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Mathematical Modeling in Online Learning Environments: Student Challenges*

Çevrim İçi Öğrenme Ortamlarında Matematiksel Modelleme: Öğrenci Zorlukları

Mustafa ALTUNTAŞ[1], **Zeynep Sonay AY**[2], **Ibrahim ÇETİN**[3]

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Abstract: This research aims to examine the difficulties encountered by secondary school students in the mathematical modeling process applied synchronous in online learning environments (OLEs). The research was conducted on 11 8th grade students (8 girls, 3 boys) studying in a public secondary school in Türkiye, using the case study method, by recording audio and videos for 6 weeks. Participants worked collaboratively within a group to complete various problems using the Dynamic Mathematics Software (DMS) GeoGebra. The themes that students had difficulty with in the Online Mathematical Modeling (OMM) process were determined as technical difficulties, access to information and reliability, limited view, shared tasks, limited interaction, time management and time constraints. Using digital tools and instruments in the modeling process offers many advantages to students, however it can also create technical problems. Conspicuous difficulties encountered in the Mathematization and Working Mathematically process is noted, particularly in relation to the DMS. In addition, it was found that the difficulties encountered by students while obtaining information from different sources sometimes negatively affected their solution suggestions. Limitations about the students' interactions with their peers, teachers, and technology during the OMM process caused various difficulties in the stages of the modeling cycle. Future research should focus on developing methods to increase students' interaction and collaboration in OMM processes by overcoming technical difficulties.

Keywords: Mathematical Modeling, Online Learning, Challenges, GeoGebra

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Öz: Bu araştırmanın amacı, çevrim içi öğrenme ortamlarında (ÇÖO) eş zamanlı olarak gerçekleştirilen matematiksel modelleme sürecinde ortaokul öğrencilerinin karşılaştığı zorlukları incelemektir. Türkiye'de bir devlet ortaokulunun 8. sınıfında öğrenim gören 11 öğrenci (8 kız, 3 erkek) üzerinde durum çalışması yöntemiyle gerçekleştirilen bu araştırma, 6 hafta süresince ses ve görüntü kaydı alınarak yürütülmüştür. Katılımcılar, çeşitli matematiksel modelleme problemlerini grup iş birliği ile dinamik matematik yazılımı (DMY) GeoGebra kullanarak tamamlamışlardır. Bu bağlamda, öğrencilerin modelleme sürecinin hangi aşamasında ne tür zorluklarla karşılaştıkları detaylı bir şekilde ele alınılarak incelenmiştir. Çevrim içi matematiksel modelleme (ÇMM) sürecinde öğrencilerin zorlandıkları temalar; teknik zorluklar, bilgi erişimi ve güvenilirlik, sınırlı görünüm, görev paylaşımı, sınırlı etkileşim, zamanlama ve süre kısıtlamaları olarak belirlenmiştir. Modelleme sürecinde dijital araçların kullanımı, öğrencilere birçok avantaj sunarken, aynı zamanda teknik sorunlara da yol açabilmektedir. Matematikselleştirme ve matematiksel çalışma aşamalarında, özellikle dinamik matematik yazılımından kaynaklanan zorluklar dikkat çekici bir şekilde ortaya çıkmıştır. Ayrıca öğrencilerin farklı kaynaklardan bilgi edinirken karşılaştıkları zorlukların çözüm önerilerini zaman zaman olumsuz etkilediği tespit edilmiştir. ÇMM sürecinde öğrenciler akranları, öğretmenleri ve teknoloji ile sınırlı etkileşimleri modelleme döngüsünün farklı aşamalarında çeşitli zorluklara neden olmuştur. Gelecekteki araştırmalar, OMM süreçlerinde öğrencilerin teknik zorlukları aşarak etkileşim ve iş birliğini artıracak yöntemler geliştirmeye odaklanmalıdır.

Anahtar Kelimeler: Matematiksel Modelleme, Çevrim içi Öğrenme, Zorluklar, GeoGebra

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1 Sorumlu Yazar: Mustafa ALTUNTAŞ, Milli Eğitim Bakanlığı, altuntas2012@gmail.com, 0000-0002-5352-4233
2 Doç. Dr. Zeynep Sonay AY, Hacettepe Üniversitesi Eğitim Fakültesi, Matematik Eğitimi ABD, zsp@hacettepe.edu.tr, 0000-0002-1037-7106
3 Dr. Öğr. Üyesi, İbrahim ÇETİN, Necmettin ERBAKAN Üniversitesi Ahmet Keleşoğlu Eğitim Fakültesi, Matematik Eğitimi ABD, ibrahimcetin44@gmail.com, 0000-0003-4807-3295

1. INTRODUCTION

Real world problems are known to be generally complex, involving many variables. Examining these variables, understanding the connections in between and developing effective solutions with this information has become an inevitable need for students. In this context, mathematical modeling provides students with the ability to understand the relationships between these complex variables and develop effective solutions (Erbas et al., 2014). Mathematical modeling improves students' skills in dealing with real-world problems (Kaiser et al., 2010; Lesh et al., 2010; Cuong and Quang, 2020) and improves their critical thinking and problem-solving abilities (Sahin et al., 2017). In order to understand such problems and formulate solutions, students need to analyze these variables, understand the relationships between them and develop effective strategies with this information. Although mathematical modeling contributes to gaining important skills in learning Mathematics, it is known that the process is not always easy. Soon, Lioe and McInnes (2011) argued that the mathematical modeling process presents different challenges for both students and educators. For the purpose of the studies examining the difficulties experienced by students in the mathematical modeling process, different researchers mentioned that students have difficulty in stages such as understanding the task (Çoksoyler and Bozkurt, 2021), transforming real-world problems into a mathematical model (Deniz and Kurt, 2022; Jankvist and Niss, 2020), solving the problems using the model and interpreting the results (Klock and Siller, 2020; Saka and Celik, 2018); once they have developed the model, they further had difficulty in verifying and approving the model (Dede, 2017; Deniz and Kurt, 2022) and understanding the mathematical concepts and techniques used in the modeling process (Çevik and Cihangir, 2020; Meisya and Arnawa, 2021). Studies also revealed that students generally experience difficulties at every stage of the mathematical modeling process (Ozkan, 2021; Zulkarnaen, 2018). It is argued that different digital tools such as Dynamic Mathematics Software (DMS) and Web 2.0 tools can contribute to eliminating the difficulties experienced in the modeling process. In this context, different researchers conclude that using digital tools can offer students new opportunities to explore mathematical situations and better understand real-world problems (Molina-Toro et al., 2022) and that a modeling process can be created more effectively by using digital tools (Siller and Greefrath, 2010; Geiger, 2011; Daher and Shahbari, 2015). Digital tools are expected to support students in complex calculations and verification (Lingefjärd, 2000; Greefrath et al., 2018) and contribute to finding more comprehensive solutions to real-world problems (Hidiroglu, 2022).

Technology-supported mathematical modeling applications have generally been implemented in face-to-face education environments (Greefrath and Siller, 2018; Çevikbaş et al., 2023). However, the applicability of such training in online learning environments (OLEs) has gained significance with the technology becoming prevalent in education and the popularization of online learning (Yılmaz et al., 2023). With the impact of the COVID-19 pandemic, there was a comprehensive shift from the traditional classroom settings to virtual classrooms and educational platforms (Basilaia and Kvavadze, 2020). Students were given the opportunity to receive education wherever and whenever they want, without any space or time limitations. These developments in recent years have directly affected students' access to information and learning processes; accordingly some changes have been experienced. The use of technology-aided applications by institutions and educators has facilitated students' access to information and learning processes have become more flexible. Students now have access not only to information but also to different learning resources, interactive content and real-time feedback. This transformation has required educators to adopt new pedagogical approaches and strategies while providing students with more flexible learning opportunities. El-Sabagh (2021) emphasized how the role of technology in education changes not only the means of access to information but also students' learning styles, motivation and participation. Recent changes have inevitably affected mathematics education. For the purpose of the studies on mathematics education in online learning environments, particularly throughout the COVID-19 epidemic, the adaptation processes of students and educators to online education (Radmehr and Goodchild, 2022; Morton and Durandt, 2023), the use of new approaches and applications (Alabdulaziz, 2021; Lo, Cheung, Chan and Chau, 2021; Fan et al., 2021), difficulties and opportunities related to mathematics education in online environments (Adnan and Boz, 2015; Salsabila et al., 2022) have been discussed. Furthermore, some studies addressed on how students effectively learn mathematics in online learning environments and the factors affecting their motivation positively or negatively (Bringula et al., 2021; Santi et al., 2022; Rutherford, et al., 2022). Although online learning environments have become so widespread, it is observed that recent research on mathematical modeling is mostly focused on face-to-face education environments (Hankeln and Greefrath (2021); Hıdıroğlu et al., 2018; Molina-Toro et al., 2022). Focusing on technology-aided mathematical modeling processes in face-to-face education, Çevikbaş et al., 2023 examined the difficulties that students face due to the complex nature of digital technologies and technology disruptions whereas Klock and Siller (2020) emphasized the limitations that students face in using technology and drew attention to the deficiencies in this regard. At the end of a literature review, it was found that there were studies examining in detail the difficulties that students face when using technology and the impact of these difficulties on the modeling process as well as critical opinions on how digital tools can be effectively integrated into education. In this context, the integration of digital tools and instruments into the modeling process have revealed new perspectives on how students can improve their ability to understand and solve problems.

According to the approach based on the articulation of digital tools into the modeling process, illustrated in Figure 1, students define the real-life problems and interpret their content in Understanding the Task step. In the simplifying/structuring step, they identify relevant and irrelevant data in the problem, examine the relationship between these data, conduct research, determine the variables to be used in the model and make assumptions. In the mathematization step, models such as terms, equations, figures, diagrams and functions are developed and in the working mathematically step, the problem is solved through the mathematical model developed. In the interpretation step, the applications of the model and mathematical results are interpreted and associated with real life. In the validation step, the validity of the model is evaluated by considering the conditions before the solution of the model and if necessary, the model is reproduced. In the final stage, students summarize the work they have performed throughout the entire process and the results they have obtained (Blum and Leiß, 2007; Greefrath, Kaiser, Blum and Borromeo Ferri, 2013).

