Keskin (2008) observed that at the end of the application process he carried out with pre-service teachers for a semester, they were more successful in the mathematical modeling skill test compared to the pre-trial process. In the control and experimental group study of Blum and Leiß (2007) it was determined that the modeling competencies of the experimental group students who were integrated into the lessons showed more improvement in their modeling competencies than the control group students who were not given the modeling cycle. When the studies in the literature are investigated, it is observed that the teaching processes for mathematical modeling contribute to the development of modeling competencies. It can be said that this situation expresses the necessity of an appropriate teaching process for the development of modeling competencies.

When the data obtained from the modeling problems applied after the learning process are examined and each of the modeling competencies of the control and experimental groups is examined separately, it is observed that there is a statistically important difference on behalf of the experimental group in all of the modeling competencies. In addition, when it is investigated whether there is a significant difference between the total scores of the post-test and pre-test modeling competencies of the experimental group students, there is a meaningful difference between the post-test and pre-test understanding, simplifying, mathematizing, mathematically working and interpreting competencies of the experimental group students on behalf of the post-test; However, it was specified that no statistically meaningful difference is found between the validating competencies. Although the score increases as regards the total scores of the modeling competencies differed in each of the competencies, the least increase was in the interpreting competency. It is possible to see similar results in studies in the literature. In his quantitative relational study conducted with middle school students at different grade levels, Tekin Dede (2017) found that modeling competencies increased as the grade level increased. In the case study she conducted with middle school students, İnan (2018) determined that the students did not have the validating competence in solving the modeling problem, but only checked whether there were deficiencies or errors in the transactions they made; Şahin and Eraslan (2017), on the other hand, found that students generally accept the correctness of operations without interpreting or validating in solving modeling problems. On the other hand, İnan Tutkun and Didiş Kabar (2018) report that middle school students do not interpret the mathematical results as part of real life and do not check the accuracy of the results after reaching the desired solution in the modeling process. Sol et. al (2011), on the other hand, found that students had difficulty in solving modeling problems at different stages of the modeling process, as well as in the validating phase. In the study conducted by Çoksöyler and Bozkurt (2021), it was revealed that secondary school students completely ignored the interpretation and verification steps in the mathematical modelling process.

Govender and Machingura (2023) observed in their study with high school students that very few participants interpreted their solutions or checked if the solutions initially met the stated conditions. It is possible to see similar results in the case study conducted by Tekin Dede and Yılmaz (2013) with pre-service teachers. In this study, it was determined that pre-service teachers worked in the context of all competencies and showed an inadequate approach in interpreting competence. In another study conducted with pre-service teachers (Kaya & Keşan, 2022), it was specified that pre-service teachers had problems in interpreting mathematical results and validating the validity of the results in a real-life problem. When the studies are evaluated, it can be said that there is a developmental problem in interpreting and validating competencies in general (Baran Bulut & Türker, 2022; Biccard & Wessels, 2011; Greefrath & Siller, 2017; Korkmaz, 2010). In these studies, it can be said that while the interpretive competence is either underdeveloped or undeveloped, there is no improvement in the validating competence in general. There may be various reasons for this situation. As a matter of fact, as a result of his study, Aydın Güç (2015) determined that modeling competencies were affected by many variables such as model building activities, the designed learning environment, the beliefs and past experiences of the study group throughout the process. However, Çavuş-Erdem et al. (2021) concluded that modeling skills are affected by problem-solving habits, mathematics and science achievements required by the activity. In addition to the studies carried out, one of the reasons why the interpreting competence does not develop at the desired level may be that students are exposed to multiple-choice questions and are not asked to interpret in the context of daily life in mathematical problem solutions. Similarly, it can be said that one of the reasons why the validating competency does not improve at the wanted degree is that students are not asked to verify like the validating step in modeling while solving problems, and they are only based on checking the accuracy of the consequence of the operations. In addition, Lu and Kaiser (2022) stated in their study that the mathematical modelling process requires creativity and that there is a significant relationship between creativity and competencies such as interpretation and verification of mathematical results in this process. Therefore, it can be said that developing students' creativity in modelling processes can contribute to their interpretation and verification competencies.

