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# Cognitive Mathematical Modeling Competencies of Primary School Teachers Candidates[1]

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**Abstract.** This research aims to reveal the development of cognitive modeling competencies of primary school teachers candidates throughout their mathematical modeling education. The research was designed as a case study. The research was carried out with the participation of 12 primary school teachers candidates. Research data were collected online through Microsoft Teams due to the ongoing COVID-19 outbreak conditions. 11 mathematical modeling activities selected from the literature were used. Research data consisted of the answers provided by the primary school teachers candidates within the scope of mathematical modeling activities. Data collection tools used were the modeling problems extracted from the literature along with the rubric. Research findings revealed that pre-service teachers got the highest and the lowest scores in the lower stages of rubric from understanding the problem and the validating dimensions respectively. The second dimension in which the pre-service teachers were more frequently successful was the interpreting dimension. Their success in the simplifying, mathematizing and working mathematically dimensions were observed as rather moderate. The most successful problem of all groups is the Whitewash Problem. Except for one group, the most unsuccessful problem of all groups was the Tooth Brushing Problem.

***Keywords:*** Pre-service primary school teacher, Mathematical modeling activities, Problem solving.

[1]This study was created from a part of the master's thesis titled "The Effect of Mathematical Modeling Training on the Problem Solving Skills of Pre-service Teachers and their Attitudes towards Mathematics (Manisa Celal Bayar University Example)" conducted by the first author under the supervision of the second author.

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## Introduction

Mathematics education not only provides individuals various skills necessary to maintain their lives but also aims to add them skills that may be updated in accordance with the requirements of the age. Although the researchers define the skills of 21st century in different ways, the common point of all definitions is the problem solving ability (Aydın, & Derin, 2020). Polya (1997) defined problem solving as finding a way to get rid of the difficulties, as well as reaching the result. Problem solving, according to Cooper (1986), is trying to find a solution to an unknown question or problem in any situation. Schoenfeld (1989) defined problem solving as having the knowledge of how to act without knowing the exact way to reach a solution. Yeşilova (2013), on the other hand, expressed problem solving as an effort to use previously acquired individual knowledge and skills and to figure out what is expected in an unknown situation. Problem solving is a fundamental skill associated with all learning domains; it is also a meaningful learning process that expands and deepens mathematical knowledge as well as consolidating it (MoNE, 2015). A great emphasis is put on mathematical modeling in the UK and it is incorporated as a part of problem solving in the mathematics curriculum (Berry, 2002).

Mathematical modeling activities act as an important bridge that provides a transfer between school and daily life by expressing the mathematics topics taught in the classroom with situations from daily life (Doruk, 2010). Mathematical modeling activities teach students how to use mathematical knowledge in the real world (Sriraman, 2005). Incorporating mathematical modeling in mathematics education makes it easier for students to learn mathematics and associate it with daily life (Asempapa, & Sturgill, 2019; Biembengut, & Hein, 2013). Furthermore, the inadequacy of problem solving activities and traditional methods in enabling students to transfer their mathematical knowledge to daily life and to improve their problem solving skills and mathematical thinking led educators interested in mathematics to work on mathematical modeling (Mousoulides, Christou, & Sriraman, 2006).

Mathematical modeling supports the learning of mathematics, helps the development of various mathematical abilities and provides a more meaningful learning of mathematics. Bukova Güzel and Uğurel (2010) defined mathematical modeling as a method that represents transferring the existing or fictionalized problematic situations in areas other than the world of mathematics (physics, biology, sociology, politics, art, entertainment etc.) in the language of mathematics and trying to find the solution using mathematical knowledge and approaches. Niss (1999) expressed mathematical modeling as the combination of one or more mathematical formations designated to represent the expectations of real-life situations and the relationship between these formations. English and Sriraman (2010) argued that students learn mathematics while working with models. It has been emphasized that mathematical modeling activities incorporated in mathematics lessons will improve students' modeling skills (Blum, 2011) and that long-term applications should be planned in order to achieve this development (Biccard, & Wessels, 2011).

The incorporation of mathematical modeling in mathematics curriculum will lead to the formation of a new learning environment and will soon introduce a new approach to the aims of mathematics teaching (D'Ambroiso, 2009). Mathematical modeling that covers the key competencies of mother tongue communication, learning to learn, foreign language communication, digital competencies, competencies in mathematics, science and technology, social sciences and humanity, entrepreneurship, cultural awareness and expression along with 21st century skills and that helps students to better understand mathematics and the real world, learn mathematical concepts and relate mathematics to other branches of science has already been incorporated in mathematics curricula with its features such as being open-ended, not having a definite and single result and suggesting different solutions (MoNE, 2018). Incorporating mathematical modeling in curricula is considered as essential for the future of our country. The current educational philosophy and approaches should be preserved and mathematical modeling activities should further be applied effectively in the lessons in order to help Turkey to catch up with the educational power that will guide today's needs as soon as possible (Bukova Güzel, 2021).