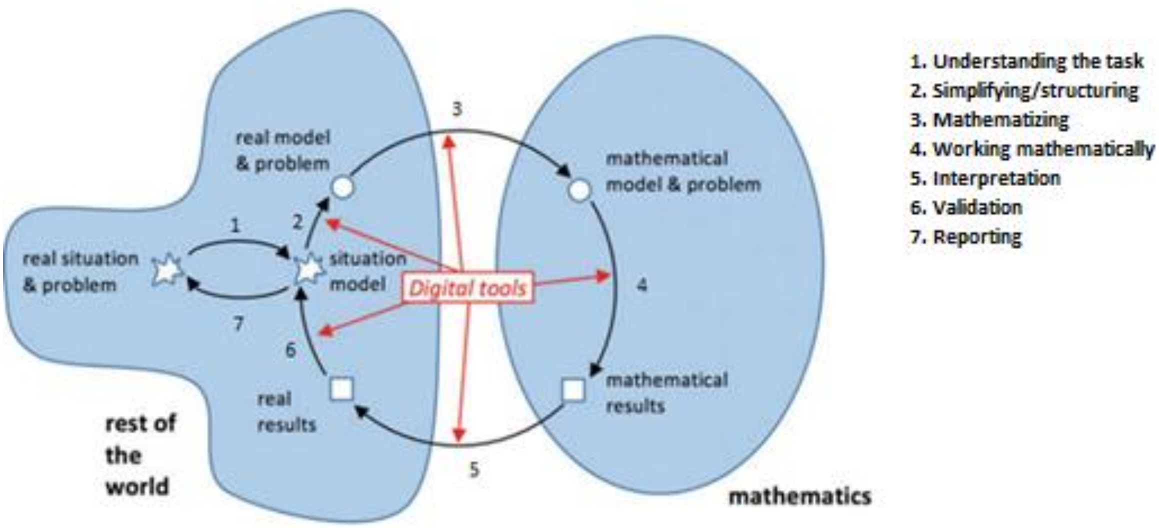

Figure 1. *Integration of digital tools into the modeling cycle (Greefrath and Siller, 2018)*

This study was based on the approach developed by Greefrath and Siller (2018) in which technological tools are integrated into the modeling cycle (Figure 1). This approach, based on the Blum and Leiß (2007) cycle, adopts the use of digital tools from problem posing, which is the beginning of the modeling cycle, to the reporting stage.

1.1. Purpose of the study

This research aims to examine the difficulties encountered by secondary school students in the mathematical modeling process applied synchronously in OLEs. The research focuses on the difficulties encountered with the use of technology in the mathematical modeling process, which aims to understand and solve real-life problems using mathematical structures. In this process, it is aimed to reveal in detail the problems experienced by students in the mathematical modeling process applied in the online environment. It is further aimed to contribute to how educators can support the OMM process more effectively. For this purpose, *"What are the difficulties encountered by students in the mathematical modeling process applied synchronously in online learning environments?"* was determined as the research question.

1.2. Significance of the study

This study makes a valuable contribution to the field by examining the effects of the mathematical modeling process implemented in OLEs. The difficulties experienced during the modeling process have already been examined in face-to-face learning environments within the scope of various studies (Coksoyler and Bozkurt, 2021; Deniz and Kurt, 2022; Jankvist and Niss, 2020; Klock and Siller, 2020; Saka and Celik, 2018; Dede, 2017; Meisya and Arnawa, 2021). For the purposes of this research, the difficulties experienced throughout the OMM process were identified and the stages of the modeling cycle where difficulties were experienced and how these difficulties were overcome were examined. Thus, the groundwork has been laid for developing practical solution suggestions for educators. The results obtained from this research will enable students to use mathematical modeling more effectively in online learning environments and strengthen the role of educators in this process. Unlike the studies conducted by researchers such as Aversi-Ferreira et al. (2021) and Yılmaz et al. (2023) that focused on prospective teachers, this study rather examines the online mathematical modeling processes for students at the K-12 level. The heightening role of technology in education and the transformation caused by online learning in educational approaches, particularly during the COVID-19 pandemic, increases the significance of this research. Understanding how the OMM process improves students' skills in solving real-world problems is thought to contribute to improving student's success by allowing educators to use these methods more effectively.

2. METHOD

2.1. Research design

In this research, the difficulties encountered in the OMM process were examined in depth by adopting a case study, which is one of the qualitative research methods. Case studies examine a phenomenon or situation with certain boundaries in detail (Yin, 1994). The situation that will be examined in depth for the purposes of this study is the difficulties experienced in the OMM process. This in-depth review is intended to help better understand and improve the OMM process.

2.2. Participants

The participants of the research consist of 8^{th} grade students of a public secondary school within the borders of a city center in the Central Anatolia region of Türkiye. Participating students from this institution, where the first researcher actually works, were determined on a voluntary basis. Participants were determined using the convenience sampling and criterion sampling techniques one of the purposeful sampling methods. Students who will participate in the research were required to have a tablet, phone or personal computer with internet access. This requirement is a significant factor to ensure that students participate in online courses with similar technical equipment during the distance education process. Participants were expected to work collaboratively to suggest solutions to modeling problems given in the online learning environment. Students were informed verbally, and their parents were informed in writing, that a number of data collection tools would be used to reveal the difficulties that may be experienced during the process. The students who participated in the research voluntarily were selected from 8th grade students. The students were allocated to 3 groups of 5 students each, in line with their own preferences and these groups were named Group-1, Group-2 and Group-3, respectively. Table 1 provides information about student groups that were asked to collaboratively solve modeling problems through the Online learning platform (Zoom). The research was scheduled after the High School Entrance Exam (LGS) to ensure active participation of students in the activity. However, two male students were noted to have declared that they could not participate in the study process due to reasons such as technical requirements and the need to rest after the exam. In addition, two female students dropped out after online introduction activities about mathematical modeling and GeoGebra software in the first weeks of the research and the study was conducted with a total of 11 students (8 girls, 3 boys). Pseudonyms were used to keep the identities of the students participating in the research confidential (Table 1).

Table 1.
Participants and Their Characteristics

	Participants	Gender	Class
G1	Banu, Rana, Selin, Zeynep	Girl	8-A
G2	Aylin, Ceyda, Ebru, Hülya	Girl	8-B
G3	Serkan, Ensar, Tarık	Boy	8-C

Table 1 reveals that the study participants consist of 8th grade students who were allocated into three groups as G1, G2 and G3. G1 and G2 consisted entirely of female students (Banu, Rana, Selin, Zeynep, Aylin, Ceyda, Ebru, Hülya) whereas G3 consists of male students (Serkan, Ensar, Tarık). Groups were created in accordance with the students' own preferences.

2.3. Data collection tool

The research was conducted over a 6-week period via the online learning platform (Zoom). Various data collection tools, including audio and video recordings and focus group interviews, were used throughout the research process. The Big Foot Problem (Lesh and Doerr, 2003) and the Sinkhole and Mevlana Museum Problem developed by the researcher were used within the scope of Modeling Activities (Table 2). While preparing the Modeling Problems, the characteristics that mathematical Modeling activities should have were taken into consideration, and the Sinkhole and Mevlana Problems were revised by taking into account the opinions of two experts who completed their PhD in the field of modeling. The implementation started after the pilot scheme performed in OLEs. In order to facilitate the communication between student groups, WhatsApp groups specific to each group were created. Before the implementation, students were provided with basic concepts and applied information about using GeoGebra dynamic mathematics software and mathematical modeling. These trainings were performed online by a mathematics educator with the participation of researchers and students.

Table 2.
Modeling Activities Used in the Study

The Bigfoot Problem	The feet of a person repairing the broken swing chains in a playground are 38 cm long and 12 cm wide. Based on this information, the children of the neighborhood were asked to estimate the height and weight of the helpful person and send a thank you letter.
Sinkhole Problem	Sinkhole Application and Research Center affiliated to Konya Technical University wants to remotely determine the dimensions of the sinkhole in Karapınar district in order to minimize the possible dangers on the ground, by using the photo of the sinkhole taken with a drone. In this context, the diameter and area of the sinkhole should be estimated. The report requests a detailed explanation of how these estimates were made and which methods were used.
The Mevlana Museum Problem	It includes an analysis and prediction based on the number of visitors of the Mevlana Museum between 2009 and 2021. The aim is to estimate the total number of visitors in 2022, the number of visitors lost due to the COVID-19 pandemic, and when the museum will be able to reach its previous visitor numbers. A report describing the methodology used for these estimates is requested.

Access to Big Foot, Sinkhole and Mevlana Museum Problems was provided through the *Classroom* interface available on the www.*geogebra*.org platform using PCs, tablets or smartphones. Audio and screen recordings of the activities performed in OLE setting were recorded and a focus group discussion was held after each activity about the difficulties encountered in the OMM process to reveal the students' opinions and suggestions on the subject. During these interviews, the following questions were asked to the students to reveal the stages in the modeling process in which they had experienced difficulties:

- Which stage or stages of the problem solving process did you have the most difficulty with? Can you explain the reasons underlying these difficulties?
- How did you make use of technological tools during this activity? What impact did using these tools have on the solution process?
- Were you able to overcome the difficulties you encountered? What did you experience throughout this process?
- How would the process have developed if this activity had been conducted in a face-to-face classroom setting instead of an online learning environment? Please explain your views.

Two experts in the field of mathematics education and qualitative research were consulted about the interview questions, and necessary corrections were made in line with their opinions.

2.4. Data analysis procedure

Audio and video recordings derived from the focus group interviews held with the participants after the Modeling activities were transferred to the MAXQDA 2022 program for qualitative data analysis. These recordings were then examined independently and in detail by the researcher who conducted the interviews and an academician who has expertise in mathematical modeling. The modeling cycle developed by Blum and Leiß (2007) was used as a basis to ensure that activities proceed in accordance with the modeling processes. The difficulties encountered by the participants were identified in line with this cycle and coded accordingly. Table 3 gives the examples used to determine the codes. First, encoder 1 (E1) examined the interview forms, performed certain coding and evaluated the data using the content analysis method. Then, the second encoder (E2) performed coding independently on the same data set.