The findings obtained from the answers given to the question in the final opinion form about the importance of using modeling tasks in students' courses were examined. According to student opinions, it has been revealed that mathematical modeling contributes positively to students' interest, motivation, success and understanding, and is effective in connecting mathematics with other disciplines and daily life. It is possible to see similar results in the literature. For instance, in their study with middle school students, Zihar and Çiltaş (2018) determined that there was an increase in students' interest in mathematics lessons with mathematical modeling problems. Özdemir (2014), in his study with middle school students, about modeling tasks by students; interesting, intriguing, related to daily life and providing more motivation. In the study conducted by Şeker (2019) with middle school students, positive thoughts such as that the lessons and modeling problems were fun and enjoyable and contributed to the love of mathematics more were found in the students' opinions after the modeling process. As the study's a result conducted by Güder and Gürbüz (2018) using interdisciplinary modeling tasks with middle school students, it was specified that students improved their interdisciplinary connection skills, their attitude towards disciplines changed positively, and interdisciplinary modeling tasks should be included in the school curriculum. Cabrera-Baquedano et al. (2022) observed in their study with high school students that interdisciplinary modeling activities provide suitable environments for enhancing students' financial literacy levels. As a result of his semi-experimental study with middle school students, Sandalcı (2013) determined that the students' level of awareness of the relationship between mathematics and real life improved, and in the interviews, students with medium and low achievement levels increased their interest in the course and had a better understanding of the lesson. In the study conducted by Deniz and Akgün (2014) with middle school students, the students stated that mathematical modeling is more comprehensive, interesting and thought-provoking than the mathematical problems they have encountered in their lessons before, and they have realized how high the relationship of mathematics is with daily life. Additionally, Wang et al. (2023) have found that students with high proficiency in mathematical modeling also exhibit high levels of creativity, and they have concluded that mathematical modeling influences creativity.

It is possible to see similar results in studies with teachers and pre-service teachers. Özkaya et al. (2023) in their study with pre-service teachers determined that interdisciplinary mathematical modeling activities improved participants' mathematical thinking skills such as problem solving, reasoning, and higher-level thinking, as well as their mathematical literacy and modeling skills. In addition, the participants evaluated the application process with mathematical modeling activities with positive opinions such as being interesting, developing creativity and imagination, and using mathematics in real life. Genç (2023) examined pre-service teachers' mathematical connection with mathematical model building activities. In this study, it was seen that the participants stated that connection mathematics with other disciplines would give students an interdisciplinary perspective. In the study conducted by Urhan and Dost (2016) with mathematics teachers, the participants stated that modeling activities contribute to mathematics such as connection mathematical concepts, connection the subject with daily life, motivation and permanent learning. In the study conducted by Korkmaz (2010) with pre-service teachers, the participants remarked that although modeling is a complex and long-lasting process, they enjoy living this process and realize the importance of mathematics in daily life. As a result of his study with pre-service teachers, Başkan Takaoğlu (2015) found that the pre-service teachers' interest in interviews increased with the courses carried out using modeling and interdisciplinary connection, and in parallel with this, the level of connecting mathematics with physics and daily life improved. When the students' views on the importance of mathematical modeling are examined, it is seen that they are in parallel with the relevant research in the literatures. This shows that the learning process with modeling tasks contributes affirmatively to the opinions of the students after the process compared to the pre-process. In addition to modeling competencies, it can be said that the learning process also contributes positively to the understanding, success, interest, motivation, and attitudes expressed in the opinions of the students.

