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The Pre-service Teachers' Modeling Cycles in the Mathematical Modeling Process: The Task of Solar Energy System

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Abstract: This study aims to explore the modeling cycles that emerge in the pre-service teachers' mathematical modeling activities. A case study was employed in the research. 119 pre-service teachers in their fourth class participated in the research. The pre-service teachers worked in groups. So, there were a total of 28 different groups. The modeling task was posed by considering the modeling criteria. The data collection tools consisted of the pre-service teachers' working papers. The content analysis method was applied in the data analysis. The pre-service teachers created four different modeling cycles. The first consisted of 7% of the groups and was the cycle that included the pre-service teachers who could reach the real model. The second cycle consisted of 68% of the groups and included the pre-service teachers who could reach the mathematical results from the real model without posing any mathematical model. The third cycle consisted of 7% of the groups and included the pre-service teachers who completed the processby reaching the mathematical model. The fourth was the cycle that consisted of 18% of the groups and included the pre-service teachers who completed the modeling cycle. It was determined that the cycle in the second group occurred the most among the modeling cycles. Therefore, the pre-service teachers can be supported to pass the fourth modeling cycles.

Keywords: Mathematical modeling, modeling cycle, modeling task

Matematiksel Modelleme Sürecinde Öğretmen Adaylarının Modelleme Döngüleri: Güneş Enerji Sistemleri Görevi

Öz: Bu çalışmanın amacı öğretmen adaylarının matematiksel modelleme etkinliklerinde ortaya çıkan modelleme döngülerinin incelenmesidir. Araştırmada durum çalışması deseni kullanılmıştır. Çalışmaya 119 dördüncü sınıf öğretmen adayı katılmıştır. Öğretmen adayları gruplar halinde çalışmışlardır. Böylece toplamda 28 farklı grup bulunmaktadır. Modelleme görevi, modelleme kriterleri dikkate alınarak tasarlanmıştır. Veri toplama araçlarını öğretmen adaylarının çalışma kağıtları oluşturmaktadır. Verilerin analizinde içerik analizi yöntemi kullanılmıştır. Elde edilen bulgulara göre, öğretmen adaylarının dört farklı modelleme döngüsü oluşturduğu belirlenmiştir. Birincisi, grupların %7'sini kapsamaktadır ve gerçek modele kadar ilerleyebilen öğretmen adaylarının oluşturduğu döngüdür. İkincisi, grupların %68'ini oluşturmakta olup matematiksel model oluşturmadan gerçek modelden matematiksel sonuçlara kadar ilerleyen öğretmen adaylarının oluşturduğu döngüdür. Üçüncüsü, grupların %7'sini kapsayan ve

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matematiksel modele kadar ilerleyerek süreci sonlandıran öğretmen adaylarının oluşturduğu döngüdür. Dördüncüsü, grupların %18'ini içeren ve modelleme döngüsünü tamamlayan öğretmen adaylarının oluşturduğu döngüdür. Modelleme döngülerinden en fazla ikinci gruptaki döngünün gerçekleştiği tespit edilmiştir. Öğretmen adayları, dördüncü modelleme döngüsüne geçiş yapmaları için desteklenebilir.

Anahtar kelimeler: Matematiksel modelleme, modelleme döngüsü, modelleme görevi

Introduction

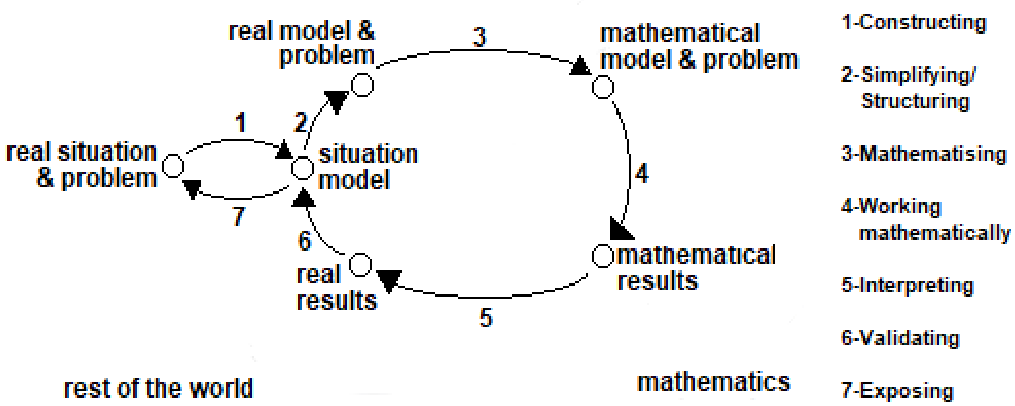
Mathematical modeling is increasingly becoming more popular and taking its place in international school curricula (Blomhøj & Kjeldsen, 2006; Common Core State Standards Initiative [CCSI], 2010; Ministry of National Education [MoNE], 2017). Niss (2015) explains the purpose of mathematical modeling as using mathematical phenomena as a tool to reply to, comprehend, analyze and represent practical, intellectual, and scientific questions. In other words, the mathematical modeling is described as using mathematical methods to solve real-life problems (Stender & Kaiser, 2015). For instance, which of the internet packages should I choose? What is the long-term evolution of population growth? When should a vineyard owner harvest the grapes? While these questions are not answered only by mathematical means, no answers can be satisfactorily satisfied without mathematics (Niss, 2015).

The mathematical modeling process is represented by a cycle designed according to different perspectives, including realistic or applied modeling, contextual modeling, educational modeling, socio-critical modeling, and cognitive modeling (Greefrath & Vorhölter, 2016; Perrenet & Zwaneveld, 2012). Niss and Blum (2020) stress that the modeling cycles are tools configured to understand the modeling process. Vos and Fredj (2022) explain the modeling cycles as a schematic diagram demonstrating the mathematical modeling as a cyclic process. There are a lot of different modeling cycles in the literature (i.e.., Blum, 2015; Kaiser & Stender, 2013; Perrenet & Zwaneveld, 2012). They were devised with distinct motivations and objectives. In assessing these cycles, it is essential to bear in mind the original intentions underpinning their development (Vorhölter, Greefrath, Borromeo Ferri, Leiß, and Schukajlow, 2019). The ensuing classification elucidates these cycles' diverse aims and objectives in both research and practical applications. The cycles include the didactical or pedagogical modeling cycle, the psychological modeling cycle, and the diagnostic modeling cycle or modeling cycle from a cognitive perspective (Borromeo Ferri, 2018).