Table 3.
Sample Coding Scheme Used for Data Analysis

Sample Expression	Encoder 1	Encoder 2	Themes
"First of all, let's draw something like a line on this car, can you do that? How can I do that? I don't know how to use GeoGebra very well either, but I think it will work if you can put a dot at one end of the car and a dot at the other end..."	GeoGebra tool selection and use	GeoGebra tool selection and use	Technical Difficulties
"Isn't the size of the car too big? When we calculate from 5 thousand and divide by hundred... We will end up with something like 50 meters, right? Yes, the length of the car probably won't be 50 meters... I think we made a mistake somewhere. (laughs)"	Validation	Validation	Validation
"I think we calculated while the trunk is open, the photo was small and probably didn't show any detail..."	Technical Difficulties	Limited View	Technical Difficulties
"We tried to find a solution right away without understanding well enough, so it turned out wrong. We need to put forward a solution proposal based on these data. I think we need to further understand the problem..."	Understanding the Task	Simplifying/ Structuring	Understanding the Task

Both experts worked using the MAXQDA program and the analysis results were brought together for comparison purposes. The reliability of the research was confirmed by calculating the degree of concordance between the codes and the final degree of concordance. Following the analysis, two different MAXQDA files were combined into a single project and the degree of concordance between the codes and the final degree of concordance were calculated. At the end of the calculation performed with the Agreements/(Agreements+Disputes) formula, this value was calculated as 90.7%. Miles and Huberman (1994) recommend reaching an agreement of 80% to ensure a consensus between coders. As a result, inconsistencies that emerged between different codings were reconsidered in detail until reaching a consensus.

3. FINDINGS

This chapter discusses the difficulties faced by students throughout the OMM process. Based on the analysis of the collected data, these difficulties and their frequency are shown in Figure 2. The difficulties encountered in the OMM process are presented with their frequencies (red) based on the modeling steps (blue) developed by Blum and Leiß (2007). The thickness of the strips indicates that the relevant difficulty is encountered more frequently, thus the frequency has a higher value.

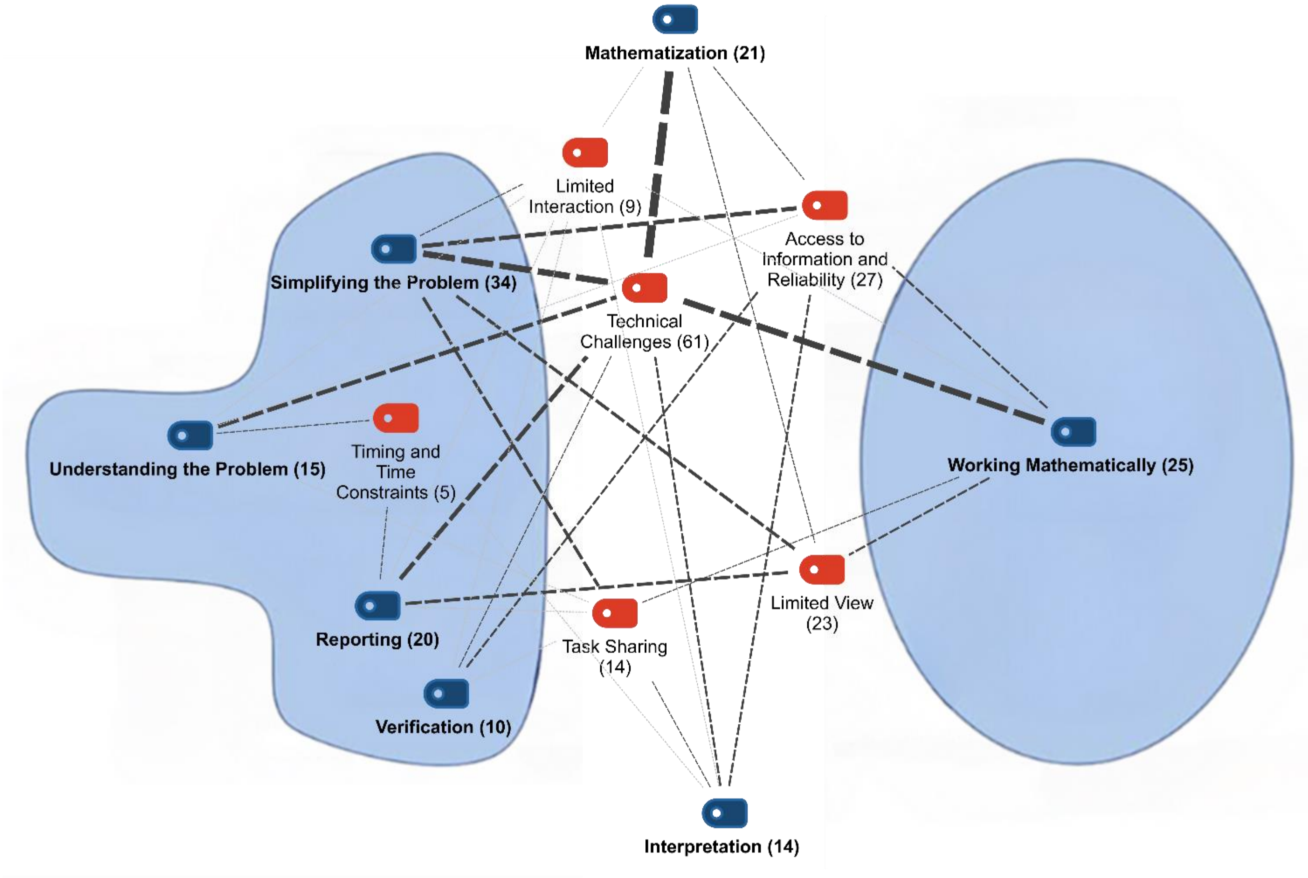

Figure 2. *Challenges Encountered by Students in the OMM Process*

Figure 2 exhibits the difficulties experienced by students in OLE, based on the mathematical modeling cycle. What kind of difficulties were encountered at which stages of the OMM process are presented with the frequency table (Table 3).

Table 3.

Difficulties Encountered by Students in the OMM Process

	Technical Challenges	Access to Information and Reliability	Limited View	Task Sharing	Limited Interaction	Timing and Time Constraints	Total
Understanding the Problem	9	1	1	1	1	2	**15**
Simplifying the Problem	10	8	6	7	3	-	**34**
Mathematization	15	3	2	-	1	-	**21**
Working Mathematically	12	5	5	2	1	-	**25**
Interpretation	4	4	2	2	1	1	**14**
Verification	3	5	-	1	1	-	**10**
Reporting	8	1	7	1	1	2	**20**
Total	**61**	**27**	**23**	**14**	**9**	**5**	

According to Table 3, students encountered various difficulties at various stages of the mathematical modeling process. In this context, each difficulty is addressed together with the relevant modeling stages. Difficulty in the modeling cycle was most frequently (34) experienced in the simplifying/structuring step. While Working Mathematically (25) and Mathematization (21) stages presented significant difficulties for the students, Reporting (20), Understanding the Task (15), Interpretation (14) and Verification (10) steps were less difficult. Most prominent difficulty encountered nearly at every stage of the mathematical modeling cycle was Technical Difficulties (61). Second most frequently encountered difficulty in the OMM process was under the sub-theme of access to information and reliability (27). Another significant difficulty encountered is under the Limited View (23) sub-theme whereas other difficulties identified are listed as Shared Tasks (14), Limited Interaction (9) and Time Management and Time Constraints (5). Each of these difficulties were addressed in the research, and it was observed that some of them have been experienced more clearly at certain modeling stages.

Most common difficulty that students encountered in the first stage of the modeling cycle, namely Understanding the Task, was technical difficulties (9). Student dialogues addressing this difficulty were presented at each stage of the modeling cycle. The technical difficulties generally experienced at this stage were expressed as audio and video problems, internet connection problems and connecting with two digital tools. At the beginning of the Mevlana Museum Problem, one of the students from the group asked the question *"Can you understand what he wants?"* and Ensar from G3 answered the question as *"I was trying to log in to GeoGebra, so I'm reading the problem once again."* In addition, at the beginning of the Sink-hole Problem, Ebru from G2 spoke up and said *"I'm sorry I'm late because of the internet connection..."* when she was talking about poor internet connection. Technical problems encountered by students at the beginning of the OMM process and the problems experienced in participating in OLE created a negative impact on understanding the Modeling Activities. Audio and video problems related to microphones, speakers or cameras are considered among the main factors that make students' participation difficult. Serkan, who was sharing the screen by connecting through his personal computer, had an audio problem and his friends advised him to check the technical settings of the device or the headphone connection to solve the problem. Serkan's audio problem was temporarily resolved after making the necessary the adjustments and the lecture was resumed. Students further had difficulty in understanding the content as they could not determine what data was given and what was required in the problem, could not establish a relationship between them or established the wrong relationship. Incomplete and insufficient data provided in modeling problems was another factor that challenged the students. To solving the sinkhole problem, the students wanted to make use of the length of the vehicle in the sink-hole visual to calculate the radius of the sinkhole, but they had difficulties as they did not have any data regarding the length of the vehicle. At this stage, it was observed that students had difficulty with time management and time constraints (2) in the OMM process due to factors like online activities scheduled at times when they are not suitable, time constraints (40 minutes) etc. In the focus group interview held after the Modeling Activities; Banu, a G1 group student, declared that she had problems to concentrate and understand which caused the learning process to get difficult by saying: *"I had a busy day so I had difficulty in understanding the question."*. Due to the difficulty in understanding the content, students attempted to solve the problem without understanding it properly as the variables in the real-life problem were rather dense and not very clear compared to traditional problems. Hülya, from the group G2, trying to solve the Mevlana Museum Problem spoke up about this situation by saying: *"We tried to find a solution right away without understanding well enough, so it turned out wrong. We need to put forward a solution proposal based on these data. I think we need to further understand the problem..."*.