Developing students' modeling competencies is one of the main goals of mathematics teaching (Blum, 2011). For this reason, the concept of "modeling competencies" has begun to be discussed in modeling studies (Tekin Dede, 2017). Researchers have defined modeling competencies based on the steps of the modeling process (Maaß, 2006). Maaß (2006) stated that mathematical modeling competencies include the ability and skills to go through the modeling process for the purpose and individuals should be willing in this process. In addition, Kaiser and Maaß (2007) defined mathematical modeling competencies as the ability to pattern problems covering real-life situations. The definitions provided with regard to modeling competencies have indicated that the modeling process is represented in all definitions (Tekin Dede, 2017). Although modeling competencies are in compliance with the steps of the modeling process, steps alone are not sufficient to describe modeling competencies (Maaß, 2006). As cognitive skills should be developed in order to take a step in the modeling process steps (Borromeo Ferri, 2010), cognitive modeling competencies may be mentioned in parallel with the modeling steps (Bukova Güzel, 2021). Borromeo Ferri (2006) listed cognitive modeling competencies as follows.

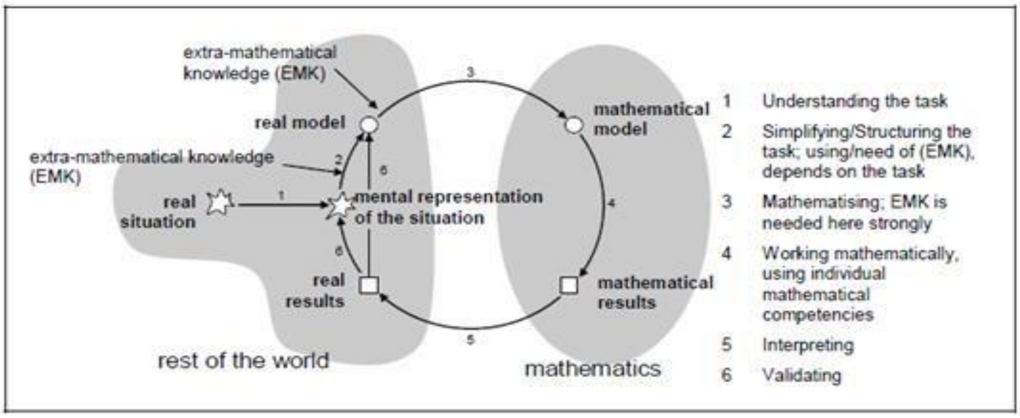



Figure 1. Modeling cycle under a cognitive perspective *note.* (Borromeo Ferri, 2006).

Understanding the problem step of the cognitive modeling cycle requires individuals to define and interpret the problem adapted from real life. Simplifying step requires individuals to examine the correlations between the data in the problem, to identify the variables and the assumptions for the solution of the problem. Mathematising step requires the formulation of the real-life situation. Working mathematically refers to figuring out the problem through developed mathematical model/s. Interpreting refers to interpreting model applications and mathematical results and associating them with real life situations. Validating requires the confirmation of the validity of the model and reproduction of the model when deemed necessary (Hıdıroğlu, & Bukova Güzel, 2013; Saka, & Çelik, 2018; Aktaş, 2019).

It is crucial to confront children with real-life complex situations from an early age and to create environments where children will have the opportunity to produce original solutions for the problematic situations they encounter. Using the mathematical modeling activities beginning with primary school will be beneficial in transferring the basic skills aimed at providing the above-mentioned effective environment within the curriculum (English, 2006). Mathematical modeling activities provide an effective and productive environment for students to learn mathematics in primary school (English, 2006). Therefore, it is essential for primary school teachers and primary school teachers candidates, who will introduce students to mathematics at an early age, to have knowledge about mathematical modeling activities. Primary school teachers, as the persons who will mediate the acquisition of the competencies and skills that the curriculum aims to provide, are expected to assume significant roles in this regard. Consequently, this research is considered to be specific as it investigates the cognitive mathematical modeling competencies of primary school teachers candidates. There are prior studies in the literature examining the topic specific to pre-service secondary school mathematics teachers (Aydoğan Yenmez, & Özpınar, 2017; Deniz, & Akgün, 2018; Duran, Doruk, & Kaplan, 2016; Eraslan, 2011, 2012; Erdoğan, 2019; Saka, & Çelik, 2018; Şahin, & Eraslan, 2019; Tekin Dede, & Yılmaz, 2015; Tuna, Biber, & Yurt, 2013; Ural, 2014; Ural, & Ülper, 2013) and pre-service high school mathematics teachers (Bukova Güzel, & Uğurel, 2010; Dede, Akçakın, & Kaya, 2018; Delice, & Taşova, 2011; Hıdıroğlu, & Bukova Güzel, 2015; Özaltun, Hıdıroğlu, Kula, & Bukova Güzel, 2013; Taşova, & Delice, 2012; Yanık, Bağdat, & Koparan, 2017). This research is thought to provide contributions to the literature as it examines the mathematical modeling learning process of primary school teachers candidates who further teach mathematical modeling for the first time, their progress in this process and the solution of mathematical modeling problems. The aim of this research is to reveal the cognitive modeling competencies of primary school teacher candidates. To search for an answer to the question "What is the current level of mathematical modeling competencies of primary school teachers candidates?" constitutes the primary purpose of the study.

## Method

This study, which tried to reveal the cognitive modeling competencies of primary school teacher candidates, was designed as a case study. Case study is an approach used to seek answers to scientific questions (Büyüköztürk, 2019). McMillan (2000) defines case study as a method that examines one or more events or interconnected systems whereas Creswell (2012) defines it as a research design used in many areas, in particular assessment processes, in which the researcher deeply examines a situation, event, process or one or more individuals.