When the opinions of the experimental group students in the final opinion form regarding the contribution of modeling tasks to the mathematics course were examined; It was reflected in the opinions of the students that modeling tasks provided positive improvements in students' course achievements, connection skills, problem-solving skills, and helped permanent learning, comprehension, and subject repetition. Biccard and Wessels (2011) stated that modeling studies showed a significant change in students' cognitive and metacognitive competencies and student beliefs in their studies with middle school students. English (2007), in his study with fifth grade students using an interdisciplinary modeling activity, states that students develop mathematical operations that extend beyond their regular curriculum. In addition, students stated that their mathematical understanding of these modeling problems allowed them to develop separate ways of learning with different dimensions, as opposed to traditional classroom problem solving. Similarly, English and Watters (2005) reveal that modeling tasks are powerful tools for developing important mathematical ideas and problem-solving processes starting from primary school years. Kaiser and Schwarz (2006), in their studies with middle and undergraduate students, found a positive change in students' and pre-service teachers' mathematical beliefs about mathematics and mathematics teaching after the application. In addition, in studies where a teaching plan was made with mathematical modeling, it was found that the participants supported their learning and developed skills for the relevant concept (Çavuş Erdem & Gürbüz, 2018; Güder & Gürbüz, 2018b; Zihar & Çiltaş, 2018) and modeling tasks will promote the improvement of both general cultural and educational values and mathematical values have been found to contain very rich experiences (Doruk, 2012; Villa-Ochoa, & Berrío, 2015). Similarly, in his study with undergraduate students, Spooner (2022) concluded that mathematical modeling contributes to students' active participation in the lesson, their association with real life and mathematics, their promotion of learning, and the development of their thinking skills. Karabacak and Akbaş (2024) conducted a study with secondary school students and found that the use of mathematical modelling activities in mathematics lessons would have various positive effects such as higher-order thinking, creative thinking, permanent learning and socialisation. Wei et al. (2022) have concluded that mathematical modeling enhances students' mathematical thinking skills and also provides opportunities for developing communication skills, critical thinking, and independent thinking. It is seen that the opinions of students on the contribution of mathematical modeling to the mathematics course and in the literature the relevant studies’ the results are similar. For this reason, it can be said that mathematical modeling tasks have a positive effect on students' mathematics learning, success, development of mathematical concepts and connections, attitudes, and beliefs towards mathematics.

When the students' opinions on the final opinion form regarding the negative aspects of modeling tasks, if any, were examined, almost all of the students expressed positive opinions, while a small number of students expressed negative opinions. When the positive answers were examined, in parallel with the previous opinion questions, they stated positive thoughts such as that modeling tasks contributed to their interest in mathematics, helped them to succeed in the course, contributed to their connection with other disciplines and daily life, and improved their problem solving, comprehension and interpretation skills. However, in the opinions of the students who gave negative opinions, it was seen that the students mainly complained that the activities were too long. In their study with middle and undergraduate students, Kaiser, and Schwarz (2006) stated that mathematics teaching with mathematical modeling examples was more positive than traditional teaching, but it was observed that there was a consensus among students that the lessons became much more challenging and time-consuming. When the studies conducted in the literature are examined, the number of studies in which the participants express negative opinions about mathematical modeling is almost negligible. This situation shows that the contribution of mathematical modeling to mathematics teaching is exceedingly high, and its negative aspects are almost non-existent. When we look at the opinions of the students who gave negative opinions, it is mentioned that the modeling tasks are long and time-consuming. It can be said that the reason for these thoughts is related to the fact that students have encountered multiple-choice and short-answer questions that are mostly used in lessons.

According to the qualitative results of the study, it was revealed that interdisciplinary mathematical modelling activities improved students' mathematical thinking, problem solving and making connections with other disciplines and led them to a deeper and more permanent learning experience. In addition, interdisciplinary mathematical modelling activities were found to increase not only students' achievement in mathematics course but also their achievement in different disciplines and their connections with these disciplines. Özkaya et al. (2023) also stated in their study that interdisciplinary mathematical modelling activities improve students' mathematical thinking skills (problem solving, reasoning, higher order thinking tendencies, etc.) and lead to the positive development of mathematical modelling skills. As a result of the study conducted by Güder and Gürbüz (2018) with secondary school students using interdisciplinary modelling tasks, it was stated that students' interdisciplinary connection skills improved, their attitudes towards disciplines changed positively, and interdisciplinary modelling tasks should be included in the school curriculum. These studies in the literature also confirm that such activities improve students' creative thinking, problem solving and critical thinking skills. In this context, including more interdisciplinary mathematical modelling activities in educational processes will contribute to students' acquisition of 21st century skills and associating mathematics with daily life.