Most common difficulties expressed by students in the simplifying/structuring step were related to technical difficulties (10), access to information and reliability (8) and shared tasks (7). The difficulties students experienced in determining necessary/unnecessary variables and making realistic assumptions became the most frequently encountered (34) difficulties in the modeling cycle at this stage, when considered together with technical difficulties. With regard to the difficulty encountered in estimating the length of the car, given the drone image, in the sink-hole problem; the student named Serkan from G3 said: *"I think we calculated while the trunk is open, the photo was small and probably didn't show any detail..."* The resolution of the images used in the Modeling Activity and the screen dimensions of the digital tool used may directly affect the solution proposed for the problem. Accordingly, G1 group students who had difficulty in determining the length of the vehicle in the sink-hole problem tried to estimate the dimensions of the vehicle by comparing it with a similar brand. When speaking about this code, it was observed that the student named Banu had difficulty in associating foot length and shoe size in the Big Foot Problem and that she was confused: "*When talking about 38 cm of foot length, I thought it was a very small number...*". In particular, the problem of access to information and reliability stood out as a critical difficulty (8) during the Simplifying/Structuring step. However, this is a difficulty frequently encountered at other steps of the process whose impact can be seen until the final stage, when students submit a final solution proposal. Students who started the OMM process with a quick internet search due to missing or insufficient data about the problem further encountered difficulties in distinguishing between necessary and unnecessary data in the later stages of the modeling process. Regarding this difficulty, Selin from the G1 asked her friends to explain her the text and table in the Mevlana Museum Problem in a more comprehensible way. Students sometimes may encounter information sources with questionable reliability while they collect the data they need at different steps of mathematical modeling. Ebru, from Group G2, working on the Big Foot Problem saw a single comment on the website while she was searching and said that: *"Hey guys, the length of the foot of a 1.60 m tall person should be 35-37, but this is only one person's comment...*". On the other hand, another group member emphasized the significance of reliable sources by stating that the information they use should be reliable, so they should avoid individual comments on websites. Another difficulty encountered was that students could not find sufficient information on the internet regarding all the data they needed. Screenshots and conversations of two students from the G3 group regarding their research while working on the Sinkhole Problem were presented in Figure 3:

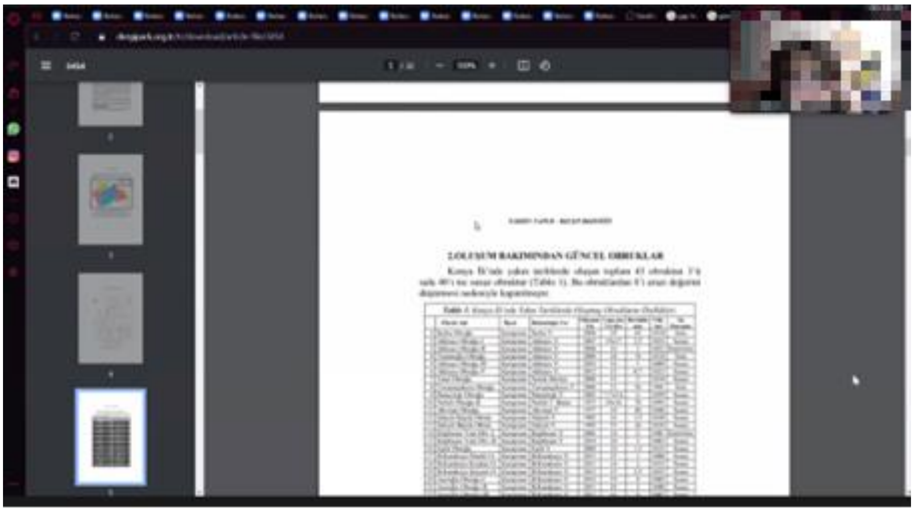

Figure 3. *Screenshot of Students Searching on the Internet (The Sinkhole Problem-G3)*

Serkan*: What is the name of this sinkhole? Many sinkholes, formed in Konya, are mentioned here. All of them are given with their names and diameters.*

Tarık*: ...but the name of the sinkhole given in the image is missing.*

Serkan and Tarık's statements reflected the difficulties of accessing specific data even though the internet provides extensive information resources. The complex structure of real-life problems led students to make incorrect or incomplete assumptions and focus on solutions without fully understanding the task.

Accordingly, Banu's statements saying that *"When talking about 38 cm of foot length, I thought it was a very small number..."* can be cited as an example of a wrong evaluation made by confusing foot length with shoe size. Students tried to find the specific information they needed on the internet but could not find the data they were looking for. This indicates that accessing some specific information may be difficult or impossible. The students' inability to accurately determine the problem data and requirements caused some further difficulties. The statements of Selin from G1, expressed while looking at the image of the sinkhole problem, saying *"... let's look at the brand of the car, the back of the car seems a bit long... It says 4,5-5 m, so let's assume the car is 500 cm long..."* can be given as an example. In case all data is not given clearly in Modeling Activity, it was observed that students had difficulty in identifying this data and they generally made decisions following an internet search or by consulting people around. For example, one of the students referred to his dad to find out the brand of the vehicle presented in the image given in the Sinkhole problem during the application and proceeded with the internet search after obtaining the necessary information. At this step, students experienced difficulties categorized under the sub-theme of access to information and reliability, due to reasons such as not being able to find sufficient data on the internet and unreliable sources.

Another difficulty encountered during the Simplifying/Structuring step of the OMM process was determined as shared tasks (7). Students, who tried to propose solutions to Modeling Activities by collaborating with their group friends, participated in the OMM process with different digital tools such as computers, tablets and smartphones. Students connecting via their PCs were particularly expected to use GeoGebra and share their screens. For example, Hülya from Group G2 working on the Big Foot Problem, assumed the task of screen sharing as she was the only student connecting via a computer. Furthermore, some individual abilities and potentials of the students, such as skills for effectively using the digital tools and mathematics achievements, also contributed to their shared tasks. It was observed, in this case, that students' individual abilities and characteristics play an important role in the OMM process. While solving the Modeling Activities, students progressed by adopting roles appropriate to their abilities and potential. Students who had difficulty making decisions were determined to have difficulty in transferring modeling activities to the mathematical world. In this case, some students kept on working on the research process in line with their individual interests and curiosities. Students proceeded with the assumption that other students could review their work. Therefore, students had limited opportunity to share their research on variables for current modeling problems with their peers. The GeoGebra link was shared with each student via the chat box on the Zoom platform, and students could access the modeling task from the GeoGebra course platform. While each student could access the dynamic page including the modeling task via the shared link, other students could also view the activity in case one of the group members shared the screen. Students connecting via their computers were particularly requested to share their screens so that GeoGebra could be used more efficiently. It was observed that the tasks were shared, and students worked in cooperation to solve the modeling problem. Hülya, one of the G2 group students, stated that she authorized Ebru to share her screen to contribute to the solution of the problem, but Ebru stated that she could not get this authorization due to internet connection problems. Hülya further authorized other friends to share her screen and expected her friends to experience and contribute despite the technical problems. During the modeling process, it was observed that students distributed tasks based on their personal abilities and skills. Students who felt less competent in using digital tools such as GeoGebra and Zoom or who were anxious about making mistakes tended to delegate such tasks to their more experienced friends, thus, they wanted the tasks to be performed more quickly and systematically.

In the mathematization step, students were expected to correctly develop the necessary mathematical model(s), explain the model(s) and to establish the necessary relationships based on the assumptions made in the previous step. While expressing her opinion about the difficulties experienced in this process, a student named Hülya from G2 stated that she could not find a specific rule for solving the Big Foot Problem with the following words: *"I think the height can be calculated based on the length of the feet, but we need to know* *the relevant formula...".* Students thought that they had difficulty in developing such mathematical models as they did not have the necessary formula. While transferring data derived from Modeling Activity to GeoGebra software, students encountered technical difficulties (15) such as *selection and the use of right tool*, *converting data into graphics* and *adding images*. Quotations from G1 group students' conversations about the difficulty they experienced on how to express the length of the vehicle presented in the sinkhole problem with a line segment in the GeoGebra environment are presented in Figure 4.

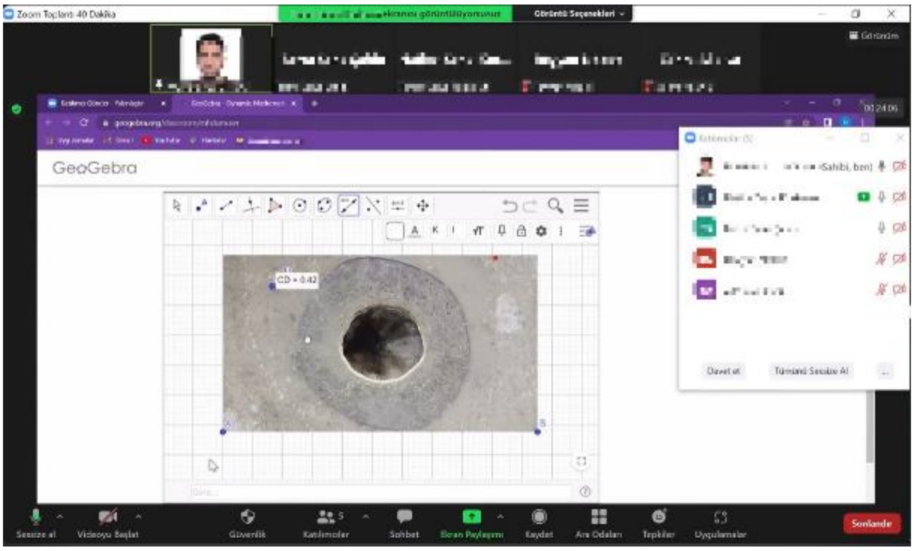

Figure 4. *Screenshot of Measuring the Length with GeoGebra (The Sinkhole Problem-G1)*

Banu*: Firstly, let's draw something like a line segment on this car, can you do that? How can I do that? I don't know how to use GeoGebra very well either, but I think it will work if you can put a dot at one end of the car and a dot at the other end...*

Selin*: Should we connect the image with a line segment or just put a dot?*

Banu*: Good point; believe me, I don't know either. Let's try whichever one works...*

Selin*: Let's try the line segment, shall I put it here?*

Banu*: Yeah, did she say that it will work? Can you see how many centimeters it corresponds to, or probably not centimeters, but how long?*

Selin*: No (laughs)*

As can be seen from the dialogue, Banu and Selin found the length of the line segment [CD] as 0,42 units by placing dots on the ends of the vehicle in the upper left corner of the image. Both students were found to use the measurement tool of GeoGebra software to determine the length of the vehicle in the image. They interacted with each other and approximately determined the length of the vehicle image by trial-and-error method.