### Participants

12 primary school teachers candidates studying at the faculty of education of a state university as of the 2020-2021 academic year constituted the participants of the research. Primary school teachers candidates participated in the study on a voluntary basis. Primary school teachers candidates were classified into four groups consisting of three people each. In order to ensure the homogeneity, the groups were formed by the researchers taking into account the letter grades entitled to each pre-service primary school teacher in the "Fundamentals of Primary School Mathematics" course. The reason why the grades taken from this course are taken as a criterion is that the subject of mathematical modeling is taught within the scope of this course.

The group information of the primary school teachers candidates participating in the research is exhibited in Table 1.

Table 1.
Group information of the primary school teachers candidates

| Groups | Primary school teachers candidates | Fundamentals of Primary School Mathematics Scores | Fundamentals of Primary School Mathematics Letter Grades |
|---|---|---|---|
| | PSTC 1 | 76 | BB |
| 1st Group | PSTC 2 | 79 | BA |
| | PSTC 3 | 56 | CC |
| | PSTC 4 | 98 | AA |
| 2nd Group | PSTC 5 | 72 | BB |
| | PSTC 6 | 62 | CB |
| | PSTC 7 | 88 | AA |
| 3rd Group | PSTC 8 | 69 | BB |
| | PSTC 9 | 54 | CC |
| | PSTC 10 | 89 | AA |
| 4th Group | PSTC 11 | 52 | DC |
| | PSTC 12 | 83 | BA |

The distribution of the primary school teachers candidates on the basis of their gender is exhibited in Table 2.

Table 2.
Distribution of the primary school teachers candidates on the basis of their gender

| Gender | *f* | % |
|---|---|---|
| Female | 10 | 83.33 |
| Male | 2 | 16.67 |
| Total | 12 | 100.00 |

Table 2 data reveals that 10 (83.33%) of the 12 primary school teachers candidates participating in the research are female and 2 (16.67%) are male.

The distribution of the primary school teachers candidates on the basis of their high schools is exhibited in Table 3.

Table 3.
Distribution of the primary school teachers candidates on the basis of their high schools

| Type of High School Graduated | *f* | % |
|---|---|---|
| Anatolian High School | 8 | 66.67 |
| Vocational High School of Health Services | 2 | 16.67 |
| High School | 1 | 8.33 |
| Social Sciences High School | 1 | 8.33 |
| Total | 12 | 100.00 |

Table 3 data reveals that 8 (66.67%) of the 12 primary school teachers candidates participating in the research graduated from Anatolian High Schools, 2 (16.67%) graduated from

Vocational High School of Health Services, 1 (8.33%) graduated from High School and 1 (8.33%) graduated from Social Sciences High School.

The distribution of the primary school teachers candidates on the basis of their "Fundamentals of Primary School Mathematics" course Scores, Letter Grades and Grade Point Averages (GPA) is exhibited in Table 4.

Table 4.
Distribution of the primary school teachers candidates on the basis of their "fundamentals of primary school mathematics" course scores, letter grades and grade point averages (GPA)

| Primary school teachers candidates | Fundamentals of Primary School Mathematics Scores | Fundamentals of Primary School Mathematics Letter Grades | GPA |
|---|---|---|---|
| PSTC 1 | 76 | BB | 2.88 |
| PSTC 2 | 79 | BA | 3.40 |
| PSTC 3 | 56 | CC | 3.51 |
| PSTC 4 | 98 | AA | 3.67 |
| PSTC 5 | 72 | BB | 3.42 |
| PSTC 6 | 62 | CB | 3.18 |
| PSTC 7 | 88 | AA | 3.58 |
| PSTC 8 | 69 | BB | 3.55 |
| PSTC 9 | 54 | CC | 3.41 |
| PSTC 10 | 89 | AA | 3.09 |
| PSTC 11 | 52 | DC | 3.75 |
| PSTC 12 | 83 | BA | 3.28 |

Table 4 data reveals that 3 (25%) of the 12 primary school teachers candidates participating in the research scored AA, 2 (16.67%) scored BA, 3 (25%) scored BB, 1 (8.33%) scored CB, 2 (16.67%) scored CC and 1 (8.33%) scored DC. The grade point average (GPA) figures of the primary school teachers candidates with regard to the 1st, 2nd and 3rd semesters revealed that the GPA of 1 (8.33%) of the 12 primary school teachers candidates is between 2.50-3.00, the GPA of 6 (50%) 00) is between 3.01-3.50 and the GPA of 5 (41.67%) is between 3.51-4.00.

**Data Collection Tools**

Model-Eliciting Activities (MEAs) were extracted from the literature and used in the research line with the opinions of experts. Model-Eliciting Activities (MEAs) used throughout the implementation phase were selected from within the problems found in the literature. Model-Eliciting Activities (MEAs) were determined in accordance with the primary school teachers candidates and applied in order from easy to difficult. Model-Eliciting Activities (MEAs) applied on a weekly basis are exhibited in Table 5.