In line with the results of the research, various suggestions can be made for researchers and practitioners. Considering the positive contributions of mathematical modeling to students' opinions on mathematical skills and mathematics, and their opinions on other disciplines, it is thought that mathematical modeling tasks should be included frequently. New studies focusing on the development of each sub-competence separately should be included, and studies on interpreting and validating competencies should be increased. However, in addition to various studies that will contribute to the development of students' modeling competencies, it is thought that situations that may prevent development are also a subject that needs to be investigated. The study was carried out in such a way that it was limited to the mathematics applications course and 2 lessons per week. In future studies, more extensive studies can be carried out in mathematics courses.

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TÜRKÇE GENİŞLETİLMİŞ ÖZET

Giriş

Bu çalışmanın amacı, disiplinler arası modelleme etkinlikleri ile tasarlanmış bir öğrenme ortamında ortaokul öğrencilerinin matematiksel modellemeye yönelik bilişsel yeterliklerini ve bu süreç hakkındaki görüşlerini incelemektir. Farklı ülkelerin matematik yönelik öğretim standartlarında ve öğretim programlarında yer alan ve önemle vurgu yapılan (CPDD, 2012; Lingefjärd, 2006; Milli Eğitim Bakanlığı [MEB], 2017, 2018a, 2018b; NCTM, 2000; Yüksek Öğretim Kurulu [YÖK], 2018) matematiksel modelleme; katılımcıların üst düzey matematiksel düşünmelerine katkı sağlarken (Biccard & Wessels, 2011), katılımcıları problem çözmeye teşvik etmektedir (English, 2004).

Yöntem

Araştırmada iç içe deneysel karma desen kullanılmıştır. Çalışma yedinci sınıf kontrol ve deney gruplu altmışbir öğrenciyle yürütülmüş; uygulama süreci ve ön test-son testler olmak üzere toplam onbeş hafta sürmüştür. Veri toplama aracı deney ve kontrol gruplarına üçer hafta süreyle ön test-son test matematiksel modelleme problemleri ile ön görüş/son görüş formu uygulanmıştır. Öğrencilerin modelleme yeterliklerini değerlendirmek için "Modelleme Yeterlilikleri

Değerlendirme Rubriği"nden (Tekin Dede & Bukova Güzel, 2018) yararlanılmıştır. Deney grubu öğrencileriyle modelleme etkinlikleri ile tasarlanan dokuz haftalık uygulama süreci yürütülürken her bir etkinlik yapılandırmacı yaklaşıma uygun olarak hazırlık, uygulama ve değerlendirme olmak üzere üç aşamada uygulanmıştır. Veri analizi yapılırken nicel verilerin analizinde alternatif testlerden Wilcoxon işaretli sıralar testi ve Mann Whitney U-testi; nitel veriler için ise betimsel analiz ve içerik analizi kullanılmıştır.

Bulgular

Araştırmanın nicel verilerine ilişkin bulgulara göre eğitim süreci sonrasında gruplar karşılaştırıldığında modelleme yeterlikleri açısından gelişimin deney grubu lehine gelişim gösterdiği belirlenmiştir. Deney grubunun ait nicel verilerine bakıldığında ise eğitim süreci öncesine göre eğitim süreci sonrasında modelleme yeterlikleri puanlarının anlamlı bir şekilde artış tespit edilmiştir. Deney grubu öğrencilerinin modelleme yeterliklerine ait nicel verilerin analizinde ön test-son test modelleme yeterliklerinde doğrulama yeterliği hariç diğer tüm yeterliklerde son test lehine anlamlı fark oluştuğu tespit edilmiştir. Bununla birlikte deney grubu öğrencilerinin modelleme problemlerine yönelik yanıtlarına da bakıldığında, ön testlerdeki vermiş oldukları yanıtlara göre son test testlerdeki yanıtların gözle görülür bir ilerleme katettikeri belirlenmiştir.