For the purpose of the Working Mathematically step of the modeling cycle, students were expected to make calculations using their mathematical knowledge correctly. Most common difficulties expressed by students in this step were related to technical difficulties (12), access to information and reliability (5) and limited view (5). Students further experienced difficulties in how to use GeoGebra tabs and tools to transform data into graphics in the transformation between representations. Figure 5 exhibits the difficulties experienced by students working on the Mevlana Museum Problem in the GeoGebra environment while expressing the annual number of tourists with a line graph.

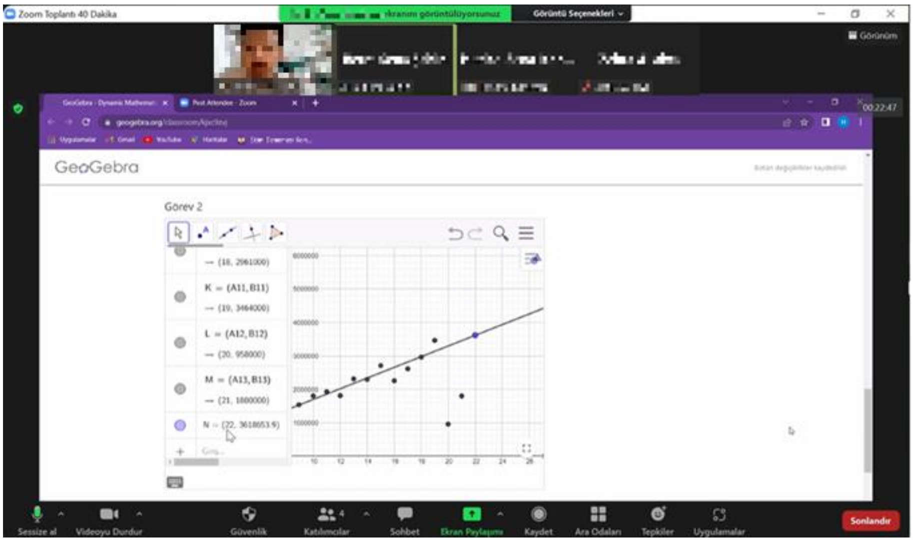

Figure 5. *Screenshot of Drawing a Line Graph with GeoGebra (Mevlana Museum Problem-G1)*

Students wanted to use the algebra window to determine the approximate number of visitors for 2022 by drawing a suitable line graph on the coordinate system using the points representing the annual number of visitors. Although they should have displayed the number of visitors for the year 2022 as 22 in the algebra window, they chose to mark it with a dot in the geometry window. Concerning the change in the number of visitors over the years, the exact value of 22 corresponding to year 2022 was calculated as 22,1149. This fact was interpreted by the student named Selin with the words: *"This value, 22.1149, seems ridiculous... Shouldn't we delete that fractional value here?"*. During this process, students were undecided about which tools to use in the GeoGebra tabs. A similar situation was experienced in the Sinkhole Problem, which includes visual content. Students wanted to transfer the sinkhole and vehicle image to the GeoGebra environment in order to determine their dimensions. Students experienced certain difficulties while transferring the sink-hole image despite they tried various methods such as copy-paste and drag-and-drop. Selin, one of the G1 group students, asked *"Does copy and paste work?" Zeynep answered the question by saying "Copy and paste doesn't work, I tried it."* After trials and errors, the students overcame this difficulty by saving the image as a different file.

For the purpose of the next stage of the mathematical modeling cycle, students were expected to interpret the results they found in a real-life context. Difficulties experienced at this stage were categorized under the sub-themes of technical difficulties (4) and access to information and reliability (4). Difficulties such as limited view (2), shared tasks (2) and interaction (1) further created an obstacle in the interpretation stage. For example, Serkan, one of the G3 group students, approximately calculated the diameter required in the Sinkhole Problem (using a real ruler on the screen) and conveyed the result he obtained to his other friends. Other group members stated that it would be appropriate for their friend to explain to them how he achieved this result. Serkan enlightened other friends and his teacher by allowing them to see the measurement he performed on the screen. This situation can be interpreted as an indication that the OMM process potential has a limited view. It was observed that there was limited interaction between teacher-student and peers during the OMM process. The feedback provided in this process was observed to be limited or delayed. In the focus group meeting, Ebru from G2 group emphasized this situation by saying: "*Many students do not speak up in online classes. If this were a face-to-face class, more students would attend and we could make brainstorming."* Some of the students stated that brainstorming with limited students (3-4 people) was less effective. It was observed that students generally focused on their own screens during the OMM process. This caused the students think that other participants were also seeing the same screen. However, students' failure to realize that the information available on different screens is not similar may be interpreted as restricting their ability to comment on Modeling Activity. This situation further caused problems such as not being able to make joint decisions and not understanding the solutions within the group. The dialogue between G3 group students regarding the change in the number of visitors of Mevlana Museum is given below:

> Serkan: *…increased by 900.000 visitors due to the virus. Considering both the 900.000 additional visitors due to the virus and additional 40.000 visitors adjusted based on the rate increase, this figure becomes 2.740.000. What if we make predictions in this direction for 2022?*
>
> Tarık: *I guess this is not the case.*
>
> Serkan: *Why not?*
>
> Tarık: *Do you think an increase of 950.000 visitors reasonable? I don't think so.*

These statements illustrated the difficulties experienced by the students in interpreting their results in a real-world context. Furthermore, considering the Big Foot Problem, Ceyda, one of the G2 group students talked like that: "*Sultan KÖSE, the tallest man in the world, had a foot length of 36,6 cm, a shoe size of 60 and a height of 2,51 meters. Therefore, I think it will be a little longer than Sultan KÖSE. Because the foot length is longer…*". Ceyda shared the information she had found with other students and suggested that they should hold an in-group discussion. Evaluating the information about the feet of the world's tallest man, the students wanted to discuss this information through a shared screen however they faced limited view and interaction difficulties. Selin, a student in the G1 group, claimed that she could not see her friend's screen and asked her to convey the procedures verbally. Other group members also stated that it would be more beneficial to share the full screen but currently they could only see the calculator. This time, Selin shared her full screen on the Zoom platform, thus making full screen visible. This situation suggests that students in an OLE have the idea that their screens are viewed as the same by their peers.

In the validation step of the modeling cycle, students are expected to check whether the results they obtained are meaningful in terms of the real world context. Difficulties experienced at this stage were categorized particularly under the sub-themes of access to information and reliability (5) and technical difficulties (3). G1 group students questioned how appropriate the dimensions they calculated for the vehicle given in Figure 6 after searching on the internet were compatible in real life context.

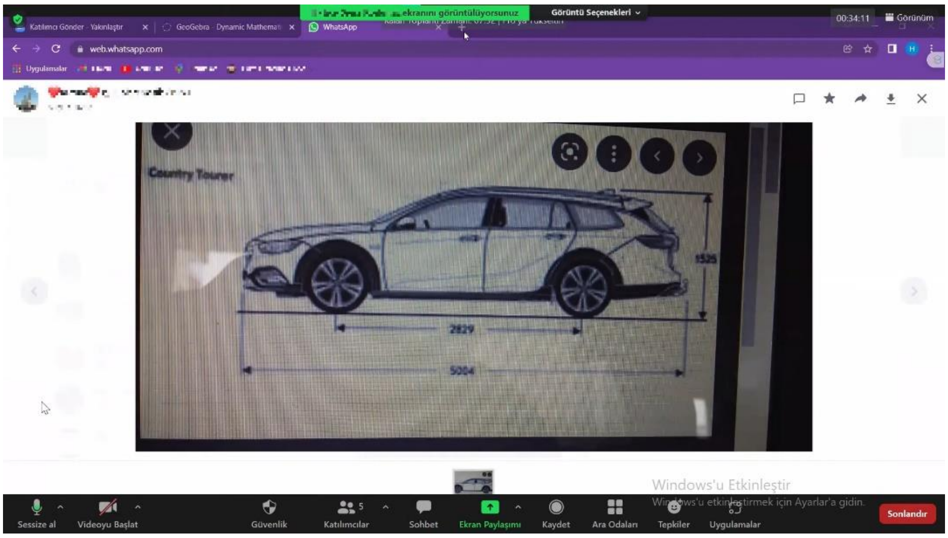

Figure 6. *Screenshot of Internet Search on Vehicle Dimensions (The Sinkhole Problem-G1)*

Following conversations between Banu and Zeynep about the dimensions of the vehicle were recorded in their conversation before moving on to the reporting stage:

Banu: *Let me tell you something I just realized. What was that, 5.000 or? Normally one meter is equal to 100 cm, so it does not seem that reasonable... The answer here is 5.004, 100 centimeters is 1 meter, so isn't that figure for the length of the car too high? When we calculate considering 5.000 cm and divide it by a hundred, we get something like 50 meters, right? Yes, the length of the car probably won't be 50 meters... I think we made a mistake somewhere. (laughs)*

Zeynep: *Is that millimeters? (laughs)*

Banu: *I don't know. (laughs)*

During the conversation they held in between about the dimensions of the vehicle, Banu and Zeynep figured the length of the vehicle as 50 meters, because of a mistake made by Banu, but thereon they realized that this might be wrong. This reveals that incorrect unit-based conversions regarding vehicle size can easily cause errors. The validation made on any web page within the scope of the internet search also paved the way for this situation.

In the reporting step of the modeling cycle, students uploaded the work they performed during the application and the results they obtained by adding text or images to the relevant section in the GeoGebra interface. Difficulties most frequently experienced at this stage were categorized particularly under the sub-themes of technical difficulties (8) and limited view (7). An example of students' sharing the results of the research they performed through digital devices such as smartphones, tablets and computers on the GeoGebra platform is presented in Figure 7.