Table 5.
Sequence of the model-eliciting activities (MEAs) applied

| Sequence of Application | Model-Eliciting Activities (MEAs) |
|---|---|
| 1st Week<br>Warm-up Exercises | Big Foot Problem (Tekin Dede, & Bukova Güzel, 2011)<br>Apple Pie Problem (adapted from Schukajlow, Leiss, Pekrun, Blum, Müller, & Messner, 2012 by Tekin Dede, 2015) |
| 2nd Week | Tooth Brushing Problem (Maaß, & Mischo, 2013),<br>Uncle Tailor Hikmet Problem (Kal, 2013),<br>Team Ranking Problem (Carmona, & Greenstein, 2010) |
| 3rd Week | Apartment Problem (Maaß, & Mischo, 2011; adapted by Tekin Dede, 2015),<br>Most Convenient Way to the Eiffel Tower (Kal, 2013)<br>The Whitewash Problem (Tekin Dede, 2018) |
| 4th Week | The Highway Problem (Jahnke, 1997; Maaß, 2006)<br>The Annual Paper Airplane Contest Problem (English, & Watters, 2005)<br>Weather Report Problem (Adapted from Doerr, & English, 2003 by İnan Tutkun, & Didiş Kabar, 2018) |

The Big Foot Problem and the Apple Pie Problem were solved together with the primary school teachers candidates as a warm-up activity within the scope of mathematical modeling applications. Thereafter, the problems stated in the table were solved as a group activity, with three problems each week.

## Procedure

Research data were collected online through Microsoft Teams due to the ongoing COVID-19 outbreak conditions. Primary school teachers candidates were provided mathematical modeling training in four weeks of the six-week training with the purpose to allow them to learn more about mathematical modeling activities. The first week of the mathematical modeling training was allocated to learning Models and Modeling, Model-Eliciting Activities (MEAs) and the significance of modeling at primary school. Thereafter, the groups were asked to go to the Discussion Rooms created in Microsoft Teams and to solve the “Big Foot Problem” and “Apple Pie Problem” as part of the warm-up exercises. The primary school teachers candidates solved the mathematical modeling problems in a group activity. They were allowed to use all kinds of materials in the problem solving process. After all the groups completed their problem solving session, they came together at the main meeting and discussed their solutions. The first author provided an opportunity for the participants to prove their solutions by creating a discussion environment.

In the second week of the training, the participants were explained the role of the teacher in mathematical modeling activities. The pre-service primary teachers solved the “Tooth Brushing Problem”, “Uncle Tailor Hikmet Problem” and “Team Ranking Problem” within the scope of a group activity. After the groups solved the modeling problems, they came together in the main meeting and shared their ideas about the problem situation.

In the third week of the training, the participants were explained the significance of the group work in mathematical modeling activities and how many people the groups can consist of.

Thereafter, the groups met in the Discussion Rooms and solved the “Apartment Problem”, “Most Convenient Way to the Eiffel Tower Problem” and the “Whitewash Problem”. In the “Whitewash Problem”, unlike the other problems, primary school teachers candidates were asked to prepare a poster. Pre-service teachers were left free in the material and program they would use in solving this problem as in solving other problems. Pre-service teachers were given one week to prepare their posters. The groups which completed their problem solving session came together at the main meeting and explained their answers to other group mates.

In the fourth week of the training, the participants were explained the difficulties that can be encountered in mathematical modeling activities. Thereafter, the groups met in the Discussion Rooms and solved the “Weather Report Problem”, “The Annual Paper Airplane Contest Problem” and the “Highway Problem”. After the groups completed their problem solving session, they attended the main meeting and discussed their ideas and the solutions about their problem situations with their friends in the other groups. Twelve primary school teachers candidates who participated in the research precisely completed their work in the data collection process.

**Data Analysis**

The answers given by the primary school teachers candidates to the problems solved within the scope of mathematical modeling were analyzed using the Rubric for Assessment of the Modeling Skills [RAMS] developed by Tekin Dede and Bukova Güzel (2014). RAMS has 6 sub-dimensions: understanding the problem, simplifying, mathematizing, working mathematically, interpreting and validating. Understanding the problem sub-dimension further has 5 levels, simplifying sub-dimension has 4 levels, the mathematizing sub-dimension has 4 levels, the working mathematically sub-dimension has 5 levels, the interpreting sub-dimension has 5 levels and the validating sub-dimension has 7 levels. Scoring in RAMS is performed by giving 0 points to Level 1 and 1, 2, 3, 4, 5 and 6 points to other levels, respectively. In the light of this information, the highest and the lowest scores that can be obtained from RAMS will be 25 and 0 respectively. The levels of competency derived in line with the scores obtained from RAMS analyzes are exhibited in Table 6.

Table 6.
Levels of mathematical modeling competencies

| Score from the Mathematical Modeling Problem | Levels of Mathematical Modeling Competencies |
|---|---|
| 0 – 6 points | Not competent in Mathematical Modeling |
| 7 – 12 points | Somewhat competent in Mathematical Modeling |
| 13 – 21 points | Acceptably competent in Mathematical Modeling |
| 22 – 25 points | Highly competent in Mathematical Modeling |

Throughout the assessments with regard to RAMS, the solutions of the groups to mathematical modeling exercises were examined. The existence and the degree of existence of each sub-dimension were then determined during the examinations. Total scores of the groups were calculated upon determining the degrees for all sub-dimensions. In order to confirm the reliability of the data analysis, the assessments of the researchers and another expert in the field were compared. The ratio of the number of congruent assessments to the total number of assessments [reliability = number of agreements/number of agreements + disagreements] was calculated pursuant to Miles and Huberman's (1994) Inter-Rater Reliability (IRR). IRR was calculated as 72%. The reliability of the data analysis was confirmed as the inter-rate reliability coefficient was over 70%.