Araştırmanın nitel bulguları incelendiğinde ise deney grubu öğrencilerinin modelleme problemlerine yönelik görüşlerinin son görüş formunda daha olumlu düşüncelere sahip oldukları görülmüştür. Son görüş formundaki öğrenci görüşlerine göre modelleme etkinlerinin öğrencilerin; matematiğe yönelik motivasyon, ilgi, başarı ve anlamalarına olumlu katkılar sağladığı söylenebilir. Bununla birlikte matematiksel modelleme; öğrencilerin matematiğin diğer disiplinler ve günlük hayat yönünden önemini daha iyi kavramalarına katkı sağladığı, problem çözme ve ilişkilendirme becerilerinde gelişim sağladığı söylenebilir. Genel olarak araştırmanın bulgularından elde edilen verilere göre eğitim sürecinin deney grubu öğrencilerinin hem modelleme yeterliklerinde hem de modellemeye yönelik görüşlerinde olumlu değişimler sağladığı söylenebilir.

Tartışma, Sonuç ve Öneriler

Eğitim süreci öncesinde uygulanan ön test modelleme problemlerine ait verilere bakıldığında; kontrol grubu öğrencileri ile deney grubu öğrencilerinin matematiksel modelleme yeterlikleri toplam puanları ile her bir modelleme yeterliği puanları arasında anlamlı bir fark bulunmadığı, birbirine benzer ve düşük düzeyde olduğu görülmüştür. Benzer sonuçları alanyazında hem ortaokul öğrencileriyle (Biccard & Wessels, 2011; Genç & Karataş, 2017; Şeker, 2019; Tekin Dede, 2015; Yurtsever, 2018) hem de öğretmen adayları ile (Çakmak Gürel, 2018; Duran vd., 2016; Karacı, 2016) yapılan çalışmalarda görmek mümkündür.

Eğitim süreci öncesine yönelik ön görüş formunda yer alan matematik derslerinde daha önce modelleme etkinliklerinin uygulanıp uygulanmadığına ilişkin deney grubu öğrencilerinin görüşlerine bakıldığında; modelleme problemlerinin öğretmenler tarafından hiç kullanılmadığı, modelleme problemlerine öğrencilerin hiç rastlamadıkları ve matematiksel modelleme hakkında bilgi sahibi olmadıkları söylenebilir. Alanyazında incelendiğinde benzer sonuçlara rastlanmaktadır. Örneğin öğretmen adayları ile yapılan farklı çalışmalarda (Çiltaş & Işık, 2013; Özer Keskin, 2008) katılımcıların matematiksel modelleme ve problemleri hakkında bilgi sahibi olmadıkları görülmüştür.

Deney grubu öğrencilerinin modelleme yeterliklerine ait nicel verilerin analizinde ön test-son test modelleme yeterliklerinde doğrulama yeterliği hariç diğer tüm yeterliklerde son test lehine anlamlı fark oluştuğu tespit edilmiştir. Öğrenme süreci sonrasına ait nicel veriler incelendiğinde kontrol ve deney gruplarının matematiksel modelleme yeterliklerinde istatistiksel olarak deney grubu lehine anlamlı bir iyileşme tespit edilmiştir. Deney grubunun son test-ön test nicel verileri karşılaştırıldığında ise öğrencilerin modelleme yeterliklerinin doğrulama yeterliği hariç diğer tüm yeterliklerde son test lehine anlamlı fark oluştuğu saptanmıştır. Benzer sonuçları alanyazındaki çalışmalarda da görmek mümkündür. Sol vd. (2011) yapmış oldukları çalışmalarında katılımcıların modelleme problemlerini çözerken farklı aşamalarda zorlanmaları yanı sıra doğrulama basamağında da zorluk yaşadıklarını belirlemişlerdir. Tekin Dede ve Yılmaz (2013) ise öğretmen adaylarıyla yürütmüş oldukları araştırmada katılımcıların özellikle yorumlama yeterliğinde yetersiz kaldıklarını belirlemişlerdir. Öğretmen adayları ile yapılan bir başka çalışmada (Kaya & Keşan, 2022) öğretmen adaylarının gerçek hayat probleminde matematiksel sonuçların yorumlanmasında ve sonuçların uygunluğunun doğrulanmasında zorluklar yaşadıklarını görmüşlerdir. Yapılan farklı araştırmalarda ise genellikle modelleme yeterliklerinde daha güçlü olmalarına rağmen, yorumlama ve doğrulama yeterliklerinde eksiklikler olduğu saptanmıştır (Baran Bulut & Türker, 2022; Biccard & Wessels, 2011; Greefrath & Siller, 2017; Korkmaz, 2010). İncelenen araştırmalara göre, genel olarak yorumlama ve doğrulama yeterliklerinde bir gelişim zorluğu olduğu belirtilebilir.