This study aims to uncover the individuals' modeling cycles according to the cognitive modeling approach based on learning mathematical modeling as a purpose. Therefore, the first version of the modeling cycle that described the process according to the cognitive theory was developed by Blum and Leibb (2007), and the new version by Blum (2015). This cycle is presented in Figure 1.

Figure 1

Mathematical Modeling Cycle According to Blum (2015)



As presented in Figure 1, Blum (2015) describes the mathematical modeling cycle's basic stages in six stages. These are real situation, situation model, real model, mathematical model, mathematical result and real result. First, individuals read the real situation (problem or task) and construct the situation model. When the situation model has been simplified, a real model emerges. During the mathematising process, the real model transforms into a mathematical model by using mathematical means (graphs, equations). Then, the solution process of the mathematical model is realized by using some strategies. At the end of his process, the mathematical result is obtained. The mathematical result transforms into real results by interpreting the real world. Another significant sub-competency is to confirm and validate these results. The basic question here is "can the result be applied to the real world?" (Blum & Leibb, 2007). Finally, the result related to the real problem is presented by exposing the validity of the obtained model. The realization of the sub-competencies that are expressed indicates the mathematical modeling competency (Zöttl et al., 2010). The classification of modeling cycles can be based on their level of detail (Borromeo-Ferri, 2006). The first category encompasses modeling cycles that do not incorporate situation and real models, instead directly translating the real situation into a mathematical model. In contrast, the second category comprises modeling cycles that solely consider the real model phase and do not incorporate the situation model. Finally, the third category encompasses modeling cycles that account for the real situation, the situation model, and the real model as distinct components (Author, 2018). Borromeo Ferri (2010) states that the modeling cycle given in Figure 1, which used the situation model for the first time, is quite detailed and, therefore, a suitable tool for analyzing the cognitive process.

The individuals' modeling processes are not as easy as the ideal behaviors expressed in the modeling cycles, but they are quite complicated (Haines & Crouch, 2010). The individuals in this process jump back and forth between phases, turn back a few steps and repeat several steps back and forth (Borromeo Ferri, 2011; Doerr, 2007). In the conducted studies, it was found that the individuals followed a unique path in the modeling cycle and this process was not linear (Ärlebäck, 2009; Borromeo Ferri, 2007; Czocher, 2016; Galbraith & Stillman, 2006). However, most of the phases are observed in a place of the individuals' modeling processes. Yet, the cycles are not a recipe that should be followed (Vos & Fredj, 2022). Therefore, the reason why individuals have different modeling cycles is wondered. In this context, various results have been reached in the literature reviews.

1. The individual's previous life and scholastic experiences (Matsuzaki, 2011; Thompson & Yoon, 2007)
2. The individuals have different thinking styles (Blum & Borromeo Ferri, 2009; Borromeo Ferri, 2010; 2012)
3. Having experience in mathematical modeling (Author, 2018)
4. The individuals' experiencing some difficulties in the modeling process (inability to understand the situation, inability to construct the real model, inability to pose the mathematical model) (Blum & Leiß, 2007; Galbraith & Stillman, 2001)

Upon examination of the studies, it was revealed that students encountered challenges in several areas. Specifically, they experienced difficulties understanding the task, constructing a real model by defining the pertinent variables of the situation and making assumptions, generating a mathematical model, conducting mathematical calculations, and verifying the models (Abay & Gökbulut, 2017; Anhalt, Cortez and Bennett, 2018; Bukova Guzel, 2011; Deniz & Akgün, 2018; Deniz & Yıldırım, 2018; Galbraith & Stillman, 2006; Maaß, 2006; Schaap, Vos & Goedhard, 2011; Tekin Dede, 2016). Especially, it was observed that many pre-service teachers have a habit of solving problems without creating a model (Özer & Bukova-Güzel, 2020). It has been established that pre-service teachers tend to solve problems using the numerical values presented in the context rather than employing model construction (Tekin Dede, 2016). The studies suggest that students and pre-service teachers face this problem due to their limited capacity to fully internalize it (Kaya & Keşan, 2022). They do not plan their approach to the problem carefully and often resort to obtaining a mathematical solution by using the provided numerical values. (Çoksöyler & Bozkurt, 2021; Genç & Karataş, 2017; Kaya & Keşan, 2022). It may be interesting to see how these challenges are reflected in advances in the modeling cycle. Difficulties in the modeling process may lead to variations in the modeling cycles of pre-service teachers.

It is importance to systematically determine the different modeling cycles that emerge in a modeling activity. Acquiring knowledge of diverse modeling cycles by educators can be crucial in providing support to their students. In addition, the students will notice the different modeling cycles that the teachers notice and will be able to direct their learning. This research aims to explore the modeling cycles systematically that emerge during the mathematical modeling activities. Sub-problems are:

1. What are the modeling cycles of pre-service teachers?
2. How do the characteristics of pre-service teachers' modeling cycles change?

Method

As it is aimed to investigate the modeling cycles that emerge during the pre-service teachers' (PST) modeling activities in this study, a case study among the qualitative approach method was used. The case study is to determine the situation related to the research and examine the determined situation in depth (Bogdan & Biklen, 2007).