The analysis of the answers given by the groups at each mathematical modeling proficiency level is given in detail below. The tooth brushing problem of the first group is as follows (Figure 2).

**DİŞ FIRÇALAMA PROBLEMİ**

Dişlerini fırçalarken suyu açık bırakmaları durumunda, dört kişilik bir ailenin yıllık 26.000 litre su harcadığı bilinmektedir (Almanya Gazetesi, 2008). Gazete yazısı her ailenin dişlerini fırçalarken çeşmeyi kapatmaları halinde her yıl 26.000 litre su tasarrufu yapabileceğini söylemektedir. Bu durum hakkında ne düşünüyorsunuz? Gerçekten mümkün müdür? Gerekçelerinizi belirtiniz. (Maaß ve Mischo, 2013)

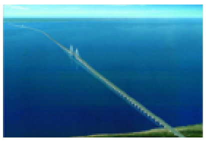
Cevap:

- Harcanan su miktarını fazla bulduk. Kullanılan su miktarının böyle devam etmesi durumunda çeşitli sorunlar ortaya çıkarabilir.
- Evdeki bireylerin su kullanımına dikkat etmesi yaş çeşitliliği, kadın-erkek dağılımı ve bireylerin dikkat oranları gibi değişkenlerden etkilenebilir.
- Musluk başlıkları tasarrufa uygun bir şekilde değiştirilirse ve sensörlü musluk kullanımı artarsa su tasarrufu sağlanabilir.

Figure 2. Group 1's answer to the tooth brushing problem.

When the answers given by the 1st Group to the Tooth Brushing Problem were examined according to MYDR, it was seen that the problem was understood to some extent, a relationship could be established between what was given and what was requested, and they received 1 point from the understanding the problem competence . It was observed that they had problems in identifying necessary-unnecessary variables and they got 0 points from the simplifying competence. It was seen that they could not create a mathematical model and they got 0 points from the mathematizing competence. They did not provide a mathematical solution and received 0 points from the working mathematically competence. Since the solution created for the problem was misinterpreted in the context of real life, they received 1 point from the interpreting competence. It was observed that they got 0 points from the validating competence because they did not take the validation approach. When the scores obtained were examined, it was observed that the 1st Group got a total of 2 points from the Tooth Brushing Problem and did not have modeling competence. The highway problem of the third group is as follows (Figure 3).

**OTOYOL PROBLEMİ**



Dünyanın en büyük köprüsü Çin'in doğusunda, Hangzhou Körfezi üzerinde inşa edilen köprüdür ve 36 kilometre uzunluğundadır. Bu köprü boyunca trafiğin tıkandığını düşünürseniz, sizce köprü boyunca trafikte kaç araç vardır? Çözümünüzü gerçekleştirirken düşüncelerinizi ayrıntılarıyla yazınız. (Jahnke, 1997; Maaß, 2006)

1. Problemi çözmek için hangi bilgilere ihtiyacınız vardır?
- Araçların uzunluğu
- Ardışık araçlar arasındaki ortalama mesafe
2. Problemi çözmek için gereken işlemleri yazınız ve problemi çözünüz.
- Araçların uzunlukları toplanır.
- Araçlar arasındaki ortalama mesafe toplanır.
- Araçların uzunlukları ve ortalama mesafe toplanılır.
- Bulunan toplam sonuç köprü uzunluğuna bölünür.
3. Bulduğunuz sonuç mantıklı mı? Yanıtınız evet ise nedenini açıklayınız. Yanıtınız hayır ise sonucunuzu mantıklı bir hale getiriniz.
- Gereken veriler sağlandığında işlemler verdiğimiz sırayla yapılırsa çözüme ulaşılır ve sonuç mantıklı olur.
4. Yaptıklarınızı kontrol ediniz. Sizce yaptığınız çözüm doğru mu? Evet ise nedenini açıklayınız. Hayır ise çözümünüzü düzeltiniz.
- Yaptıklarımız bizim için doğrudur. Çünkü mantık çerçevesinde düşündük.

Figure 3. Group 3'rd answer to the highway problem.

When the answers given by the 3rd group to the Highway Problem were examined according to MYDR, it was seen that they were successful in determining what was given and what was requested and in establishing a relationship between them, and they got 4 points from understanding the problem competence. It was observed that they were able to simplify the problem, determine necessary-unnecessary variables, and make realistic assumptions, and they got 3 points from the simplifying competence. They could not create a mathematical model and got 0 points from the mathematizing competence. It was seen that they did not offer a mathematical solution and they got 0 points from the working mathematically competence. Since the solution created for the problem was misinterpreted in the context of real life, they received 1 point from the interpretating competence. It was observed that they got 0 points from the validating competence because they did not take the validation approach. When the scores obtained were examined, it was observed that the 3rd Group got a total of 8 points from the Highway Problem and had somewhat competent in mathematically modeling. The team ranking problem of the second group is as follows (Figure 4).

