Comparing the Learning Environments Related to Mathematical Modelling Through Distance Education

Demet DENİZ YILMAZ
Muş Alparslan University
d.deniz@alparslan.edu.tr

Zeynep ÇAKMAK GÜREL
Erzincan Binali Yıldırım University
zcakmak@erzincan.edu.tr

Meryem ÖZTURAN SAĞIRLI
Erzincan Binali Yıldırım University
msagirli@erzincan.edu.tr

This study aims to compare two different learning environments designed online in terms of their contributions to developing mathematical modeling competencies. A triangulation research method was employed in the research. In this method, qualitative and quantitative research methods are used together. The participants consisted of 53 fourth-class pre-service teachers studying at a university's mathematical teaching department. While the quantitative data were analyzed with the paired samples t-test and Wilcoxon test, the qualitative data were analyzed with the content analysis. As a result, while a significant difference was found in favor of the post-test between the modeling competencies of the pre-service teachers who attended the distance education in groups, the modeling competencies of the pre-service teachers who attended individually did not differ. In addition, it was observed that the participants who attended individually had difficulty expressing themselves throughout the process. It was determined that those who worked with groups tried to verify their results more modeling than those who participated individually.

Keywords: Mathematical modeling, distance education, pre-service teachers, group working, individual working

Introduction

Digitalization in education has become more important in recent years due to the Covid 19 pandemic, which affected the world between 2019-2020. To ensure continuity in education since the epidemic, all the countries in the world applied distance education platforms (i.e, Basilaia & Kvavadze, 2020; Toquero, 2020) such as television, webinars, and videoconference. In a short time, the positive and negative sides of these platforms were begun to be discussed in the literature (Balaman & Tiryaki, 2021; Bakker & Wagner, 2020; Mailizar et al., 2020; Sarı & Nayır, 2020; Zaharah & Kirilova, 2020). Aside from its positive or negative aspects, the education and training activities provided only with distance education during the pandemic offer an unprecedented experience for researchers (Mailizar et al., 2020). The results that will be reached are significant in turning distance education into an opportunity (Basilaia & Kvavadze, 2020).

After the pandemic, it is necessary to reevaluate mathematics education in terms of theoretical and pedagogical aspects and introduce a viable system (Khirwadkar et al., 2020). Online applications that will be developed in mathematics education will inevitably address the skills in the mathematics curriculum. Mathematical modeling was first included, as a skill, in the middle school mathematics curriculum revised in 2017, in Turkey. Mathematical modeling, which is regarded as the skill of finding solutions to real-life problems through mathematics (Ministry of National Education [MoNE], 2017) has gained momentum in mathematics education (Asempapa & Brooks, 2020).

Mathematical Model and Modeling

Mathematical models are the conceptual systems referred to with the external display formats (Greefrath & Vorhölter, 2016) and are used to explain, describe or configure real-life situations (Lesh & Doerr, 2003). With this definition, mathematical models are the conceptual structures that represent much more than an external representation (e.g. equations, graphs, algorithms, tables, words) (Czocher, 2018). On the other hand, mathematical modeling is described as the process of forming a mathematical model of a real situation (Sriraman, 2006). According to Blum and Borromeo Ferri (2009), mathematical modeling is a bidirectional transformation process between the real and mathematical worlds. Many researchers define mathematical modeling as cyclic (Blum & Leiß, 2007; Borromeo Ferri, 2006; Schaap, Vos & Goedhart, 2011). According to the modeling cycle by Blum and Leiß (2007), this process is defined in six stages. These are real situations, situation models, real models, mathematical models, and real results. In addition, the modeling sub-competencies in which the transfer between these stages is provided are defined. These are understanding, simplifying or structuring, mathematizing, working mathematically, interpreting, validating, and presenting. First, individuals read the real situation (problem or task) and construct the situation model. A real model emerges when the situation model has been structured and simplified with extra mathematical knowledge. In the mathematizing process, the real model turns into the mathematical model. The solution process of the mathematical model is carried out using mathematical tools. The mathematical result obtained at the end of this process is interpreted into the real world, and real results are reached. The last stage is to validate these results and ensure their validity. The basic question is, "can the results reached apply to the real world?" Finally, the accuracy of the obtained model is verified, and the result related to the real problem is presented (Blum & Leiß, 2007; Borromeo Ferri, 2006). Developing these sub-competencies is one of the significant fields in recent years (Brand, 2014; Grünewald, 2012).

Development of Mathematical Modeling Competencies

Several learning environments were designed to develop the modeling competencies in the literature. One of these learning environments is based on the holistic and partial approach-based learning environments (Blomhøj & Jensen, 2003). While the modeling competencies aim to be developed simultaneously in the learning environment designed according to the holistic approach, in the partial approach, the learning environment is organized at different times with a focus on developing specific competencies (Grünewald, 2012). That the modeling competencies are significant in both approaches is suggested in the literature (Brand, 2014; Kaiser & Brand, 2015). Besides, one of the learning environments designed to develop the modeling competencies is to present the students with a solution plan that consists of the modeling stages (e.g., Beckschulte, 2020; Durandt & Lautenbach, 2020; Schukajlow et al., 2015). It has been found that the solution plan applied in these studies is significant in developing their modeling competencies. Another way to develop modeling competencies is through groupwork and cooperation (Biccard & Wessels, 2011; Maaß, 2006). The literature reports that groupwork supports the modeling competencies more than individual studies (Delice & Taşova, 2011).