Study Group

The study group consisted of 119 pre-service secondary school mathematics teachers. They were in their fourth year of study at the Faculty of Education in the 2022-2023 academic year. The PSTs have participated in 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. In the research, four different modeling problems were solved, automatic irrigation system, solar energy system, fire station location determination and cargo company selection, respectively. The data relating to the solar energy system were applied in this research. Thus, it can be claimed that while the PSTs were familiar with model modeling concepts from the first activity, their experience was quite new. Therefore, the PSTs were divided into groups of four or five according to their wishes during the research. Since the students had similar academic backgrounds in mathematical modeling, this criterion did not be considered while forming the groups. Additionally, academic success in mathematics does not necessarily guarantee success in mathematical modeling activities. Previous research has demonstrated that low-achieving students can excel in mathematical modeling activities as identified through conventional assessment methods (Zawojewski, Lesh, English, 2003). Consequently, academic achievement was not employed as a criterion for group formation. Instead, the formation of groups was based on the students' expressed preferences and ability to communicate effectively. This latter criterion was considered significant as group dynamics play an essential role in mathematical modeling activities (Biccard and Wessels, 2011). Hence, groups were formed based on the student's willingness to participate in the activity. Thus, a total of 28 different groups were constituted. The working papers of each group were collected and coded as Group 1, Group 2, ..., and Group 28. The excerpts from the working papers are included in the findings section.

Data Collection Tools and Process

As the data collection tool in this study, the working papers that include the mathematical modeling problem were used. The data collection tool includes two parts. The first is the part that includes the warm-up talks.

In the working paper, a piece of news was shared with the PST to create a discussion related to solar energy systems. "The solar energy systems are of great significance today. What do you think about the solar energy systems that the European countries want to build in the African regions? For you, why did they try to build the solar energy system in the lands of Africa? Please discuss.

After the groups had finished the discussion, they reached several variables that could affect the situation, such as the duration of sunshine, the angle of incidence of the sun's rays, the amount of energy to be imported from Africa, the cost, the size of the area to be established. Then, a modeling problem was given to the PSTs "With the increase in the electricity prices, a family plans to install a solar energy system on the building they live in. Develop a model and share your results to decide whether it is profitable". This task was evaluated in terms of the criteria given by Wess and Greefrath (2019). These are presented in Table 1.

Table 1

The Criteria for Mathematical Modeling Problem

Categories	Question	Yes	No
Reality	Is the problem definition presented in a non-mathematical out-of-school context?	☒	☐
Relevance	Is the problem situation from the students' environment, closely related to the students or interesting for them?	☒	☐

Authentic	Is the problem origin authentic? Is the origin of the problem related to real people?	☒	☐
	Is the problem sentence authentic? Can the solutions to the problem be applied to real life?	☒	☐
Openness	Can be problem situation be applied to the alternative solutions? Is it available to determine different variables, make assumptions or develop models?	☒	☐
Promoting sub-competencies	Simplifying/structuring: Does the problem definition require making assumptions, and specifying variables?	☒	☐
	Model creating: Does the problem definition require model creating?	☒	☐
	Working mathematically: Does the problem definition require solving the model?	☒	☐
	Interpreting: Does the problem definition require interpreting?	☒	☐
	Validating: Does the problem definition necessitate questioning its validity in real life?	☒	☐

Three experts analyzed the solar energy systems problem regarding the criteria in Table 1. The consensus of all the experts was that the problem was suitable for the modeling problem criteria. The solar energy problem was evaluated based on modeling task criteria by two experts with significant experience in mathematical modeling. Their assessment revealed that the created mathematical modeling problem is contemporary, grounded in students' real-life experiences, leads to results with tangible real-world implications, offers open-ended opportunities for self-assessment, and enables the utilization of modeling competencies. One of the experts recommended augmenting the problem's authenticity by integrating a news story into the scenario, following which the pertinent news item was incorporated into the problem.

The researcher administered modeling problems to PSTs for an academic term. For the solar energy modeling problem employed in this study, the data collection process was carried out over two weeks. In the first week, 28 groups were divided into four different classes. The modeling problem was applied to these four classes. The interaction of the PSTs with each other was banned to not influence their solution processes. The researcher was in the role of the instructor during the whole solution process and guided the groups. The researcher provided motivation, feedback, and strategic support to the students during the modeling stages throughout the application. The researcher avoided directing them. The researcher has facilitated access of PSTs to multimedia environments such as the internet and computers. In the second week, again, the 28 groups were divided into four classes and allowed to make their presentations. Thus, all the groups presented their works, and the researcher confirmed what they understood from their working papers. While the groups were making their presentations, the researcher took field notes. Therefore, the data collection process was completed.

Data Analysis

The working papers of the 28 groups were applied as a data source. These working papers were reviewed through the modeling cycle developed by Blum and Leibb (2007). According to Vos and Fredj (2022), the modeling cycle is a significant mean used to analyze the students' works. This cycle enables to reveal modelers' cognitive processes in the mathematical modeling activities. By taking the theoretical framework of the mathematical modeling cycle, inductive analysis, among the qualitative content analysis, defined by Mayring (2015), was used to analyze the data. Four different cycles were determined within the scope of the study. The definitions and indicators of the six levels of the mathematical modeling cycle developed by Ji (2012). The six levels proposed in the modeling process represent an idealized framework. However, it has been observed that PSTs deviated from this ideal process and skipped certain steps. Consequently, this study aimed to identify modeling cycles that diverge from the ideal process. Drawing on the definitions provided in the ideal process, this study extracted four distinct cycles from the PSTs' worksheets, with their indicators identified through content analysis. The definitions and indicators of the modeling cycle are presented in Table 2.

Table 2

Mathematical Modeling Cycle of PSTs

Cycle	Definition	Indicator
1	Understand the real-world situation, form a situation model, simplify the situation model, and create the real model	Draw the representation of the given situation, make assumptions, determine the variables, and make predictions about these variables. So, simplify the situation. But they could not mathematize.
2	Understand the real-world situation and create a real model. Could not mathematical model. Moving from a real model to mathematical results and real results.	Draw the given situation's representation and simplify it, but they could not mathematize. Reaches only one mathematical result and interprets it.
3	Understand the real-world situation, form a situation model, and create the real model. Create the mathematical model.	Draw the representation of the given situation, simplify the situation, and create the mathematical model. But they could not solve the mathematical problem.
4	They complete the modeling cycle	Draw the given situation's representation, simplify it, set up the mathematical model, solve the mathematical problem and get mathematical results, interpret mathematical results, and test their validity.