**TAKIM SIRALAMA PROBLEMİ**

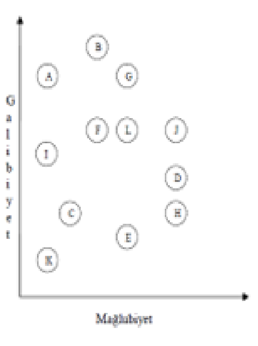
Yandaki şekilde her bir daire 12 takımdan oluşan bir futbol ligindeki her bir takımın galibiyet-mağlubiyet grafiğini göstermektedir.

**Hazırlık Soruları:**

- Hangi takım veya takımlar en çok kazandı? Nasıl anladınız?
- Hangi takım veya takımlar en çok kaybetti? Nasıl anladınız?
- Tüm takımlar aynı sayıda maç yaptı mı? Nasıl anladınız?

**Problem:**

Şimdi sizden istenen 12 takım arasından kimin birinci, kimin ikinci, kimin üçüncü, kimin dördüncü ve kimin beşinci olacağına dair bir metot geliştirip, bunu neye göre ve nasıl oluşturduğunu açıklamak (Carmona ve Greenstein, 2010).




**Çözüm:**

- İlk olarak grafikte verilen takımların bulundukları yerler orantısında belirlediğimiz sayıları grafiğin alt kısmında sağa doğru arttırarak ve sol kısmında ise yukarı doğru arttırarak yazdık. Örneğin K takımının grafikte verildiği yere galibiyet kısmına 1 yazarken mağlubiyet kısmına da 1 yazdık. Daha sonra diğer takımların bulundukları yerlere ve boşluk olan yerlere göre de sayılarımızı yerleştirdik.
- Bu işlemleri yaptıktan sonra B takımının galibiyet ve mağlubiyet sayısının toplamı olarak en fazla maça çıktığı kanaatine vardık. Soruda bahsedilen bir lig olduğu için ve her hafta her takımın maç yapma zorunluluğu olduğu için diğer takımların grafikte yansımayan maç eksikliklerini berabere kaldığını varsayarak ele aldık.
- Berabere kaldığı maç sayılarını da belirledikten sonra takımların her galibiyetine 3 puan, mağlubiyetine 0 puan, beraberliğini de 1 puan verdik.
- Bunun sonucunda takımların puan durumu

| Takımlar | Galibiyet | Mağlubiyet | Beraberlik | Puan |
|---|---|---|---|---|
| A Takımı | 8 | 1 | 3 | 27 |
| B Takımı | 9 | 3 | - | 27 |
| C Takımı | 3 | 2 | 7 | 16 |
| D Takımı | 4 | 6 | 2 | 14 |
| E Takımı | 2 | 4 | 6 | 12 |
| F Takımı | 6 | 3 | 3 | 21 |

Figure 4. Group 2'nd answer to the team ranking problem.

When the answers of the 2nd group to the Team Ranking Problem were examined according to MYDR, it was seen that they understood the problem completely, they were able to establish a suitable relationship between them by determining what was given and what was requested, and they got 4 points from the understanding the problem competence. It was observed that they were able to simplify the problem, identify necessary-unnecessary variables, and make realistic assumptions, and they received 3 points from the simplifyinf competence. It was observed that they created correct mathematical models in accordance with the assumptions they created and they were able to explain the mathematical models they created by associating them with each other, and they got 4 points from the mathematizing competence. It was seen that they reached the correct mathematical solution by using the mathematical models they created, and they got 4 points from the working mathematically competence. Since the correct mathematical solution obtained was correctly interpreted in the context of real life, they received 4 points from the interpretating competence. It was observed that they got 0 points from the validating competence because they did not take the validation approach. When the scores obtained were examined, it was observed that the 2nd Group got a total of 19 points from the Team Ranking Problem and had an acceptably competent in mathematical modeling When the answers of all groups were examined, it was observed that there was no group with highly competent in mathematical modeling.

**Ethical Procedures**

Prior to initiating the research, the ethics committee approval was obtained from the Social Sciences and Humanities Scientific Research and Publication Ethics Committee of Manisa Celal Bayar University (based on the Meeting Resolution No: 2020/10 dated 29/09/2020).

## Results

In this section, the solutions of the primary school teachers candidates to the problems posed within the scope of mathematical modeling will be interpreted by prioritizing group success. The general table demonstrating total scores of all groups from the sub-dimensions of RAMS was interpreted in accordance with the mathematical modeling competency levels given in Table 6.

The scores entitled to 1st Group based on the mathematical modeling problems are exhibited in Table 7.

Table 7.
Scores entitled to 1st group based on the mathematical modeling problems

| 1st GROUP | Understanding the problem | Simplifying | Mathematizing | Working Mathematically | Interpreting | Validating | Total | Levels of Mathematical Modeling Competencies |
|---|---|---|---|---|---|---|---|---|
| Tooth Brushing | 1 | 0 | 0 | 0 | 1 | 0 | 2 | Not competent in Mathematical Modeling |
| Uncle Tailor Hikmet | 2 | 1 | 0 | 0 | 0 | 0 | 3 | |
| Team Ranking | 2 | 1 | 0 | 0 | 0 | 0 | 3 | |
| Apartment | 2 | 1 | 0 | 0 | 1 | 0 | 4 | |
| Eiffel Tower | 1 | 0 | 0 | 0 | 2 | 0 | 3 | |
| Whitewash | 4 | 3 | 3 | 3 | 3 | 0 | 16 | Acceptably competent in Mathematical Modeling |
| Highway | 4 | 3 | 2 | 3 | 3 | 0 | 15 | |
| Paper Airplane | 4 | 3 | 2 | 3 | 4 | 0 | 16 | |
| Weather Report | 2 | 1 | 0 | 0 | 0 | 0 | 3 | Not competent in Mathematical Modeling |
| Total | 30 | 18 | 7 | 9 | 20 | 0 | 84 | |

Table 7 reveals that the problems in which the 1st group was most successful were the Whitewash Problem and the Paper Airplane Problem. The problem in which the group was not successful at the expected level was the Tooth Brushing Problem. The scores obtained from the sub-dimensions of RAMS revealed that the group got the highest score from understanding the problem sub-dimension and the lowest score from the validating sub-dimension.