The development of online learning environments or modules for mathematical modeling is recent (Geiger et al., 2018). The pandemic illuminated the need to investigate online mathematical modeling education and to support the development of students' modeling competencies in distance education (Schonbrodt, Wohak, & Frank, 2022). Developing, applying, and researching online mathematical modeling activities is significant. Most modelling competencies studies were conducted in a face-to-face education environment until the pandemic. The adoption of distance education to develop modeling competencies has gained popularity, particularly in response to the pandemic. This study investigates the effects of individual and groupwork in online environments on mathematical modeling competencies. An online learning environment was designed to develop mathematical modeling sub-competences. This study aimed to compare two online learning environments about mathematical modeling. Thus, it hopes to contribute to the spread of mathematical modeling education through online learning environments. In this context, creating and comparing exemplary online learning environments is very valuable.

The online learning environments created for mathematical modeling education in this study adopt the idea expressed by Johnson & Johnson (2014), “Technology does not have to isolate and separate students. When technology is used effectively, it can bring students together in collaborative work and improve student experiences” (p, 3) In one of the learning environments, online groupwork is done in the context of collaborative learning. In this environment, students can communicate with each other and the teacher, the teacher can easily see how the students are coping, and group discussions can be held (Schonbrodt, Wohak, & Frank, 2022). Another online learning environment is designed to support students’ modeling competencies individually. Revealing the differences and similarities between the two environments will contribute to the mathematical modeling literature.

Therefore, this study aims to compare the contribution of the two different online learning environments designed to develop mathematical modeling competencies. According to this purpose, these research questions were asked:

1. Is there a significant difference in the modeling sub-dimensions of the pre-service teachers working in groups or individually in the online learning environment?
2. How do the perceptions of modeling sub-competencies of the pre-service teachers working in groups or individually in the online learning environment change throughout the modeling activities?
3. What are the opinions of the pre-service teachers working in groups or individually about the online learning environment created related to their modeling sub-dimensions?

Methodology

The Study Design

This research investigated the effect of these methods, applied to the pre-service mathematics teachers studying at the fourth class and getting the mathematical modeling course through distance education. Also, the opinions of the pre-service teachers were tried to be determined. For the research method, the triangulation research method, which is one of the mixed research methods in which the quantitative and qualitative research methods are used simultaneously, was used (McMillan & Schumacher, 2006). In this design, the quantitative and qualitative data of the research are collected at the same time. The weight of the collected data (quantitative and qualitative) in the research is equal (Creswell & Plano-Clark, 2007). This method allows using two or more methods that support and integrate each other. Thus, it is an application that aims to enrich the method. Many quantitative and qualitative data collection tools can be used while diversifying data (Creswell & Plano Clark, 2018). This makes it possible to use qualitative methods such as interviews, observations, and examination of records, as well as quantitative tools such as questionnaires and scales in the same study (McMillan & Schumacher, 2006).

The quantitative part of the research has the characteristics of experimental research without a pre-test post-test control group. In one of the groups, the mathematical modeling course was carried out with the group, and the mathematical modeling course was carried out individually in the other group. At the end of the process, the effect of these practices on the achievements of the groups in their mathematical modeling test was explored. In the qualitative part of the research, the participants' opinions were handled after each mathematical modeling problem was applied to both groups during the study process and with the forms applied at the end of the implementation process. The triangulation method aimed to determine whether the data support each other using the obtained findings from both methods.

The Study Group

In this study, the study group consisted of 52 (31 participants participated in the groupwork, 21 individually) pre-service secondary school mathematics teachers. They were in their fourth year of study at the faculty of education at two universities in two different medium-scale provinces (by population) in the east of Turkey. A purposeful sampling technique was used to determine the reachable participants during the pandemic. The research was carried out in the fall term of the 2020-2021 academic year. This process coincided with the time at which all of the higher education institutions in the country were continuing their activities with online education. Each university continued its education-teaching activities through distance education infrastructure or different opportunities in this process. In both universities where we conducted our research, the courses were given in line with the lessons determined by the Higher Education Council for the Education Faculties undergraduate programs and the contents determined for these courses. In this sense, the readiness levels of the participants were assumed to be the same. The average age of the participants was 22. The pre-service teachers have participated in the courses (i.e., algebra, arithmetic, statistics) in the mathematics field and courses (problem-solving, material development, teaching methods) related to mathematics education for four years. They first came across mathematical modeling within the scope of this study. Pre-service teachers have similar academic backgrounds. Some randomly selected pre-service teachers worked with modeling activities individually, and others as a group.