Araştırmanın sonuçlarına dayanarak, araştırmacılara ve uygulayıcılara çeşitli önerilerde bulunulabilir. Matematiksel modellemenin, öğrenci görüşlerine, matematik becerilerine ve farklı disiplinlere olumlu katkıları göz önüne alındığında, matematiksel modelleme etkinliklerine düzenli olarak yer verilmesi gerektiği önerilmektedir. Ayrıca, her bir alt yeterliğin ayrı ayrı gelişimine odaklanan yeni çalışmalara odaklanılmalı ve özellikle doğrulama ve yorumlama yeterlikleri üzerine yapılan araştırmaların sayısı artırılmalıdır.

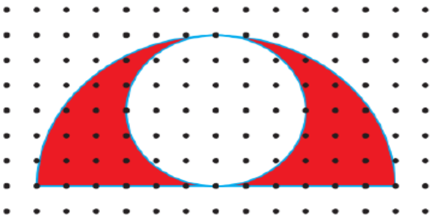
Appendix-1: Sample Modeling Activity and Daily Lesson Plan

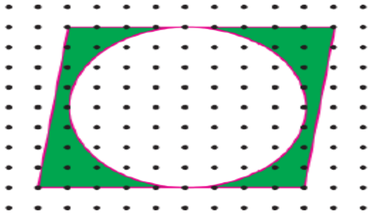
Course	Mathematics Applications Course
Class	Seventh Grade
Duration	80 min.
Learning Areas	Geometry and Measurement; Numbers and Operations
Sub-Learning Areas	Circle and Circular Region, Ratio and Proportion
Skills	Modeling, Problem solving, connection, communication, reasoning
Methods And Techniques	Mathematical modeling, question and answer, problem solving, brainstorming, discussion, estimation strategies, presentation, lecture.
Outcomes Related to The Mathematics Course	Mathematics:7.1.4.1. When one of the two multiplicities is given to each other, it finds the other. 7.3.3.3. Calculates the area of the circle and the circle segment.
Outcomes Related to The Related Course(s)	Social studies: 6.2.2.1. Makes inferences about the changing features of the map when the scale changes by using maps drawn at different scales. 7.5.1. Explain the importance of soil in production and management with examples from history.
Tools & Materials	Mathematical modeling activity, smart board, video clip, Google Earth program.
Objective Of the Activity	This modeling task aims to help students grasp the significance of our agricultural lands within the context of the social studies lesson. It seeks to establish connections between the topics of maps and scales in social studies and the concepts of ratio-proportion and area topics in the mathematics. The purpose of giving it as a modeling problem is for the student to assume the area of an irregular region as a regular shape and to produce a solution to the problem. Thus, the student is expected to realize that the approximate value of the area can be calculated by converting irregular shapes into regular shapes.
Application Process of The Activity	After the students are divided into upper, middle and lower groups according to their mathematics achievement, the activities will be distributed after they are divided into groups of three, one student from each level, and the students will be asked to read the article part of the activity and focus on the photo. Brainstorming will be done in the classroom about the modeling sub-problems in the activity, and the incomprehensible parts will be tried to be found by the teacher with questions. After the sub-problems are discussed step by step, students will be given time to write their thoughts and solutions as a group on the activity sheets.

Preparatory Work (20 Minutes):

Presentations of students on board work and homework are taken for the research topics given from the previous week. Studies are carried out for the readiness of the students.