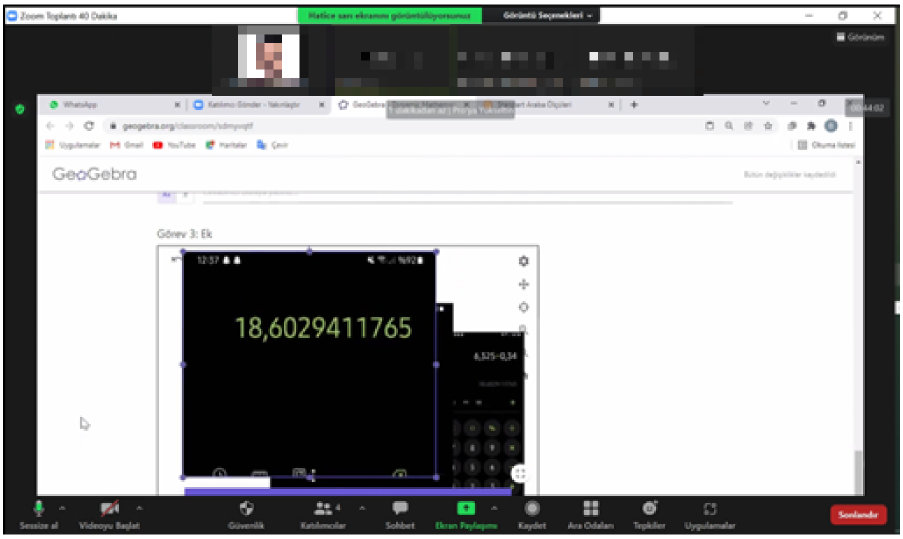

Figure 7. *Screenshot of Uploading Images to GeoGebra Environment (Sinkhole Problem-G2)*

G2 group students, trying to upload the calculations they performed while working on the sinkhole problem, to the relevant section on the GeoGebra platform (Figure 7). At this stage, difficulties most frequently experienced by the students were expressing with appropriate notation while writing a text on the GeoGebra platform, changing size and rotation when adding images. It was observed that students sharing posts in the WhatsApp group and the chat section of the Zoom experienced similar difficulties. Towards the end of the OMM process, Ebru from G2 expressed the technical problems she experienced by saying: *"I have consistently been disconnected from the course because of poor internet connection, I would not have this problem if this were a face-to-face course ..."*. Some students had to use more than one device (smartphone-computer) due to the technical problems they encountered. For example, Zeynep from G1 joined the *Zoom* platform from her smartphone however she used the GeoGebra software from her computer due to a technical problem. Difficulties encountered during the reporting step, such as *not being able to view students' work, not being able to view shared screen and working on a screen instead of paper*, are classified under the theme of limited view (7). This situation may limit the information and ideas exchanged between students and with their teachers. During the reporting step of the modeling cycle, students stated that they also had difficulty due to timing and time constraints. This situation made it difficult for them to convey their results and suggestions accurately and comprehensibly regarding the task. While discussing on the Mevlana Museum Problem, Selin, one of the G1 group students, reflected this situation by saying, *"We had calculated the other one, then the difference between these two… Err… that could occur in the epidemic… Oh, I couldn't explain…"* Ending Zoom sessions due to time constraints and having to reconnect each time constituted a factor that made it difficult for students to combine their previous work. Additionally, factors such as timing and time constraints (2) were found to affect students more towards the end of the application. While discussing on the Mevlana Museum Problem, Serkan, one of the G3 group students, reflected this situation by saying, *"Okay, I ignore what Tarık said as I cannot understand it and I will write down what Mehmet said."*

4. CONCLUSION and DISCUSSION

Difficulties encountered by students in the OMM process were examined within the scope of this research. Research results revealed that students most frequently encountered technical difficulties throughout this process. Main reason for these technical difficulties experienced in the OMM process is due to various technical problems while using digital tools and GeoGebra software. This situation poses a significant obstacle before the mathematical modeling process of students.

Preliminary results of the research indicated that the students faced difficulties beginning with the Understanding the Task step from the very beginning of the modeling process carried out in OLE. This difficulty was determined to be caused by missing or insufficient data in the Modeling Activity. Similar results were obtained in face-to-face mathematical modeling applications. Çoksöyler and Bozkurt (2021) suggested that secondary school students found the data provided in Modeling Activity to be incomplete or insufficient. The studies by Sağıroğlu and Karataş (2018), Gündüzalp (2019) and Schaap et al. (2011) revealed that students had difficulty in understanding the task. Considering that this research was conducted in OLE, it is possible to conclude that students encountered difficulties in understanding the task during a Modeling Activity performed both in face-to-face learning environment and in OLE. In other words, difficulties experienced while understanding the task arise regardless of the learning environment. In order to better understand the task and comprehend the problem in depth, students expanded the scope of their research by both doing online search and by referring to family members around them. However, this time they experienced difficulties in accessing information and reliability. Students assumed that they could find all the information they required on the internet but failed to meet their expectations. Moreover, they found out that the source of some of the data/information they attained were unreliable. Considering that the results obtained in one step of mathematical modeling can indirectly affect other steps of the process, it was concluded that the difficulties experienced by students in accessing information and reliability may turn into possible problems in the later stages of the model. Accordingly, it was determined that students doing research to find the variables that were not specified in the model eliciting activities in this research reached irrelevant data and results. For this reason, students were recommended to collect data from scientific articles and corporate websites, which are considered as more reliable sources of information, during the OMM process. It was further observed that students made extra efforts to access reliable internet resources as they encountered different model eliciting activities.

Students' making different assumptions by using different data, particularly during the Simplifying/Structuring step of the modeling cycle, caused confusion in trying to submit a common solution. It was observed that students managed to overcome this obstacle to the process and achieved correct results through the interaction they established. This finding indicates that the interaction established between the students is of critical importance. Kiili (2019) stated that students tried to find reliable sources by guiding each other in the group. Similarly, Apuke and Iyendo (2018) emphasized in their research that it is of critical importance for students to access the right resources on the internet.

Considering that the mathematical modeling process is a problem-solving method based on certain assumptions, the significance of the accuracy of the assumptions becomes evident. However, the importance of validating the results obtained based on assumptions with accurate data cannot be denied. It is possible to argue that software such as GeoGebra is useful for developing mathematical models using data and further validating these models. It may then be possible to validate whether the assumptions used in the modeling process are compatible with real-world data. Questioning whether the results obtained are reasonable or not will help in reaching the results compatible with real-life facts. In the Simplifying/Structuring step of the modeling cycle, students tried to understand the model eliciting activity and express it in a rather simple way. One of the main goals of Modeling Activities is to provide students with the ability to analyze data related to their daily lives (Tekin Dede, 2022). In the early stages of OMM activities, it was observed that students had difficulty in distinguishing which information/data was relevant to the modeling problem and making realistic assumptions. Çoksöyler and Bozkurt, 2021; Özkan, 2021; Saka and Çelik, 2018 argued that students had difficulties in making realistic assumptions as they could not relate the problem to real life facts. Focusing generally on the complexity of the problem at this stage may cause the students to have trouble in deciding how to share the tasks individually or between the group members. It was further observed that they tend to establish a relationship between individual or collective ideas and different variables given in the problem (e.g. Foot length-height, epidemic-tourism figures etc.). It was also observed that students cooperated in this process and shared certain tasks and guided each other (e.g. doing searches on the internet, using GeoGebra etc.) while developing a common solution. Students who connected to the activity via their personal computers and shared their screen allowed other friends' remote access to enable them to contribute. They also progressed the process by considering their friends' personal abilities and skills when determining the shared tasks. Accordingly, they aimed to do research after making some assumptions based on the content of the model eliciting activity and the visual information provided therein. It was further observed that the researcher made suggestions to the students on some issues, then the students shared these tasks among themselves and offered their solution suggestions on a shared screen.

Throughout the Mathematization step of the modeling cycle, students went through the process of transforming the images, texts, and other contents provided in the modeling activities into mathematical language. While expressing the problems mathematically in OLE, students prepared various figures, tables and graphs using appropriate mathematical symbols and notations. However, they encountered some difficulties in tasks such as creating tables, drawing graphs and determining fit lines while using the GeoGebra program. This finding of our research is in parallel with Çevikbaş et al., (2023); Saka and Çelik (2018) and Floro and Bostic (2018) who stated that they experienced similar difficulties in the stages of the modeling cycle. Main reason for these difficulties can be interpreted as students' lack of knowledge and experience in GeoGebra. It was further determined that students had difficulty in transitioning between tables, graphs and algebraic representations. Technological difficulties in addition to the unique challenges of the modeling process may also negatively affect learning experiences (Merck et al., 2021). Arefaine Michael and Assefa (2022) emphasized that students will soon be capable to switch between different representations by making multiple applications that include similar GeoGebra activities. Accordingly, it is argued that the process of solving GeoGebra-supported Modeling Activities, carried out with the participation of students, will pave the way for students to use this software more efficiently. Wassie and Zergaw (2019) suggested that the use of GeoGebra provides students with the opportunity to use technology as a tool for discovering and solving mathematical problems. Students generally take an approach to make sense of data provided in tables and graphs; however, the fact that students' capabilities of making sense of graphs and tables are at different levels may further create difficulties, especially in interpreting more complex data (Perin and Campos, 2022). It is possible to further put forward that the training provided within the scope of this research was spread over a limited time frame and technological tools such as GeoGebra were discussed superficially. Aversi-Ferreira et al. (2021) emphasized similar results in their study where they pointed out students' lack of experience within the scope of mathematical modeling applied via OLE. Considering the significance of the advantages brought about by technological software in solving mathematical model eliciting activities, identifying technology-related challenges is of great importance.