Implementation

The research was carried out during a one-term period in which mathematical modeling courses were conducted in both universities. In the conducted research, in the group (G group) in which the mathematical modeling course was carried out, the system provided by the university with the distance education infrastructure was used. This system has the characteristics that will enable the students to meet with the course instructor at the same time every week at the pre-planned time on the online platform, where their attendance is obligatory, and communicate with audio and video within 90 minutes. It also lets one record the online courses and watch them again after the class. In addition, the students can work in groups online by dividing them into rooms thanks to the system. Besides, the system allows the groups into groups according to their wishes and to be included in the rooms with their group members. The groups determined in the first week stayed the same until the end of the term. One of the system's advantages is preventing communication between the groups. While the course teacher periodically visits the room where each group is located on the online platform, the teacher does not assist the groups in the process. The reason for visiting the rooms is to check the groups' work and keep their motivation high. Finally, one week of duration was given to the students to prepare their reports on the modeling activities and write reflective diaries. They were asked to upload them to the homework folder on the system. In the group (Group I) where the individual mathematical modeling course was carried out, Google Classroom, a virtual classroom application, was used. Through this, the course teacher opened the classroom, organized a weekly online meeting, uploaded assignments and notes, and ensured all participants could reach them. Besides, although the teacher tried to provide the opportunity for audio and video conversations with the students through Google Meet, the pre-service teachers in this group could not attend the education simultaneously since they had problems with computers, communication tools, and internet access. The course teacher tried to help the participants watch class videos by recording them.

During the data collection process, as is presented in Table 1, the participants were informed about the meanings and types of the model, modeling, mathematical model and mathematical modeling terms, and the design principles of model-building activities; the mathematical modeling process was exemplified on a mathematical modeling process. Group I tried to solve the mathematical modeling problems given after the first seven weeks, until the next lesson according to the solution plan, and uploaded their solutions to the relevant homework folder in the Google Classroom. A solution plan in which the mathematical modeling stages was offered to the participant in Group I. The course educator informed the pre-service teachers about the research's purpose, content, and application process and gave the necessary explanations. The educator who worked with the groups divided the participants into six groups of five or six members each in the first week of the application. In addition, the participants were informed about the meanings of the model, modeling, mathematical model, and mathematical modeling terms, and the modeling process was exemplified on a mathematical modeling problem. Next, the course educator gave the students a mathematical modeling problem and asked them to study it for a week. The participants were responsible for contacting their group members during the process, carrying out the mathematical modeling process with the group's help, and uploading their solutions to the system before the course. The participants in Group G were not asked to solve the modeling problems according to the solution plan.

The information related to the implementation of the application and course content is as follows:

Table 1
Information About the Implementation

Study Process	G group and I group
First Week	Applying the Mathematical Modeling Pre-test
Second Week	What is the meaning of mathematical models and modeling? What are the types of mathematical modeling? Sample activities (How do we store? (Erbaş, et al. 2016)) (The activities in the 2nd and 3rd weeks were solved by the academician and the structure of the modeling problems were introduced.)
Third Week	The cycles in the mathematical modeling process
Fourth, Fifth and Sixth Weeks	Sample mathematical modeling problems
Seventh Week	Model eliciting activities design principles and examples (obesity problem, Tekin Dede and Bukova Güzel, 2013) Applying the mathematical modeling pre-test, implementing the open-ended form
Eighth - Twelfth Weeks	Implementation of the • Insurance Company Problem (Sönmez, 2019)
	• Volleyball Problem (Kaya, 2018)
	• Parking Place Problem (Erbaş et al, 2016)
	• Feeding Problem (Erbaş et al, 2016)
	• Football Problem (Ata Baran, 2020)

Thirteenth Week	Implementation of the Open-ended Form
Fourteenth Week	Implementation of the Mathematical Modeling Post-test, Implementing the Open-ended Form

Data Collection Tools and Collecting the Data

Three types of data collection tools were used in this research. Each data collection tool coincides with the sub-problems of the research respectively. The information related to these tools and their characteristics is presented below.

Mathematical modeling test (MMT)

The MMT was applied to the participants at the end of the implementation process to determine the mathematical modeling achievements of the participants. The MMT is a multiple-choice mathematical modeling test with multiple answers developed by the researchers such as Crouch, Davis, Fitzharris, Haines, Izard, Houston, and Neill in 1991 (Lingefjärd, 2004). The test was translated into Turkish by Kertil (2008), and the validity and reliability of the test were provided. All the MMT under discussion takes place in Kertil (2008). In the present study, the Cronbach alpha reliability coefficient of the test was found as 0.75. The MMT, which was applied as the pre-test, consists of ten open-ended questions. The MMT, which was applied as the post-test, consists of twelve questions. The tests which have been applied as the pre-test and post-test are parallel. If the answers of the pre-service teachers to the mathematical modeling test were correct, they were coded as 2; if they were partially correct, they were coded as 1; if they were incorrect or empty, they were coded as 0. The example related to one of the questions is presented in Figure 1.

4. Consider the real world problem (do not try to solve it!):

What is the best size for bicycle wheels?

Which one of the following clarifying questions most addresses the smoothness of the ride?

A. Are the wheels connected to the pedals by a chain?
B. How tall is the rider?
C. Has the bicycle got gears?
D. How high is the highest kerb that can be ridden up?
E. Does terrain matter?

Figure 1. A Sample problem in MMT

Reflective diaries

To help the participants express their feelings, thoughts, experiences, and opinions related to the problems, each participant filled out a reflective diary related to each problem, so each participant completed five reflective diary forms. The researchers created the questions in the reflective diary by scanning the relevant literature. The questions relevant to this form are presented below.

- What did you think when you first encountered the problem? Did think that you could not solve the problem?
- What did you do to verify the problem after you had solved it? If your solution was incorrect, how did you develop a new solution plan by revising your solution method when you realized that your solution was incorrect?