The working papers of the 28 groups were analyzed using the indicators in Table 2. The cycle types of each group were determined. All the groups were placed into these four-cycle types.

Findings

The first sub-problem is "What are the modeling cycles of pre-service teachers?" It was found in the study that the PSTs had four different modeling cycles. The first is the cycle created by the PSTs who were able to reach the real model. The second is the cycle created by the PSTs who were able to reach from the real model to the mathematical and real results without creating a mathematical model. The third is the cycle that the PSTs end the process by progressing to the mathematical model. The fourth is the cycle that the PSTs complete the modeling cycle. The modeling cycles of the PSTs related to solar energy systems are presented in Table 3.

Table 3

The Modeling Cycles of The PSTs Related to The Solar Energy Systems

	PSTs	f	%
Cycle 1	G11, G26	2	7
Cycle 2	G1, G3, G7, G8, G9, G10, G13, G15, G16, G17, G18, G20, G21, G22, G23, G24, G25, G27, G28	19	68
Cycle 3	G6, G12	2	7
Cycle 4	G2, G4, G5, G14, G19	5	18

As seen in Table 3, 7% of the PSTs could progress to the real results in the modeling cycle (cycle 1) and 7% mathematical model (cycle 3). Those who completed the process by expressing their mathematical results directly without creating a mathematical model comprised 68% of the PSTs (cycle 2). Finally, 18% of the PSTs had cycle 4 and completed the modeling cycle.

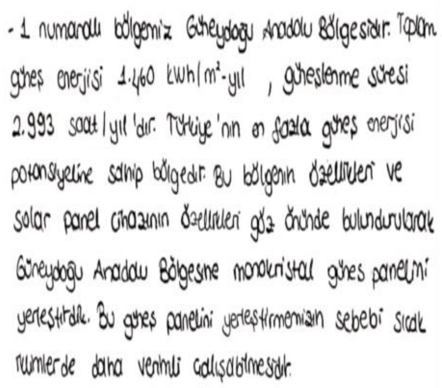
The second sub-problem is "How do the characteristics of pre-service teachers' modeling cycles change?" The characteristic features of the determined four cycles are presented below.

Cycle 1

In this cycle, the PSTs made some assumptions, determined the variables and estimated them; however, they could not develop a model to determine whether a family should install a solar energy system. An excerpt from G26 is presented in Figure 2.

Figure 2

The Excerpt of G26


- 1 numaralı bölgemiz Güneydoğu Anadolu Bölgesidir. Toplam güneş enerjisi 1.460 kWh/m²-yıl, güneşlenme süresi 2.993 saat/yıl'dır. Türkiye'nin en fazla güneş enerjisi potansiyeline sahip bölgedir. Bu bölgenin özellikleri ve solar panel cihazının özellikleri göz önünde bulundurularak Güneydoğu Anadolu Bölgesine monokristal güneş panelini yerleştirdik. Bu güneş panelini yerleştirmemizin sebebi sıcak iklimlerde daha verimli çalışabilmesidir.

The first region should be the Southeastern Anatolia Region. The total solar energy is 1.460 kWh/m^2-year, and the sunshine duration is 2.993 hours/year. Therefore, it has the highest solar energy potential in Turkey. We set a monocrystal solar panel in the Southeastern Anatolia Region by considering the characteristics of this region and the solar panel device. The reason why we placed this solar panel is that it can work more efficiently in hot climates.

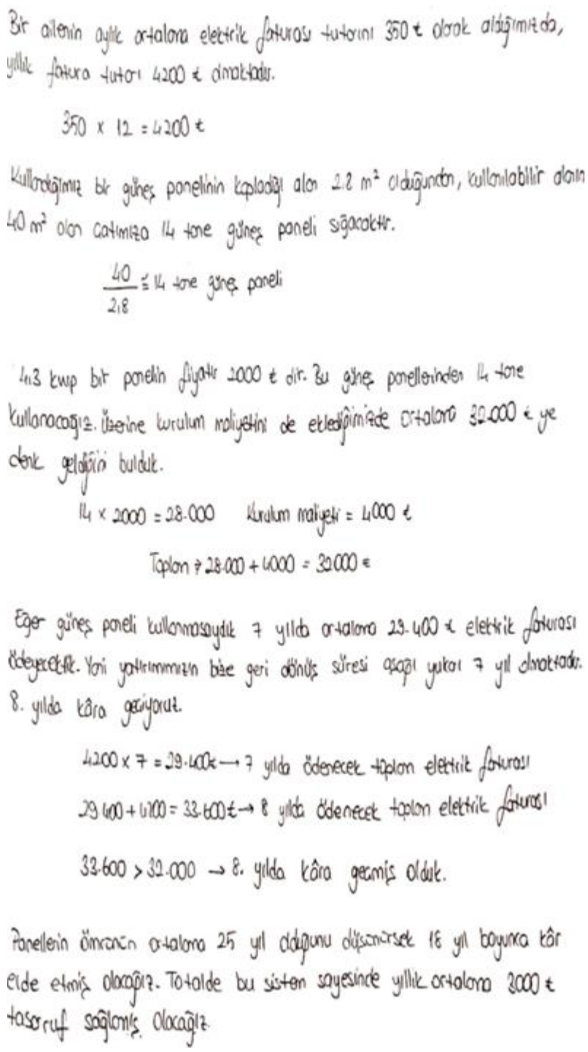
G26 coded group concluded that the average solar radiation of the regions, sunshine duration, and solar panel types are important variables for the solar energy system's installation. The group established a relationship between the solar radiation and sunshine duration of the region and decided on the type of solar panel. Thus, the place was deemed appropriate for the monocrystalline solar panel in a region with high solar energy potential. G26 partly created the real model and completed the process. However, deciding the type of solar panel does not answer the modeling question asked of the PSTs.