Throughout the Working Mathematically step of the OMM process, students encountered various problems such as adding visuals to the GeoGebra platform, image files that could not be viewed in detail and the use of mathematical symbols and signs. Difficulties, particularly with regard to transferring image files to GeoGebra software and the use of notations, have been frequently expressed at this stage of the modeling cycle. Converting length measurements, calculating the area of a circle, determining suitable points on the GeoGebra platform etc. were some of the difficulties encountered. Studies have revealed that it is difficult to teach courses that require the use of graphics and notations, especially mathematics, in online learning environments (Akdemir, 2010; Yang, 2017). It was argued that the online courses becoming widespread in the coming years may help to eliminate certain difficulties while causing new difficulties (Chang and Lee, 2022; Yohannes et al., 2021). Thus, it is possible to conclude that particularly individuals who do not have much experience in working with digital tools may face difficulties in the Working Mathematically step of solving Modeling Activities. It is thought that the OMM process may have a potential disadvantage in this respect, however this situation can be minimized by improving the experience of using digital tools. It was further determined that there are some disadvantages of conducting international exams such as PISA (Program for International Student Assessment), which uses a mathematical modeling cycle, in a computer environment. Prior research has revealed that students have difficulty in solving Modeling Activities due to reasons such as not sufficiently developed technological literacy of the students and the fact that students are rather inclined to solve math problems using a paper and pencil (Gürlen, Demirkaya and Doğan, 2019).

During the interpretation step of the OMM process, it is necessary to adopt a screen-oriented approach to solving problems. Problems related to limited view also affected this step and therefore the solution process. Adedoyin and Soykan (2020) emphasized that replacing pen and paper with a screen has caused some difficulties. When compared to environments where face-to-face communication is provided, situations such as not being able to view students' works or shared screen during the activities can be cited as an example of these difficulties. When a student is sharing his/her screen in the Online Learning Environment, it is not possible to clearly determine whether other students are engaged in extracurricular activities (e.g. research, gaming or web browsing). Lecturers are recommended to encourage the participation of silent students in OMM activities in order to ensure active participation and make in-group discussions and the learning process more effective and meaningful. It was determined that students examined the given text or image but had difficulties in determining the necessary data for solving the activity during the OMM process, particularly in the Simplifying/Structuring step. The difficulties experienced by the students in properly interpreting and analyzing the data available in the images highlight the significance of the quality and accessibility of the materials used in online education. At this stage, it was observed that students prefer to resort to doing internet searches to overcome the difficulties encountered however this method is not always useful. As a matter of fact, some of the students could not find the information and results they wanted when they searched the modeling activity on the internet. Furthermore, students experienced a limited interaction because of their limited communication with each other and with their teachers during the OMM process. As restricted interaction makes collaboration difficult, it can also decrease the understanding on how to interpret mathematical modeling in real life conditions. Weak discussions within the group may further cause difficulties in interpreting the results correctly. Yılmaz et al., (2023) stated that students had problems in expressing themselves in mathematical modeling activities in distance education. This limited their ability to interpret Modeling Activities and reach a common decision. Working with a smaller number of friends during the OMM process instead of working with a large group as in the classroom environment is concluded to restrict the interaction of students (Wulanjani et al., 2022). Accordingly, it was argued that working with small groups of 3-4 students during the OMM process is among the factors that decrease the motivation for some of the students. This situation may be caused by the fact that students who have the opportunity to establish stronger social relations with their peers in the classroom environment work with a smaller number of people during the OMM process. However, working with a collaborative group approach with 3-5 students in each group is recommended for the purpose of solving modeling activities during the OMM process (Kaygısız and Şenel, 2022). Students' inability to use their microphones and cameras due to technical problems or personal preferences restricted their interaction during the online learning process. This difficulty further caused students to participate less in others' contributions and decreased their feedback.

Difficulties encountered by students in the validation step of the modeling cycle are categorized into two main categories, namely access to information and reliability and technical difficulties. Students should be encouraged to be more selective when using internet resources and to validate the accuracy of the information by checking from various sources. Saka and Çelik (2018) argued that over-reliance on results obtained using technology can negatively affect the process of developing and validating mathematical models. In this context, giving more place to critical thinking skills in curriculum is expected to help students overcome such challenges (Kaygisiz, 2023). The ability of the students to question and evaluate the information they encounter while doing research is thought to improve their capacity to access accurate information and use this information effectively.

Another result obtained in this research is the difficulties experienced by students with regard to timing and time constraints, particularly in the reporting step towards the end. To maximize the efficiency and effectiveness when planning OMM activities, it is crucial to consider appropriate timing for both the teachers and students. Etemad-Sajadi (2016) argued that synchronous online activities can be more interesting and conducive to learning compared to asynchronous activities. Therefore, scheduling synchronous online activities at time frames when teachers and students are most convenient is very important to make learning outcomes more efficient. It was concluded by Aversi-Ferreira et al. (2021), similar to this study, that sessions held in a limited time period challenge students. For the purpose of online activities, it is also important to consider potential distractions (physical environment, technical requirements and notifications) (Junco and Cotten, 2012). As the effects of distractions will manifest differently from student to student, practices aiming to minimize these effects are of critical importance. Preparing clear guidelines for OMM and providing technical support can make participation in this process more qualified. Furthermore, incorporating regular breaks and interactive elements into online activities can help maintain engagement and reduce the effects of distractions (Tonbuloğlu and Çukurbaşı, 2023). As a result, scheduling preferences of both teachers and students should be taken into account in order to plan OMM activities and to maximize participation and learning outcomes.

Finally, experiencing technical difficulties such as poor internet connection and sound quality at every stage of the OMM process seems to be a common problem faced by the students. The negative reflection of these difficulties on the OMM process has turned the process into a more challenging experience for some students. Similar findings indicating that mathematics courses taught in online learning environment involve some technical difficulties for students have been expressed in different studies (Coşkun Şimşek et al., 2022; Tonbuloğlu and Çukurbaşı, 2023). This result suggests that technical difficulties arise due to the online learning environment regardless of mathematical model eliciting activities. OLE and Digital material-based challenges introduced to an activity process aimed at higher-level thinking skills such as Mathematical Modeling makes this process even more complex and challenging. Such a result indicates that students need to improve both their academic and technological skills in parallel. Future research should focus on finding solutions to the technical difficulties encountered by students in OMM processes and developing methods to increase student interaction and collaboration.

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GENİŞLETİLMİŞ ÖZET

1. GİRİŞ

Matematiksel modelleme, öğrencilere karmaşık gerçek dünya problemlerini anlama, analiz etme ve etkin çözümler geliştirme becerisi kazandırır. Bu süreç, öğrencilerin problem çözme ve eleştirel düşünme yeteneklerini artırırken, aynı zamanda gerçek dünya problemleriyle başa çıkma becerilerini de geliştirir. Tüm bu avantajlarının yanında, matematiksel modelleme süreci hem öğrenciler hem de eğitimciler için çeşitli zorluklar içermektedir. Öğrenciler, problemleri anlama (Çoksöyler ve Bozkurt, 2021), bu problemleri matematiksel modele dönüştürme (Deniz ve Kurt, 2022; Jankvist ve Niss, 2020), modeli kullanarak çözüm üretme ve sonuçları yorumlama (Klock ve Siller, 2020; Saka ve Çelik, 2018), modeli doğrulama (Dede, 2017; Deniz ve Kurt, 2022) ve raporlama gibi aşamalarda zorluk yaşamaktadırlar. Dijital araçların, özellikle Dinamik Matematik Yazılımları (DMY) ve web 2.0 araçlarının kullanımı, modelleme sürecindeki bu zorlukların üstesinden gelmeye yardımcı olabilir. Bu araçlar, öğrencilere matematiksel durumları keşfetme, gerçek dünya sorunlarını daha iyi anlama ve daha kapsamlı çözümler üretme fırsatları sunar (Molina-Toro vd., 2022; Daher ve Shahbari, 2015; Greefrath vd., 2018; Hıdıroğlu vd., 2022).

Teknoloji destekli matematiksel modelleme genellikle yüz yüze ortamlarda gerçekleştirilmiş olsa da, teknolojinin eğitimdeki artan rolü ve çevrim içi öğrenmenin popülerleşmesi bu eğitimlerin sanal ortamlarda da uygulanabilirliğini kaçınılmaz kılmıştır. COVID-19 pandemisi, eğitim sistemlerinde geleneksel sınıf ortamlarından sanal sınıflara ve eğitim platformlarına doğru büyük bir geçişe yol açmış, öğrencilere mekân ve zaman sınırlamaları olmaksızın eğitim alma olanağı sağlamıştır (Basilaia ve Kvavadze, 2020). Bu değişim, öğrencilere bilgiye kolay erişim ve öğrenme süreçlerinde esneklik sunarken, eğitimcileri yeni pedagojik yaklaşımlar ve stratejiler benimsemeye yönlendirmiştir. Teknolojinin eğitimdeki bu etkisi, öğrencilerin öğrenme stillerini, motivasyonlarını ve katılımlarını da değiştirmiştir. Çevrim içi ortamlarda matematik eğitimi, adaptasyon süreçleri (Radmehr ve Goodchild, 2022; Morton ve Durandt, 2023), yeni yaklaşım ve uygulamaların kullanımı (Alabdulaziz, 2021; Lo, Cheung, Chan ve Chau, 2021; Fan ve ark., 2021) çevrim içi ortamlardaki zorluklar ve fırsatlar (Salsabila ve ark., 2022) gibi konularda çeşitli araştırmalar yapılmıştır. Sonuç olarak, teknolojinin artan etkisi ile matematiksel modelleme uygulamalarının da bu yeni dönüşüme adapte olmasının önü açılmıştır. Ancak, matematiksel modelleme ile ilgili çalışmaların çoğu hala yüz yüze ortamlarda gerçekleştirilmekte, çevrim içi eğitimde teknoloji destekli matematiksel modelleme süreçleri ve karşılaşılan zorluklar hakkında sınırlı çalışma bulunmaktadır (Hankeln ve Greefrath, 2021; Hıdıroğlu ve ark., 2018; Molina-Toro ve ark., 2022).

Bu araştırmanın amacı, Çevrim içi Öğrenme Ortamı'nda (ÇÖO) eş zamanlı olarak gerçekleştirilen matematiksel modelleme sürecinde ortaokul öğrencilerinin karşılaştığı zorlukları incelemektir. Bu amaç doğrultusunda "ÇÖO'nda eş zamanlı olarak gerçekleştirilen matematiksel modelleme sürecinde öğrenciler açısından karşılaşılan zorluklar nelerdir?" araştırma sorusu olarak belirlenmiştir.