- Do you think there are other ways to solve this problem? Can you find a different way of solution?

Open-ended form

The researchers' expert opinions were applied to develop the open-ended form used in the pilot study and revised as follows for this study.

- How do you evaluate the mathematical modeling course in the distance education process?
- Do you think individual or groupwork to be more useful in distance education? Why?
- What did you experience solving questions and expressing yourself in the distance education mathematical modeling process?
- What are your recommendations related to the modeling course in distance education?

Data Analysis

SPSS 22.0 was applied to analyze the quantitative data. In the study, the paired samples t-test was used to analyze the data obtained from the participants working with groups. According to Büyüköztürk et al. (2012), the paired samples t-test is used to test whether there is a significant difference between the means of two relevant samples. When the pre-conditions of the pre-and post-tests of the achievement test in the study were examined, it was determined that the data were intermittent. The skewness and kurtosis coefficients between +1 and -1 indicated that the distributions do not deviate excessively from the normal (Büyüköztürk, 2012; Çokluk, Şekercioğlu, & Büyüköztürk, 2012). The participants who conducted the distance education as a group demonstrated normal distribution. However, since the skewness and kurtosis coefficients of the averages of the pre-and post-tests of the modeling test of the participants who conducted the distance education individually were not between +1 and -1, they could not show a normal distribution, and the Wilcoxon test was applied to this group.

The skewness and kurtosis values of the participants' pre-test-post-test scores of the modeling test are presented in Table 2.

Table 2

The Skewness and Kurtosis Values of The Participants' Pre-Test-Post-Test Scores of The Modeling Test

Participants	Tests	Mean	Skewness	Kurtosis
Those participating in the distance modeling in group	Modeling pre-test	7.54	-0.666	-0.687
	Modeling post-test	16.28	-0.59	0.273
Those participating in the distance modeling individually	Modeling pre-test	10.64	-0.286	-0.541
	Modeling post-test	12.56	–2.267	7.658

Content analysis was applied in the analysis of the qualitative data. The data on the reflective diaries and the open-ended form were analyzed separately by each researcher, and a draft code and category list were created. Then the agreement percentage of the analyses was determined. Coding reliability (Miles & Huberman, 1994) was applied, and the coding reliability was found to be 0.85. This indicated that the coding was reliable (Yıldırım & Şimşek, 2011). Experts had reached a consensus on different codes and categories. To hide the participants' identities during the data analysis, the pre-service teachers working individually were identified as I1, I2, and I3, and those who tried to solve the activities in groups were coded as G1, G2, and G3. To increase credibility in the presentation of qualitative data, the participants' views were often included with direct quotations.

Results

The findings related to the first sub-problem as "Is there a significant difference in the modeling sub-dimensions of the pre-service teachers working in groups or individually in the online learning environment?" are presented in Table 3.

Table 3

The Paired-Samples T-Test of The Modeling Test for The Participants Working in Groups

	Modeling Test	$\bar{X}$	t	p
The participants working in groups	Pre-test	7.54	-10.755	0.000
	Post-test	16.28		

The post-test score averages (16.28) related to the modeling test are higher than the pre-test score averages (754) in Table 3. The paired t-test determined that there was a statistically significant difference between the modeling achievement scores of the participants working in groups in distance education in favor of the post-test ($t_{(38)}$= -10.755; p<0.001).

The Wilcoxon test results related to the modeling test of the pre-service teachers working individually are presented in Table 4.

Table 4

The Wilcoxon Test Related to The Modeling Test of The Pre-Service Teachers Working Individually

Modeling Test	z	p
Pre-test	-2.151	0.31
Post-test		

When the results obtained from the Wilcoxon test analysis of the mathematical modeling test related to the participants who attended the distance modeling education individually are taken into consideration, it is seen that there is no significant difference between the pre- and post-test (p=0.31 > 0.05). According to these results, the distance modeling education carried out individually has no significant effect on the mathematical modeling achievements of the pre-service teachers.

The findings related to the second sub-problem as "How do the perceptions of modeling sub-competencies of the pre-service teachers working in groups or individually in the online learning environment change throughout the modeling activities?" are presented below. The participants were asked about what they thought when they first read the modeling problems in the mathematical modeling course given through distance education. The codes, categories, and frequencies obtained from the participants are tabulated in Table 5.

Table 5.

First Responses to Modeling Problems

	Mathematical Modeling Problems

Category	Code	Insurance		Volleyball		Parking place		Feeding		Football	
		I (%)	G (%)	I (%)	G (%)	I (%)	G (%)	I (%)	G (%)	I (%)	G (%)
I thought I would have a problem	It sounded difficult/complicated	29	38	29	13	24	22	29	22	19	-
	Data are big/ much	19	16	-	28	-	3	-	-	-	-
	The way of solution is not clear	5	-	14	6	14	25	5	-	-	-
	I came across first	-	19	10	9	24	6	5	6	-	-
I thought I would do	I've encountered similar ones before.	5	3	-	19	-	6	14	6	5	19
	I got accustomed.	-	-	5	-	24	22	14	22	38	22

A seen in Table 5, the categories “I thought it was difficult” and “I thought I could do it” emerged. Most of the participants of both groups thought they could not solve the problem because of the complexity of the data and the uncertainty of the solution methods. This was an anticipated result, as most pre-service teachers initially find modeling problems difficult and complex, particularly in any first activity (in this case, the insurance problem) compared to the latter activities. (It will be seen in the following activity that many pre-service teachers got used to modeling problems and no longer approached them with bias.)