Cycle 2

In this cycle, the PSTs determined various variables, such as the amount of electricity used in a month, the solar energy installation fee, and the amount of energy obtained from solar energy. However, while predicting these variables, they used a single data. Thus, developing a model that could generalize the data was impossible. The excerpt from Group 9 is presented in Figure 3.

Figure 3

The Excerpt of the G9


Bir ailenin aylık ortalama elektrik faturası tutarını 350 ₺ olarak aldığımızda, yıllık fatura tutarı 4200 ₺ olmaktadır.

350 x 12 = 4200 ₺

Kullandığımız bir güneş panelinin kapladığı alan 2.8 m² olduğundan, kullanılabilir alanı 40 m² olan çatımıza 14 tane güneş paneli sığacaktır.

$\frac{40}{2,8} \cong$ 14 tane güneş paneli

4.3 kwp bir panelin fiyatı 2000 ₺ dir. Bu güneş panellerinden 14 tane kullanacağız. Üzerine kurulum maliyetini de eklediğimizde ortalama 32.000 ₺ ye denk geldiğini bulduk.

14 x 2000 = 28.000 Kurulum maliyeti = 4000 ₺

Toplam ? 28.000 + 4000 = 32.000 ₺

Eğer güneş paneli kullanmasaydık 7 yılda ortalama 29.400 ₺ elektrik faturası ödeyecektik. Yani yatırımımızın bize geri dönüş süresi aşağı yukarı 7 yıl olmaktadır. 8. yılda kâra geçiyoruz.

4200 x 7 = 29.400₺ → 7 yılda ödenecek toplam elektrik faturası

29.400 + 4200 = 33.600₺ → 8 yılda ödenecek toplam elektrik faturası

33.600 > 32.000 → 8. yılda kâra geçmiş olduk.

Panellerin ömrünün ortalama 25 yıl olduğunu düşünürsek 18 yıl boyunca kâr elde etmiş olacağız. Totalde bu sistem sayesinde yıllık ortalama 3000 ₺ tasarruf sağlamış olacağız.

When we assume that a family's the average amount of electricity bill per month is 350 TL, the yearly amount will be 4200 TL.

350x12=4200 tl

Since the area covered by a solar panel we use is 2.8 m², 14 solar panels fit on our roof with a usable area of 40 m².

$$\frac{40}{2,8} = 14\ solar\ panel$$

A panel with 4.3 kwp costs 2000 TL. We will use 14 panels. When we add 4.000 TL of the installation cost, we found 32.000 TL of expense.

14 x 2000= 28.000 installation cost= 4000tl

Total 28.000+4.000 =30.000 tl

If we had not used the solar panel, we would have paid a 29.400 TL electricity bill in 7 years. That is, the payback period of our investment is approximately 7 years. Therefore, we will make a profit in the 8th year.

4200x7=29.400 Total amount of electricity bill to be paid in 7 years

29.400+4200= 33.600 Total amount of electricity bill to be paid in 8 years

33.600>32.000 we began to make a profit in the 8th year.

If we regard the life of the panels as 25 years on average, we will have made a profit for 18 years. Thanks to this system, we will save an average of 3000 TL annually.

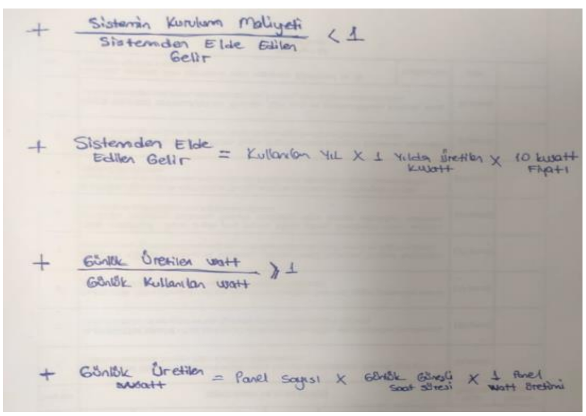
In the excerpt, the G9 took the electricity bill as a constant amount (350TL). They multiplied 350 by 12 to calculate the yearly amount of the bill. In conclusion, they found one year of bill cost as 4200 TL. Then, they predicted that a panel was 2.8 m² and the area of the roof of a house was 40 m². Thus, by dividing 40 m² into 2.8 m², they determined the number of panels that fit on a roof. They also decided the cost of a panel as 2000 TL and by multiplying the number of panels (14 panels) by the cost of one panel, they found 28.000 TL of expense. Then, they calculated the installation cost of the panel as 4000TL and added on the expenses of the panels. The total expense was found as 28.000+4.000: 32.000 TL. By comparing the electricity bill with the expenses of the solar energy system, they found that it would pay off the electricity bill in 7 to 8 years. By claiming that a solar energy system has a lifespan of 25 years and they stated that they would make a profit for 18 years. Therefore, they decided that the solar energy system was profitable. In this process, G9 explained all variables with a constant number. They concluded the process when they reached a result. However, they did not try to find answers to the questions such as “What should we do if we pay more electricity bills per month?” or “What if the installation cost was more or less?" It was determined that many groups had similar modeling cycles.

Cycle 3

In this cycle, the PSTs determined the variables and reflected the relationships between the variables in the model. However, they completed the process here. The excerpt related to G12 is presented in Figure 4.