- Do research on the history and importance of Hevsel Gardens and turn it into a panel study.
- Prepare sample problems and solutions related to the area of the circle and the circle segment. Share it with your friends.
- Research the units of measurement of length.
- Find the areas of the scanned regions below.
- Calculate the areas of the shaded regions in the figures above. (Take $\pi = 3$)

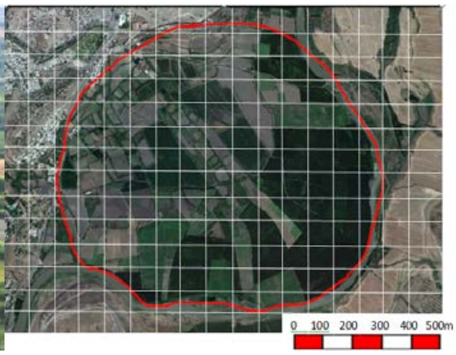




Activity Application (40 Minutes):

Worksheets will be distributed, and the problem will be solved in accordance with the steps.

<u>HEVSEL GARDENS</u>



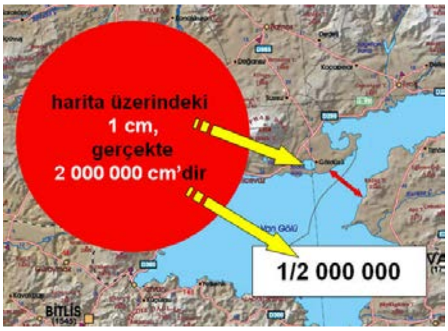
In the photos above, there are two photographs, one of which is a bird's eye view, of the Hevsel Gardens on the banks of the Tigris River, which is included in the World Heritage list by UNESCO. Hevsel gardens exist as a garden with a history of 8 thousand years, but also maintain their originality agriculturally, culturally and historically. Adhering to the photo and scale above, calculate approximately how many acres the Hevsel Gardens are.

1) Interpret what is given to you and what is asked of you by expressing the problem in your own words.
2) Make up your own assumptions about the problem.
3) Explain how you will follow a mathematical path in solving the problem.
4) Solve the problem according to your assumptions.
5) Write your comments on the result of your solution.
6) Verify your solution.
7) What do you think is the relation of this problem with your following lessons? Please explain.
• Relationship with social studies:

Evaluation Study (20 Minutes):

After the activities are collected, 1-2 students who volunteered for the modeling problem will be asked to make a presentation about the solution of the activity. Then, in the presentations made about the activity, questions will be directed by the teacher to produce different solutions to the sub-problems of modeling. In addition, a short video about Hevsel Gardens and its history will be watched by the teacher, and various pictures and Google Earth program will be used to connect the subject of scales with the Social Studies lesson.

• Check out the scales in the images below. Explain how it relates to the topic of proportion and your social studies lesson.



Appendix-2: Preliminary Opinion Form

1. Have you ever solved problems in your math classes that could be solved according to your assumptions, some of which were not given? If you have solved it, explain it with concrete examples.
2. If you were given problems in your mathematics lessons that could be solved according to your assumptions, some of which were not given, how would you solve them? Explain your thinking with concrete examples.

Appendix-3: Final Opinion Form

1. How important is it to solve problems that can be solved according to your assumptions (problems given in the form of activities in mathematics applications course) that some information is not given in your mathematics lessons? Explain your opinion with justifications. Give concrete examples.
2. Did the problems given in the form of activities in the mathematics applications course contribute to your mathematics lesson? Explain your opinion with justifications. Give concrete examples.
3. Would you like the problems given in the form of activities in the mathematics applications course to be used in your lessons? Explain your opinion with justifications. Give concrete examples.
4. Do you think there are any negative aspects to these problems? If so, what are they? Explain your opinion with justifications. Give concrete examples.
5. What are the similarities and differences between these problems and the problems you have seen before? Explain your opinion with justifications. Give concrete examples.
6. When you encounter similar problems in daily life or in your lessons, do you believe that you can solve them by applying the sub-steps given in the problems? (Will you follow the steps in the problems given in the form of activities in the math applications course? How?). Explain your opinion with justifications. Give concrete examples.