The pre-service teachers who had encountered the problem situations that took place in the modeling problems claimed that they could solve the problems when they saw them first; on the other hand, those who had no experience with the problem situation stated that they could not solve the modeling activities when they encountered them first. As seen from Table 5, both Group I and Group G stated that they were used to these problems and would be fine with encountering the following mathematical modeling activities.

I13, who thought that s/he could not solve the modeling problems as they seemed complicated at first glance, expressed the in “The Parking Place” problem: *“It seemed extremely complicated to me. I had difficulty understanding the problem and thought I could not solve it. I read several times to understand the problem. But the problem seemed difficult to me*.”

G8, who thought that s/he could not solve as the data in some modeling problems were big/much, claimed for the “Insurance Problem” that: *“There were a lot of variables that I should use to solve this problem and I did not know how to use these variables. I read several times to understand the problem*.”

I3, who thought that s/he could not solve problems when s/he encountered due to the lack of clear solutions for modeling problems, stated these words for “Volleyball Problem”: “*When we saw the volleyball problem first, I had no idea about how to solve the problem.”*

I2, who claimed that s/he had never met such situations stated in the modeling problems and thought that s/he could not solve these problems, claimed for the "Feeding Problem" that: "*When I read the problem first, I had an idea that I could never solve this problem, even make any comment. I had never met such a problem situation before. I search on the net about feeding animals and baits.*"

G24, who thought that s/he could solve the modeling problems when they met the modeling problems first, stated about the "Football Pitch Problem": *"As I was the only male in our group, I spoke immediately, of course, I tried to explain how it was in daily life. After we had thought with the group, we decided to a model close to the real life."*

As they got accustomed to the modeling problems in time, I16, who now thought that they could solve the modeling problems when they first encountered, claimed for the "Football Pitch Problem" that: *"These sorts of problems do not anymore make me afraid as before actually. So, I did not have the idea that I could not solve the problem. I had an idea about the solution immediately in my mind.*"

The participants were asked about what they did to ensure the correctness of solving modeling problems in mathematical modeling courses through distance education, and the obtained codes, categories, and frequencies are presented in Table 6.

Table 6
Validating the Solution

		Mathematical Modeling Problems									
Category	Code	Insurance		Volleyball		Parking Place		Feeding		Football Pitch	
		I (%)	G (%)	I (%)	G (%)	I (%)	G (%)	I (%)	G (%)	I (%)	G (%)
Yes	Suitability With Daily Life	10	38	19	-	10	-	10	6	5	6
	Ask Someone Who Knows	1	-	–	-	24	-	5	-	5	-
	I Completed the Stages of The Modeling Cycle	5	3	-	50	24	-	5	3	5	-
	Verify with Group Joint Decision	-	6	-	-	-	-	-	6	-	16
No	Unable To Create the Model	10	19	5	22	5	9	10	-	5	-
	The Solution Was Not Suitable for The Real-Life	19	-	14	3	19	-	-	-	-	3
	Variability of Results	5	6	-	-	-	-	10	3	-	-
	I Did Nothing to Verify	-	3	19	5	19	34	-	-	-	-

Table 6 reveals that members in Group I consulted with an expert who had information/experience related to the problem situations to validate their results. Notably, Group G members did not reach out to someone who knew related to the problem. In addition, Group G participants verified their results with the group's common decision. Another remarkable result in the table is that the members of Group G controlled their solutions throughout the stages of the modeling cycle. It was also noticed that the participants could not create a model and verify their solutions.

I20, who wanted to verify his/her result to determine the correctness of the solutions for daily use in modeling questions, states these words in the Volleyball problem: "*When I examined the features of some world-famous volleyball players to test the conformity of the problem, I noticed that they had features to support me.*"

I19, who tried to verify the solutions to the modeling questions by asking an experienced person, stated in the Insurance Company Problem, "*I searched for what does an insurance company do and why they do it at the beginning of the question. Then I spoke with my father and my uncle who had information about this topic. They gave me the same answer. Therefore, I can say that I am sure about its correctness.*"

G32, who tried to verify the correctness of the solutions in modeling questions by completing stages of the modeling cycle, claimed in the Football Pitch Problem that: *"We created a model by coming together with the group members and we realized that the same situation occurred all after we discussed with friends."*

G31, who verified the solutions of the modeling problem with the group's consensus, claimed in the Football Pitch Problem that: *"I did not experience much difficulty in solving the problem. I had almost similar thoughts with my friends. We had the same ways of solutions. We developed each other's ideas and solved the problem to reach a definite conclusion."*

Now, to mention the pre-service teachers who could not verify their solution, I15, who claimed that there was no need for verification because s/he could not create a model and s/he thought that s/he would have problems because the results s/he obtained were not suitable for real-life stated for the Parking Place Problem that: *"There were some deficiencies in the model I created because there were some deficiencies for the selection of a parking model so that the data in the problem could be applied in real life. The most significant deficiency was the lack of maneuvering information that could occur in the detection of the vehicle and its operation."*

G23, who claimed that s/he was not sure about the solution as s/he thought that the results were variable due to the occurrence of different solutions to modeling problems, claimed for the Insurance Company activity that: *"I finally realized that by determining this, the solution of the problem changes from person to person. That is, I realized that a modeling question may not have a definitive solution. As a result, I am not sure about my solution.*"

The participants were asked whether they had different solutions to the modeling problems in the online mathematical modeling courses; the obtained code, category, and frequencies are tabulated in Table 7.