Figure 4

The Excerpt of G12



$$\frac{System\ installation\ cost}{income\ from\ the\ system} < 1$$

Income from the system= Used year x kwatt produced in 1 year x The cost of 10 kwatt

$$\frac{Watt\ produced\ per\ day}{Watt\ used\ per\ day} > 1$$

Watt produced per day= number of panels x daily sunshine hours x watt production of 1 panel

The G12-coded group divided the cost of the system installation by the income from the system. It determined that a ratio greater than one would be profitable for installing the solar energy system. They multiplied the price of kilowatts and kilowatts produced in one year to calculate the income from the system. They explained the kilowatt produced in a year with the kilowatt model produced in a day. For the kilowatt produced in a day, they multiplied by the number of panels, the daily sunshine hours, and the kilowatt production of a panel. They created a model with the determining variables. However, the PSTs did not solve the model that they developed; thus, they decided whether the model worked or not. In addition, they did not interpret or validate whether the solar energy system was profitable.

Cycle 4

In this cycle, the PSTs completed the whole process. The variables were determined, and the model was created, solved and interpreted. In addition, its validity in real life was checked.

All the groups that completed the modeling cycle benefitted from the internet and determined all the variables that affected the situation. The excerpt of the G5-coded group is presented in Figure 5.

Figure 5

The Excerpt of G5

Güneş Enerji Sistemleri için gerekli malzemeler:

- Güneş Panelleri
- Jel Aküler
- İnverter
- Şarj Kontrol Cihazı
- Solar Kablo
- Konnectörler

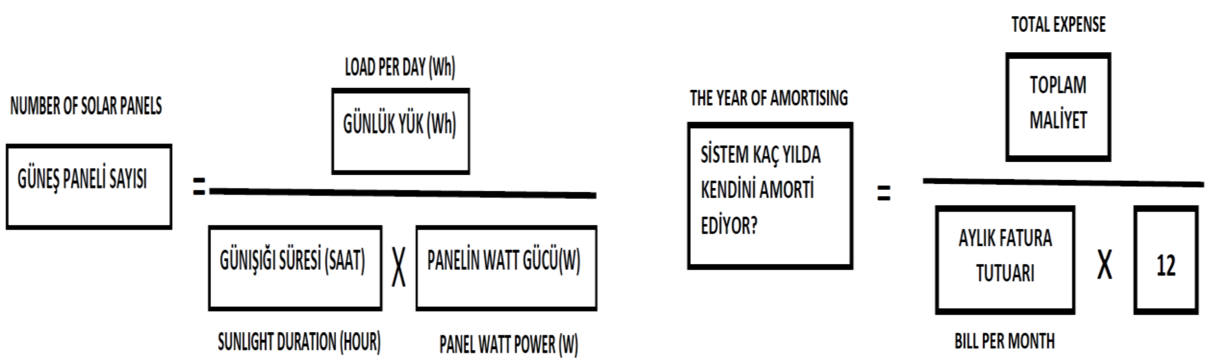
Necessary pieces of equipment for the solar energy systems:

- *Solar panels*
- *Gel batteries*
- *Inverter*
- *Charge controller*
- *Solar cable*
- *Connectors*

Then, the groups assigned variables for solar panels, and gel battery systems. They developed a mathematical model with the variables. While creating a mathematical model, three of the five groups benefited from the equations, and two used the excel tool. The equation belonging to G5 is given in Figure 6.

Figure 6

A Section of The Mathematical Models of The G5 Coded Group



From their models, the values of provinces with different sun exposure duration and families with different electricity bills were used for the solution. Finally, the mathematical results were interpreted and confirmed. During testing, the validity of different features of solar energy systems was considered. Sample excerpts are as follows:

> *G5: "The solar systems begin to make a profit in 10 years. In their remaining lifetime, we can profit from them. However, as the bank interest rates are high in our country, the payback period should be higher than the bank interest for the system to be considered profitable. Therefore, it should amortise itself in 6 years maximum. But as electrical energy is dependent on foreign currency, solar energy systems will pay for themselves in such cases, as high foreign exchange increases will rapidly increase electricity prices. So, one who will install the system should use our model and decide on their own."*

Result and Discussion

Four different modeling cycles have been determined in this study, in which the modeling cycles of the PSTs have been investigated. These are the cycles created by the PSTs who progressed to the real model, expressed and interpreted the mathematical result without creating the mathematical model, proceeded to the mathematical model, ended the process, and completed the whole process. It was determined that all the PSTs constructed the real model of the problem by identifying the variables that affect the situation and making assumptions. However, their level of competency differed. Similarly, Anhalt et al. (2018) determined that PTSs were generally able to recognize the needed assumptions and variables in the modeling cycle, but the level of proficiency they displayed varied. The PSTs who progressed to the real model and completed the process without creating a mathematical model took place in the first cycle. These PSTs could not transition from the real world to the world of mathematics. This cycle consists of 7% of the PSTs. Similarly, Blum and Borromeo Ferri (2009) determined that the students, who were unsuccessful in the modeling cycle could not adequately construct the mathematical model and ended the process in the real model. That the students who were unsuccessful in the modeling process could not make a connection between the real world and the world of mathematics and could not switch to the world of mathematics was also determined by Ji (2012). Since PSTs defined the assumptions and variables as more or less restrictive than needed (Anhalt et al., 2018), they might not create a mathematical model.

The first and second cycles it was consisted of the PSTs who have problems creating mathematical models. However, while creating the real model, the PSTs who took place in the second cycle determined the variables affecting the situation and structured them by estimating them from the internet or their previous experiences. They only estimated quantitatively in estimating the variables that affect the situation. Therefore, they obtained a mathematical result and interpreted this result. Similarly, Blum and Leibb (2007) claimed that the students completed the process when they reached any result. Even in the current study, a mathematical model was not created by the PSTs, and the results were not generalized. For instance, they searched the costs for the solar energy system installation from the net and estimated the expense.