The scores entitled to 2nd Group based on the mathematical modeling problems are exhibited in Table 8.

Table 8.
Scores entitled to 2nd group based on the mathematical modeling problems

| 2nd GROUP | Understanding the problem | Simplifying | Mathematizing | Working Mathematically | Interpreting | Validating | Total | Levels of Mathematical Modeling Competencies |
|---|---|---|---|---|---|---|---|---|
| Tooth Brushing | 2 | 1 | 0 | 0 | 3 | 0 | 6 | Not competent in Mathematical Modeling |
| Uncle Tailor Hikmet | 4 | 3 | 4 | 4 | 4 | 0 | 19 | Acceptably competent in Mathematical Modeling |
| Team Ranking | 4 | 3 | 4 | 4 | 4 | 0 | 19 | |
| Apartment | 4 | 2 | 2 | 2 | 3 | 0 | 13 | |
| Eiffel Tower | 4 | 3 | 4 | 4 | 4 | 0 | 19 | |
| Whitewash | 4 | 3 | 4 | 4 | 4 | 0 | 19 | |
| Highway | 4 | 3 | 4 | 4 | 4 | 0 | 19 | |
| Paper Airplane | 4 | 3 | 1 | 1 | 2 | 0 | 11 | Somewhat competent in Mathematical Modeling |
| Weather Report | 4 | 2 | 0 | 0 | 1 | 0 | 7 | |
| Total | 42 | 29 | 23 | 23 | 37 | 0 | 154 | |

Table 8 reveals that the problems in which the 2nd group was most successful were the Uncle Tailor Hikmet Problem, Team Ranking Problem, Eiffel Tower Problem, Whitewash Problem and the Highway Problem. The problem in which the group was not successful at the expected level was the Tooth Brushing Problem. The scores obtained from the sub-dimensions of RAMS revealed that the group got the highest score from understanding the problem sub-dimension and the lowest score from the validating sub-dimension.

The scores entitled to 3rd Group based on the mathematical modeling problems are exhibited in Table 9.

Table 9.
Scores entitled to 3rd group based on the mathematical modeling problems

| 3rd GROUP | Understanding the problem | Simplifying | Mathematizing | Working Mathematically | Interpreting | Validating | Total | Levels of Mathematical Modeling Competencies |
|---|---|---|---|---|---|---|---|---|
| Tooth Brushing | 1 | 0 | 0 | 0 | 0 | 0 | 1 | Not competent in Mathematical Modeling |
| Uncle Tailor Hikmet | 4 | 3 | 4 | 4 | 4 | 0 | 19 | Acceptably competent in Mathematical Modeling |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Team Ranking | 1 | 1 | 0 | 0 | 0 | 0 | 2 | Not competent in Mathematical Modeling |
| Apartment | 4 | 2 | 2 | 2 | 3 | 0 | 13 | Acceptably competent in Mathematical Modeling |
| Eiffel Tower | 4 | 2 | 3 | 3 | 3 | 0 | 15 | |
| Whitewash | 4 | 3 | 4 | 4 | 4 | 0 | 19 | |
| Highway | 4 | 3 | 0 | 0 | 1 | 0 | 8 | Somewhat competent in Mathematical Modeling |
| Paper Airplane | 4 | 3 | 3 | 3 | 4 | 0 | 17 | Acceptably competent in Mathematical Modeling |
| Weather Report | 2 | 1 | 0 | 0 | 2 | 0 | 5 | Not competent in Mathematical Modeling |
| Total | 36 | 24 | 20 | 20 | 29 | 0 | 129 | |

Table 9 reveals that the problems in which the 3rd group was most successful were the Apple Pie Problem, Uncle Tailor Hikmet Problem and the Whitewash Problem. The problem in which the group was not successful at the expected level was the Tooth Brushing Problem. The scores obtained from the sub-dimensions of RAMS revealed that the group got the highest score from understanding the problem sub-dimension and the lowest score from the validating sub-dimension.

The scores entitled to 4th Group based on the mathematical modeling problems are exhibited in Table 10.