Table 7
Having Different Ways of Solution

Category		Mathematical Modeling Problems									
		Insurance		Volleyball		Parking Place		Feeding		Football Pitch	
	Code	I (%)	G (%)	I (%)	G (%)	I (%)	G (%)	I (%)	G (%)	I (%)	G (%)
Possible	But I Don't Know	-	6	48	41	24	13	5	3	5	-

Impossible	Not Enough Mathematical Data	-	-	-	9	-	72	-	-	-	-

Table 7 reveals that the categories “possible” and “not possible” emerged regarding their thoughts of different solution strategies. Most participants stated that the mathematical modeling activities could also be solved in different ways, even if they could not reach the solution. On the other hand, the participants thought there could not be different solutions since there was insufficient mathematical data in modeling activities.

G2, who thought that the modeling problems could be solved in different ways but s/he could not find them, stated these words in feeding problem: *“We tried to find, but we had a hard time at this point, so we stopped the solution here. We thought of different ways of solution, but we couldn't find a different way.*”

G1, who thought that the modeling problems could not be solved in different ways because there was not sufficient mathematical data, expressed for the volleyball problem: *“I think I have problems because there are many variables and there is no mathematical data.*”

Findings related to the third sub-problem “What are the opinions of the pre-service teachers working in groups or individually about the online learning environment created related to their modeling sub-dimensions?” are presented in Table 8.

Table 8
Evaluating The Mathematical Modeling Course in Distance Education

Categories	Codes	I (%)	G (%)
Positive	The Course Is Beneficial Even If It Has Restrictions with Distance Education	23	71
	The Positive Effect of Group Work	-	53
	Gaining Multi-Directional Thinking Skill	-	19
	Understanding, Learning and Being Aware of The Significance of Mathematical Modeling	33	13
	Entertaining, Fun, Enjoyable	-	16
	Research-Examination, Reaching to The Resources, Ease	-	6
Negative	Not Suitable for Distance Education	19	3
	Intense, Tiring, Time-Consuming	-	9

More codes emerged in Group G compared with Group I. 71% of Group G and 23% of Group I thought that the course was beneficial despite the limitations of distance education. In addition, only 3% of Group G and 19% of Group I stated that the course was inappropriate for distance education. Regarding the cognitive effects of the course, participants opined that the course, formal, and material provided multi-directional thinking skills and understanding or learning regarding mathematical modeling. Some opined regarding affective dimensions, such as building a positive attitude towards the problems and the problem-solving process. Some claim that distance education has more significant opportunities to access resources, research, and review.

G28, who thought that, despite its limitations, distance education was beneficial and group work had a positive effect, claimed these words: *“I think that mathematical modeling* *course had contributed much to me although I had taken it through distance education. Even though we did not solve the problems in group rooms, we used to try until we solved the problem through Google meet, and there was no time limitation, either. So, if we had received face-to-face training and had not been able to finish the solution in class, we would not have been able to come together this much."*

G16, who thought that the mathematical modeling courses were productive although they were provided with distance education, gained a different point of view and that s/he could understand, learn, and realize the importance of mathematical modeling, claimed that: *"It was a productive course although it was distance education. With the help of this course, I learned what mathematical modeling was. When I selected this course, I thought we were going to design a concrete model."*

G14, who claimed that s/he had positive thoughts since the distance of the mathematical modeling courses provided the opportunity and convenience of research examination and access to resources, claimed that: *"Of course, it is necessary not to overlook the possibilities offered by the digital environment. One of the positive aspects was that we were able to reach the questions from the primary source and had a good grasp of the details both visually and in writing."*

Some participants claimed that the mathematical modeling courses carried out online were tiring, time-consuming, or negative in reaching superficial solutions. For instance, I14 expressed: *"Since the process (pandemic) and the problems to be applied were not given enough space, random solutions were reached."*

Findings related to the question, which is more beneficial in distance education, individual/group work, are presented in Table 9.

Table 9
The Evaluation of The Question, which is More Beneficial in Distance Education, The Individual or Group Work

Categories	Codes	I (%)	G (%)
Individual Useful	It Is Pandemic Time (Communication Problem)	29	-
	Group Work Is Not Appropriate to The Distance Education	10	-
Group Work Useful	Enables Different Viewpoints	32	75
	Enabling Us to Express Ourselves Better	-	3
Both Should Be	Individual Work Develops, Group Work Enables Different Viewpoint	10	-

The answers by the participants to the question, do you want to take the mathematical modeling course in distance education individually or with groupwork are presented in Table 9. Group G argued that carrying out the course in a group enabled bringing different opinions together. Group I thought the course should be carried out individually because of the communication problems due to the pandemic. 10% of the Group I claimed their work was inappropriate for distance education.