Similarly, they calculated the yearly cost by considering an electricity bill of a family from their previous experiences. They compared these two values. However, they ignored that the electricity bill might change from one family to another, or the installation expense may change according to the number and types of panels. Another remarkable result is that most of the PSTs (68%) took place in the second cycle. This outcome could potentially be attributed to an issue encountered during the model's generalization phase. Modelers commonly opt to address the problem using a singular conjecture and subsequently conclude the process while abstaining from modifying their suppositions and anticipations. Such a tendency could potentially obstruct the development of a more comprehensive model. The underlying difficulty can be attributed to the problem-solving approach ingrained in their cognitive behavior over a prolonged period. Similarly, it was determined many studies (Çoksöyler & Bozkurt, 2021; Deniz & Keşan, 2022; Genç & Karataş, 2017; Özer & Bukova-Güzel, 2020; Tekin Dede, 2016) the pre-service teachers had a habit of solving problems without creating a model. Pre-service teachers may take part in the second modeling cycle because they do not understand the problem (Deniz & Keşan, 2022), cannot simplify the situation (Anhalt et al., 2018), or cannot create a mathematical model (Blum & Borromeo Ferri, 2009; Borromeo Ferri, 2010; Frejd and Ärlebäck, 2011). In this sense, it is of great significance to support the PSTs and change these mathematical modeling cycles. They can be encouraged to create a mathematical model, or the results can be generalized by considering different variables. The PSTs who have this cycle are thought to experience a problem that originates from their real-life problem-solving habits.

The third cycle is the category in which the PSTs progressed to the mathematical model-creating phase. Remarkably, they did not carry out the stages of solving the mathematical model, discussing the results and verifying it. It is thought that the PSTs realize the purpose of mathematical modeling as only producing a model. Nevertheless, mathematical modeling necessitates completing the cycle at least once. Perrenet and Zwaneveld (2012) state that mathematical modeling is more than just modeling and that the modeler does not only work in the world of mathematics.

The fourth cycle consists of the PSTs who completed the mathematical modeling process at least once. The groups in this cycle comprising 18% of all the PSTs completed the cycle successfully. Specifically, in the real model stage, the correct estimation of the parameters made it easier for them to create a mathematical model. Notably, technology-supported tools such as excel in the mathematical modeling phase were used. These tools also support modeling skills other than cognitive skills (Vos & Fredj, 2022). How the PSTs who completed the modeling cycle at least once iterated, the modeling cycle can be investigated. Iteration is a significant skill for successful modelers (Perrenet & Zwaneveld, 2012).

It was determined that the PSTs with similar academic backgrounds and modeling experience had different modeling cycles. Blum and Leibb (2007) and Matsuzaki (2011) also detected that the individuals had different modeling cycles. However, to determine why the modeling cycles differed in detail, it can be analyzed in terms of the metacognitive strategies and social norms determined by Vos and Fredj (2022) that affect the modeling cycle.

Suggestions

This study applied to the cognitive dimensions; evaluating different dimensions together may give significant information about the course of modeling cycles. In this study, different modeling cycles that the PSTs may create have been put forth. The teachers must know different modeling cycles earlier to support their students. Specifically, the PSTs, who take place in the first and second, even in the third cycles, should be supported to become successful modelers.

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Geniş Türkçe Özet

Giriş

Matematiksel modelleme günümüzde giderek daha popüler hale gelmekte ve uluslararası okul müfredatlarında yerini almaktadır (Blomhøj & Kjeldsen, 2006; Blum & Borromeo Ferri, 2009; Ministry of National Education [MoNE], 2017). Gerçek hayat problemlerini çözmek için matematiksel yöntemlerin kullanılması matematiksel modelleme süreci olarak açıklanmaktadır (Stender & Kaiser, 2015). Matematiksel modelleme süreci farklı yaklaşımlara göre tasarlanan bir döngü ile temsil edilmektedir (Greefrath & Vorhölter, 2016; Perrenet & Zwaneveld, 2012). Niss ve Blum (2020) modelleme döngülerinin, modelleme sürecini anlamak için yapılandırılmış bir araç olduğunu vurgulamaktadır. Bireylerin modelleme süreçleri, modelleme döngülerinde ifade edilen ideal davranışlar gibi basit değil, oldukça karmaşıktır (Haines & Crouch, 2010). Bu süreçte bireyler, bir aşamadan diğerine atlamakta, birkaç adım geri dönmekte ve ileri geri birçok adımı tekrarlamaktadır (Borromeo Ferri 2010; 2011; Doerr, 2007; Galbraith & Stillman, 2001). Yapılan araştırmalarda bireylerin, modelleme döngüsünde kendilerine özgü bir yol izledikleri ve bu sürecin lineer olmaktan uzak olduğu belirlenmiştir (Ärlebäck, 2009 ; Borromeo Ferri, 2007; Czocher, 2016; Galbraith & Stillman, 2006). Bir modelleme etkinliğinde oluşan farklı modelleme döngülerinin sistematik bir şekilde tespit edilmesi önem arz etmektedir. Özellikle öğretmenlerin öğrencilerin farklı modelleme döngülerini önceden bilmesi, onlara destek olması açısından önemlidir. Ayrıca öğretmenlerin fark ettiği farklı modelleme döngülerini öğrenciler de fark edecek ve kendi öğrenmelerini yönetebileceklerdir.

Amaç

Bu çalışmanın amacı öğretmen adaylarının matematiksel modelleme etkinliklerinde ortaya çıkan modelleme döngülerinin sistematik bir şekilde incelenmesidir.

Yöntem

Bu çalışmada öğretmen adaylarının modelleme etkinlikleri sırasında ortaya çıkan modelleme döngülerinin derinlemesine incelenmesi amaçlanmıştır. Bu amaç doğrultusunda çalışmada nitel araştırma yöntemlerinden durum çalışması deseni kullanılmıştır.

Çalışma grubunu 119 ilköğretim matematik öğretmen adayı oluşturmaktadır. Öğretmen adayları dört yıl boyunca matematik alanına ait derslere (ör: cebir, aritmetik, istatistik) ve matematik eğitimi ile ilgili derslere (problem çözme, materyal geliştirme, öğretim yöntemleri) katılmışlardır. Matematiksel modelleme ile ilk defa bu araştırma kapsamında karşılaştılar. Araştırma sırasında öğretmen adayları kendi isteklerine göre dört ya da beş kişilik gruplar oluşturmuşlardır. Böylece toplamda 28 farklı grup oluşmuştur. Her bir grubun çalışma kâğıdı toplanmış ve Grup 1'den Grup 28'e kadar kodlanmıştır.