2. YÖNTEM

Bu araştırmada, Çevrim içi Matematiksel Modelleme (ÇMM) sürecinde öğrencilerin karşılaştıkları zorluklar, durum çalışması yöntemi kullanılarak detaylı bir şekilde incelenmiştir. Araştırmanın katılımcıları, Türkiye'nin Orta Anadolu bölgesindeki bir devlet ortaokulunun 8. sınıf öğrencileridir. Araştırmada amaçlı örnekleme yöntemleri kullanılmış, öğrenciler çevrim içi öğrenme platformu Zoom aracılığıyla gruplar halinde modelleme problemleri üzerinde çalışmışlardır. Bu süreçte, büyük ayak problemi, obruk problemi ve mevlâna müzesi problemi isimli üç farklı problem kullanılmıştır. Veri toplama sürecinde ses ve görüntü kayıtları, odak grup görüşmeleri gibi yöntemler kullanılmış ve elde edilen veriler nitel veri analizi için MAXQDA 2022 programına aktarılmıştır. Analiz sürecinde, Blum ve Leiss'in (2007) modelleme döngüsü temel alınarak Greefrath ve Siller (2018) tarafından oluşturulan teknolojik araçların entegre edildiği yaklaşıma göre öğrencilerin karşılaştığı zorluklar tespit edilmiş ve kodlama yapılmıştır. Araştırmada, kodlar arasındaki uyuum yüzdesi %90.7 olarak hesaplanarak, araştırmanın güvenirliği test edilmiştir. Bu çalışma ile ÇMM sürecinin daha iyi anlaşılmasına ve geliştirilmesine katkı sağlanması hedeflenmektedir.

3. BULGULAR, TARTIŞMA VE SONUÇ

Bu araştırmada, ÇMM sürecinde öğrencilerin karşılaştıkları zorluklar incelenirken, bu zorlukların sıklığı ve modelleme sürecinin hangi aşamalarında daha belirgin olduğu ortaya koyulmuştur. Modelleme sürecinin başında, problemi anlama aşamasında öğrencilerin zorlandığı; bu durumun, verilerin eksik veya yetersiz olmasından kaynaklandığı görülmüştür. Öğrenciler, bilgiye erişme ve güvenilirlik konusunda da zorluk yaşamış, bazı durumlarda güvenilir olmayan kaynaklardan bilgi edindikleri görülmüştür. Bu durum, modelleme sürecinin ilerleyen aşamalarında problemlere yol açabileceği için bilgi toplama süreçlerinde bilimsel yayınlar ve kurumsal web sayfaları gibi daha güvenilir kaynakları kullanmalarının önemi ortaya çıkmaktadır. Modelleme döngüsünün problemi sadeleştirme aşamasında ise öğrenciler farklı veriler kullanarak çeşitli varsayımlar oluşturmuş ve bu durum başlangıçta kafa karışıklığına yol açmıştır. Ancak, öğrenciler arasındaki etkileşim sayesinde bu engel aşılmış ve doğru sonuçlara ulaşılmıştır. Öğrencilerin birbirlerini yönlendirerek güvenilir kaynaklara ulaşmaya çalıştıkları ve internet ortamında doğru kaynaklara erişimin önemli olduğu görülmüştür. Bu süreçte, öğrenciler problemle ilgili bilgileri ayırt etme ve gerçekçi varsayımlar oluşturma konusunda zorlanmış, ancak iş birliği ve görev dağılımı yaparak ortak çözümler geliştirmişlerdir

Modelleme döngüsünün matematikselleştirme aşamasında, öğrenciler problemleri matematiksel dille ifade etmeye çalışmışlar ve bu süreçte GeoGebra yazılımını kullanarak tablolar, grafikler ve çeşitli matematiksel gösterimler hazırlamışlardır. Ancak, öğrenciler GeoGebra'yı kullanırken grafik çizme, tablo oluşturma ve uyum doğrusu belirleme gibi konularda zorluklar yaşamışlardır. Bu zorlukların ana kaynağının öğrencilerin GeoGebra konusunda yeterli bilgi ve deneyime sahip olmamaları olduğu anlaşılmaktadır. Teknolojik araçlarla ilgili yaşanan bu zorluklar, öğrencilerin öğrenme deneyimlerini olumsuz etkileyebilmektedir. Araştırmalar, öğrencilerin farklı matematiksel temsiller arasında geçiş yapma becerilerinin geliştirilmesi ve GeoGebra gibi yazılımların etkili kullanımının, benzer uygulamalar ve etkinliklerle mümkün olabileceğini vurgulamaktadır (Arefaine Michael & Assefa (2022). Aynı zamanda, teknoloji destekli modelleme problemlerinin çözümü, öğrencilerin bu yazılımları daha verimli kullanmalarını sağlayabilir. Öğrencilerin tablo ve grafikleri anlamlandırma becerilerinin geliştirilmesi gerektiği, özellikle karmaşık verilerin yorumlanmasının zorluklar içerebileceği belirtilmektedir (Perin & Campos, 2022).

ÇMM sürecinin matematiksel çalışma aşamasında, öğrenciler GeoGebra ortamında çeşitli sorunlar yaşadıkları görülmüştür. Bu sorunlar arasında görsel ekleme, görsellerin ayrıntılı görünmemesi ve matematiksel sembol ile işaret kullanımı gibi zorluklar bulunmaktadır. GeoGebra araçlarının kullanımında yaşanılan sorunlara (uygun noktaların belirlenmesi, görsel aktarımı vb.) ek olarak, matematiksel notasyon kullanımında problemler (uzunluk ölçülerinin dönüştürülmesi, dairenin alanının hesaplanması vb.) öne çıkmıştır. Matematik gibi grafik ve notasyon kullanımı gerektiren derslerin çevrim içi ortamlarda öğretilmesinin zorlukları olduğu, çevrim içi derslerin yaygınlaşmasıyla bazı zorlukların giderilse de yeni sorunlara yol açabileceği belirtilmiştir (Chang and Lee, 2022; Yohannes vd., 2021). Dijital araçlara yönelik deneyim eksikliği, özellikle modelleme problemlerinin çözümünde zorluklara neden olabilmektedir. Bu durum, ÇMM sürecinin potansiyel dezavantajlar içerebileceğini, ancak dijital araçların kullanımının artırılmasıyla bu sorunların azaltılabileceğini göstermektedir. Uluslararası bir değerlendirme uygulaması PISA (Programme for International Student Assessment) gibi bilgisayar ortamında gerçekleştirilen sınavların bazı dezavantajları olduğu, öğrencilerin teknoloji okuryazarlığının yeterince gelişmemiş olması ve kağıt-kalem yöntemine daha yatkın olmaları gibi nedenlerle modelleme problemlerinin çözümünde zorlandıkları araştırmalarla ortaya konmuştur (Gürlen, Demirkaya & Doğan, 2019). Bu bulgular, ÇMM uygulamalarında dikkate alınması gereken önemli noktaları vurgulamaktadır.

Modelleme döngüsünün doğrulama aşamasında öğrenciler, bilgi erişimi ve güvenirliği ile teknik zorluklar yaşamışlardır. İnternet kaynaklarından doğru bilgiyi seçme ve çeşitli kaynaklarla doğrulama yapma bu süreçte önem taşımaktadır. Özellikle derslerde bilgi okuryazarlığı ve eleştirel düşünme becerilerine odaklanılması, öğrencilerin bu zorlukların üstesinden gelmelerine yardımcı olabilir. Araştırmada, öğrencilerin ÇMM etkinliklerinin raporlama aşamasında özellikle zamanlama ve süreyle ilgili zorluklar yaşadıkları bulunmuştur. Etkinliklerin planlanması sırasında öğretmenlerin ve öğrencilerin zamanlama tercihlerinin dikkate alınması, etkili bir öğrenme deneyimine zemin hazırlayacağı ifade edilebilir. Eş-zamanlı (senkron) çevrim içi etkinliklerin, eş-zamansız (asenkron) etkinliklere göre daha etkili olabileceği; ancak, sınırlı zaman ve dikkat dağıtıcı unsurların öğrenciler üzerindeki etkisinin de göz önünde bulundurulması gerektiği vurgulanmıştır. ÇMM için açık ve net yönergeler, teknik destek, düzenli aralar ve etkileşimli unsurların önemi belirtilerek, bu unsurların öğrenci katılımını ve etkinlik verimliliğini artırabileceği ifade edilmiştir.

Son olarak, ÇMM sürecinde, öğrenciler yaygın olarak internet bağlantısı ve ses kalitesi gibi teknik zorluklar yaşamışlardır, bu durum süreci bazı öğrenciler için zor bir deneyime dönüştürmüştür. Benzer teknik zorluklar, çevrim içi matematik dersleriyle ilgili yapılan diğer çalışmalarda (Coşkun Şimşek vd., 2022; Tonbuloğlu ve Çukurbaşı, 2023) da belirtilmiştir, bu da teknik sorunların çevrim içi ortamın genel bir problemi olduğunu göstermektedir. Matematiksel Modelleme gibi üst düzey düşünme becerileri gerektiren etkinliklerdeki teknik zorluklar, süreci daha karmaşık ve zorlayıcı hale getirebilmektedir. Bu durum, öğrencilerin akademik ve teknolojik becerilerini aynı anda geliştirmelerinin önemini vurgulamaktadır.

ARAŞTIRMANIN ETİK İZNİ

Yapılan bu çalışmada "Yükseköğretim Kurumları Bilimsel Araştırma ve Yayın Etiği Yönergesi" kapsamında uyulması gerektiği belirtilen tüm kurallara uyulmuştur. Yönergenin ikinci bölümü olan "Bilimsel Araştırma ve Yayın Etiğine Aykırı Eylemler" başlığı altında belirtilen eylemlerden hiçbiri gerçekleştirilmemiştir.

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Bu çalışma Hacettepe Üniversitesinde yürütülen doktora tez çalışmasından üretilmiştir.