I11, who claimed that s/he preferred individual work as communication could be experienced during the pandemic, stated: *"I think that the mathematical modeling course should be processed and evaluated individually in these difficult days. Because, in this process, during the group work, our communication can be cut off, some students have no internet connection, or when group work is held, every member may not take equal responsibility, for instance, when the task is distributed as group work, some can have their* *brothers and sisters do it, or one may say that s/he doesn't want the duty or wants another, this brings a serious problem."*

I21, who found it appropriate to work with a group since it allowed them to provide different perspectives in mathematical modeling courses carried out with distance education, claimed, "*I believe that the mathematical modeling course will be more productive with group work certainly. Because I think that group work is much more efficient and necessary to develop different ways of solution, correctly understand a modeling way that we sometimes never thought of or an activity that we misinterpreted in a wrong way."*

I18, who thought that the mathematical modeling course through distance education should be given both with the group and individually, stated, "*I think both methods are useful. Because for group work, the questions depend on interpretation, they are the questions that everyone can solve in different ways, so the most logical and correct result is reached in group work but our viewpoint on mathematics has changed a lot, as we solved the problem ourselves in individual work and moved forward with our ideas, I think our thinking power has increased."*

Findings obtained from experiences in reaching resources in the distance education mathematical modeling process are presented in the table below. The categories and codes obtained when the participants were asked about what they experienced in problem-solving and expressing themselves during the mathematical modeling process in distance education are presented in Table 10.

Table 10

Problem Solving and Self-Expression During the Mathematical Modeling Process in Distance Education

Categories	Codes	I (%)	G (%)
No Problem	Ability to express oneself	-	42
There Are Temporary Problems	Overcoming problems over time	48	39
There Are Problems	Thinking That There Is a Deficiency in Self-Expression	52	16
	Experiencing Internet-Caused Problems	-	3
	Problems do not have a single solution	-	3
	Difficulty In Expression Due to Working with A Group	-	3

The participants' answers to the question "What did you experience in solving questions and expressing yourself in the distance education mathematical modeling process?" are presented in Table 10. Some participants, who claimed that they had difficulty in problem-solving at the beginning of the course and could not express themselves, stated that they overcame this in time. 52% of Group I and 16% of Group G claimed they could not overcome the problems mentioned throughout the process. These participants stated that they had problems arising from group work, internet-based, and problems arising from not having a single solution. While 42% of Group G claimed that they did not have any problems with the relevant topics, this code emerged in Group I.

G27, who thought that s/he could express him/herself since s/he she was approved by the group she was in during the mathematical modeling process in distance education, stated that: "*As my opinions that I put forth during our group work were approved by my friends and there was equality in my group, I think I expressed myself."*

I12, who thought that s/he felt deficient in the process of mathematical modeling in distance education and expressing her/himself, expressed his/her thoughts as follows: *"I had difficulty in expressing myself because it was a course that I was not used to. I did not know any answer, even though I could express myself verbally, I could not reflect myself as in the face-to-face education."*

The categories, codes, and frequencies obtained when the participants were asked what their suggestions were about the mathematical modeling course through distance education, are shown in Table 11.

Table 11

The Evaluation of The Question "What Are Your Recommendations Related To The Modeling Course In Distance Education?"

Categories	Codes	I (%)	G (%)
Recommendations for the group work	Group work is necessary	38	
	Changing of group members every week		10
	Discussing solutions with all groups		3
Recommendations for implementations	Resource support	5	14
	Having more detailed instruction for the course	-	14
	Educator guidance should be provided	10	-
	Presenting the problems with long intervals	-	3
	The distance education system should be improved	-	3

The participants' answers to the question "What are your recommendations for the mathematical modeling course in distance education?" are presented in Table 11. Notably, 38% of the participants working individually claimed it should be done with group work. Additionally, recommendations emerged about the course educator, course resources, and how to implement the course.

G16 refers that the group members changed every week: "*The groups we formed to solve problems might change every week. Thus, we have seen different ways of thinking. We could also see how other groups solved the problems in the course. Hence, we could also see the different ways of solutions."*

G4, who recommended that the distance education system be improved, claimed that: "*Most of the suggestions that I think of are related to the development of the system. For instance, it would be very useful if there was a feature where we could upload our notes during the lesson and see our instant drawings. We used to solve our problems through WhatsApp in most of this process. We used to do our homework during the course time generally but writing them took our time much."*

Discussion

In this study, pre-service teachers participating in an online mathematical modeling course are compared in terms of how they participated. It was found that while there was a significant difference in favor of the post-test in the modeling competencies of the pre-service teachers participating in the distance education in groups, the modeling competencies of the pre-service teachers participating individually did not differ. This may be because the pre-service teachers developed critical and analytical thinking skills while working in a group (Sofroniou & Poutos, 2016), and the groups developed alternative strategies and solutions (Mumford et al., 2001).

While the literature suggests that the use of a solution plan in the modeling process is a powerful tool in developing modeling competencies (Beckschulte, 2020; Durandt & Lautenbach, 2020; Schukajlow et al., 2015), Group I solving the problems according to a solution plan demonstrated less growth compared to Group G who did not employ a solution plan. This result can be interpreted in two aspects. First, while the studies in the literature use a solution plan, they also enable students to work in groups (e.g., Durandt & Lautenbach, 2020; Schukajlow et al., 2015). This study may suggest that working with a group in conjunction with following a solution plan is more effective in developing modeling competencies. Second, working with a solution plan in distance education may have a negative effect on modeling competencies.