Bu çalışmada veri toplama aracı olarak matematiksel modelleme probleminin yer aldığı çalışma kâğıdı kullanılmıştır. Çalışma kağıdında öğretmen adayları ile güneş enerji sistemleri hakkında tartışma konusu oluşturulması amacıyla bir haber paylaşılmıştır. *"Güneş enerji sistemleri günümüzde oldukça önemlidir. Avrupa ülkelerinin Afrika bölgesinde kurmak istediği güneş enerji sistemleri ile ilgili proje hakkında ne düşünüyorsunuz? Sizce neden Afrika bölgesinde güneş enerji sistemi kurulmak isteniyor tartışınız?"* Gruplar tartışmayı tamamladıktan sonra güneş alma süresi, güneş ışınlarının geliş açısı, Afrika'dan ithal edilecek enerji miktarı, maliyet, kurulacak alanın büyüklüğü gibi birçok durumu etkileyen değişkene ulaşmışlardır. Ardından öğretmen adaylarına *"Elektrik fiyatlarının artması ile bir aile, yaşadıkları binanın üzerine güneş enerji sistemi kurmayı planlıyor. Bunun karlı olup olmadığına karar vermeniz için bir model geliştiriniz ve sonuçlarınızı paylaşınız"* şeklinde bir modelleme problemi verilmiştir. Veri toplama süreci toplam iki gün sürmüştür. Birinci gün 28 grup 4 farklı sınıfa ayrılmış ve farklı zamanlarda modelleme problemi bu dört gruba uygulanmıştır. Öğretmen adaylarının çözüm süreçlerinin etkilenmemesi için grupların birbirleri ile iletişimi engellenmiştir. Tüm çözüm sürecinde araştırmacı eğitmen rolünde olup, gruplara rehberlik etmiştir. İkinci gün yine 28 grup 4 sınıfa ayrılmış ve sunum yapmaları için fırsat verilmiştir.

Çalışmada 28 grubun çalışma kâğıdı veri kaynağı olarak kullanılmıştır. Bu çalışma kağıtları Blum ve Leibb (2007) tarafından geliştirilen modelleme döngüsü boyunca incelenmiştir. Matematiksel modelleme döngüsü teorik çerçevesi temel alınarak, araştırmanın veri analizinde Mayring (2015) tarafından tanımlanan nitel içerik analizi yöntemlerinden tümevarım analizi kullanılmıştır. Her bir grubun hangi tür döngüye sahip oldukları belirlenmiştir.

Sonuç ve Tartışma

Öğretmen adaylarının modelleme döngülerinin incelendiği bu çalışmada dört farklı modelleme döngüsü tespit edilmiştir. Bunlar; gerçek modele kadar ilerleyen, matematiksel modeli oluşturmadan matematiksel sonucunu ifade edip bu sonucunu yorumlayan, matematiksel modele kadar ilerleyip süreci sonlandıran ve tüm süreci tamamlayan öğretmen adaylarının oluşturduğu döngülerdir. Öğretmen adaylarının %7'si modelleme döngüsünde gerçek sonuçlara (döngü 1) ve %7'si matematiksel modele kadar (döngü 3) ilerleyebilmiştir. Matematiksel model oluşturmadan doğrudan matematiksel sonuçlarını ifade ederek süreci tamamlayanlar (döngü 2) öğretmen adaylarının %68'ini oluşturmaktadır. Son olarak öğretmen adaylarının %18'i döngü 4'e sahip olup, modelleme döngüsünü başarılı bir şekilde tamamlamışlardır. Öğretmen adaylarının büyük çoğunluğunun (%68) ikinci döngüde yer alması ise kayda değer bir sonuçtur. Bireylerin matematiksel model oluşturma aşamasında problem yaşamaları Blum ve Borromeo Ferri (2009), Blum ve Leibb (2007), Borromeo Ferri (2010), Frejd ve Ärlebäck (2011) tarafından da belirlenmiştir. Bu anlamda öğretmen adaylarına destek verilmesi ve bu matematiksel modelleme döngülerinin değiştirilmesi önem arz etmektedir. Matematiksel model oluşturmaya teşvik edilebilir ya da farklı değişkenler dikkate alınarak sonuçların genelleştirilmesi sağlanabilir. Bu döngüye sahip olan öğretmen adaylarının gerçek hayat problemi çözme alışkanlıklarından kaynaklı bir sorun yaşadıkları düşünülmektedir.

Benzer akademik geçmişe ve modelleme deneyimine sahip olan öğretmen adaylarının farklı modelleme döngülerine sahip olduğu tespit edilmiştir. Bireylerin farklı modelleme döngülerine sahip olması, Blum ve Borromeo Ferri (2009), Blum ve Leiß (2007) ve Matsuzaki (2011) tarafından da belirlenmiştir. Fakat modelleme döngülerinin neden farklılaştığını daha ayrıntılı tespit etmek için Vos ve Fredj (2022) tarafından belirlenen ve modelleme döngüsünü etkileyen metabilişsel stratejiler ve sosyal normlar açısından incelenebilir. Bu çalışma bilişsel boyutta incelenmiş olup farklı boyutlarla birlikte değerlendirilmesi modelleme döngülerinin seyri konusunda önemli bilgiler verebilir. Bu çalışmada öğretmen adaylarının oluşturabileceği farklı modelleme döngüleri ortaya konmuştur. Öğretmenlerin öğrencilerin farklı modelleme döngülerini önceden bilmesi, onlara destek olması açısından önemlidir. Özellikle bu çalışmanın bir sonucu olarak birinci ve ikinci hatta üçüncü döngüde yer alan öğretmen adaylarının başarılı birer modelleyici olmaları için desteklenmesi gerekmektedir.