When the pre-service teachers initially encountered the modeling problems, they thought they could not solve them because the problems were complicated, often included a large amount of data, and produced uncertainty regarding solutions. This is also true in face-to-face educational formats. For instance, even in face-to-face modeling activities, pre-service mathematics teachers claim that they could not understand the long questions, that the questions were complicated and contained too many variables, that they could not find the clues as in traditional mathematical problems, and that there were uncertainties in the problems, solution strategies, and solutions (Eraslan, 2011; Karalı, 2013; Korkmaz, 2010).

Consistent with the findings of others (e.g., İncikabı, 2020; Karali & Durmus, 2015; Kertil, 2008), pre-service teachers who initially struggled when they encountered modeling problems gained experience, confidence, and ability when later encountering similar problems. Niss and Blum (2020) believe that experiences gained in mathematical modeling processes will help students deal with non-mathematical situations they will encounter. Therefore, we opine that pre-service teachers should have increased experience in modeling applications (Cetinkaya et al., 2016).

It was seen that the verification methods of the pre-service teachers working individually and in groups differed. Preservice teachers working with the group put more effort into verifying their results. This may be due to their opportunity to validate results by discussing them among the group. Unfortunately, the pre-service teachers working individually attempted to verify their solution and work by consulting more knowledgeable people with experience.

Participants working in groups considered the suitability of the results to daily life to a greater extent compared with those who worked individually and completed the steps of the modeling cycle. Thus, it had a more positive effect on creating a mathematical model than working individually. Participants who did not verify their solutions could not create a model because the results were inappropriate for real life.

Most of the participants, particularly those working as a group, stated that mathematical modeling activities can be solved differently. This result was expected because pre-service teachers working in groups can bring together different ideas during the modeling process and realize different solutions.

Many of the pre-service teachers evaluated the distance education mathematical modeling course as good and beneficial, despite the limitations of distance education. Remarkably, the participants working in a group were more positive than those working individually. Studies have suggested that individuals find group learning more fun and enjoyable (Sofroniou & Poutos, 2016). In Wang et al. (2021), participants argued that social support had become much more significant during the pandemic and that virtual work with social support was more productive. On the other hand, only participants who worked independently claimed that the course was inappropriate for distance education. This originated from the deficiency to discuss problems or exchange ideas with others.

Participants who worked in a group stated that conducting more distance education with groups would be beneficial. On the other hand, those who worked individually stated that distance education taken individually would be more beneficial. Most often, when participants working individually thought that groupwork was inappropriate for distance education, their dubious workstyle, poor study habits, technological challenges (e.g., rural living, limited internet access), and their opinion that not everyone could contribute equally during the pandemic process were probably causal. Some of the pre-service teachers who participated individually suggested that the modeling course through distance education should be carried out as group work.

Some participants in both groups stated they had difficulties solving problems at the beginning of the lesson and modeling. They claimed that they made progress in this regard in time. However, many who participated individually could not overcome the problem of self-doubt during the process. Conversely, those who work in a group learn to communicate with each other, analyze, solve problems, overcome conflicts that may arise between them, and share information in modeling education through distance education (Blazheska-Tabakovska & Januseva, 2009).

Conclusion and Recommendations

Designing online learning environments in the form of group work in mathematical modeling education is important for developing modeling competencies. This study's qualitative and quantitative findings showed that online groupwork supported the modeling sub-competencies. This result coincides with the understanding that groupwork is also effective in face-to-face environments. Herein, pre-service teachers gained belief in solving the modeling problems, thanks to their experience in online modeling.

Modeling education, whether face-to-face or through distance education, does not prevent participants from recognizing relationships between mathematics and daily life. In this study situated in distance education, participants attempted to verify their strategies and solutions more than is often seen among students in face-to-face modeling situations. Interestingly, those who participated in a group tried to verify their results more than those studying individually. To reach more accurate results in the modeling process, participants working in groups should be encouraged to reach solutions by consulting with people who know real-life data.

Although most of the pre-service teachers stated that they were satisfied with the modeling education through distance education, they stated that they had some difficulties, such as the inability to express themselves, being unable to solve problems, and noting that the situation was tiring and time-consuming. These results were parallel with the study by Aversi-Ferreira et al. (2021) related to modeling education through distance education. Aversi-Ferreira et al. (2021) argue that students lack experience in online mathematical modeling and face difficulties in self-directed learning. To overcome these difficulties, considering the demands of the pre-service teachers for detailed instruction regarding the modeling process, the instructions about the activities can be unambiguous in future distance education modeling situations. Attention should be paid to creating the infrastructure suitable for distance implementation before starting the distance modeling process.

Groupwork made the process easier in the modeling activities conducted through distance education. In distance education modeling activities, learning environments should be created where students can act simultaneously in group work, share instant solutions, share social interaction, and contribute equally.

Limitations

The participants of this study are restricted to fourth-year students in the Secondary School Mathematics Teaching Department of the two different universities. Applications were carried out to the study groups by researchers experienced in mathematical modeling. This study uncovered some important information on how mathematical modeling courses through distance education affect pre-service teachers' learning experiences. The results obtained are expected to help guide education decision-makers for future quarantine situations. There is a need for more applications related to teaching mathematical modeling through distance education in future studies.

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