Table 10.
Scores entitled to 4th group based on the mathematical modeling problems

| 4th GROUP | Understanding the problem | Simplifying | Mathematizing | Working Mathematically | Interpreting | Validating | Total | Levels of Mathematical Modeling Competencies |
|---|---|---|---|---|---|---|---|---|
| Tooth Brushing | 4 | 3 | 4 | 4 | 4 | 0 | 19 | Acceptably competent in Mathematical Modeling |
| Uncle Tailor Hikmet | 3 | 0 | 0 | 0 | 0 | 0 | 3 | Not competent in Mathematical Modeling |
| Team Ranking | 3 | 2 | 0 | 0 | 1 | 0 | 6 | |
| Apartment | 3 | 2 | 0 | 0 | 1 | 0 | 6 | |
| Eiffel Tower | 4 | 2 | 1 | 1 | 2 | 0 | 10 | Somewhat competent in Mathematical Modeling |
| Whitewash | 4 | 3 | 4 | 4 | 4 | 0 | 19 | Acceptably competent in Mathematical Modeling |
| Highway | 4 | 3 | 2 | 2 | 4 | 0 | 15 | |
| Paper Airplane | 4 | 2 | 0 | 0 | 1 | 0 | 7 | Somewhat competent in Mathematical Modeling |
| Weather Report | 4 | 2 | 0 | 0 | 2 | 0 | 8 | |
| Total | 41 | 25 | 15 | 15 | 27 | 0 | 123 | |

Table 10 reveals that the problems in which the 4th group was most successful were the Apple Pie Problem, Tooth Brushing Problem and the Whitewash Problem. The problem in which the group was not successful at the expected level was the Uncle Tailor Hikmet Problem. The scores obtained from the sub-dimensions of RAMS revealed that the group got the highest score from understanding the problem sub-dimension and the lowest score from the validating sub-dimension.

The levels of cognitive mathematical modeling competencies of all groups are exhibited in Table 11.

Table 11.
Levels of cognitive mathematical modeling competencies of all groups

| | Tooth Brushing | Uncle Tailor Hikmet | Team Ranking | Apartment | Eiffel Tower | Whitewash | Highway | Paper Airplane | Weather Report | Total Score |
|---|---|---|---|---|---|---|---|---|---|---|
| 1st Group | 2 | 3 | 3 | 4 | 3 | 16 | 15 | 16 | 3 | 84 |
| 2nd Group | 6 | 19 | 19 | 13 | 19 | 19 | 19 | 11 | 7 | 154 |
| 3rd Group | 1 | 19 | 2 | 13 | 15 | 19 | 8 | 17 | 5 | 129 |
| 4th Group | 19 | 3 | 6 | 6 | 10 | 19 | 15 | 7 | 8 | 123 |

Table 11, which contains the data on cognitive mathematical modeling competencies of the groups, reveals that the most successful group is the 2nd group and the least successful group is the 1st group. The Whitewash Problem has been the one most successfully solved by all groups; Tooth Brushing Problem and Team Ranking Problem has been the one in which most of the groups were not successful. Most striking result is that no group were considered as highly competent in Mathematical Modeling as a consequence of the problem solving sessions with the mathematical modeling exercises.

## Discussion and Conclusion

This research aims to reveal significant conclusions with regard to the cognitive modeling competencies of primary school teachers candidates. Each week of this mathematical modeling training, primary school teachers candidates were provided information about mathematical modeling and they were required to collectively solve problems [Model-Eliciting Activities (MEAs)] selected from the literature. The solution methods for the mathematical modeling problems revealed that the groups got the highest score from the Understanding the problem step. Similarly, Bal and Doğanay (2014) also stated that pre-service teachers' understanding the problem scores have increased at the end of such a training. Canbazoğlu and Tarım (2021), on the other hand, stated in their study that primary school teachers candidates were not sufficiently competent in understanding the problem step. The reason underlying this difference may be explained with the fact that the primary school teachers candidates, as the participants of the research, were familiar with Model-Eliciting Activities (MEAs) as they were taught within the scope of "Fundamentals of Primary School Mathematics" course.

The second sub-dimension in which the primary school teachers candidates were mostly successful was the interpreting step. Contrary to the results herein, Bukova Güzel (2011) stated in her study that pre-service mathematics teachers have difficulties in interpreting the problems.

The solution methods of the primary school teachers candidates for the mathematical modeling problems revealed that the groups got the lowest score from the Validating step. Similar to the results herein, Canbazoğlu and Tarım (2021) concluded in their study, in which they examined the mathematical modeling processes of primary school teachers candidates, that pre-service teachers were not sufficiently competent in the Validating step. Bukova Güzel (2011) also stated in her study that pre-service mathematics teachers had difficulties with the Validating step.

The solution methods of the primary school teachers candidates for the mathematical modeling problems revealed that the groups of pre-service teachers got a somewhat acceptable scores from the Simplifying, Mathematizing and Working Mathematically steps. Contrary to the results herein, Ulu (2017) determined, at the end of the studies, that students were able to transform the problems into mathematical expressions. This conclusion may be interpreted as an indication that students' mathematizing and working mathematically skills have improved throughout the research/training (Ulu, 2017). Bukova Güzel (2011) stated in her study that pre-service mathematics teachers were competent in the Simplifying step. Kaygısız (2021) also stated in his study that students performed as somewhat competent or acceptably competent in the Mathematizing sub-dimension. He further stated that the students had sufficient scores without any difficulty with regard to the mathematical knowledge competency. In addition Kaygısız (2021) stated that the students could not have sufficient scores in the Simplifying sub-dimensions, but the situation changed in the following weeks.

The solution methods of the primary school teachers candidates for the mathematical modeling problems in this research revealed that the groups of pre-service teachers got the highest scores in Understanding the problem step, could not get the expected scores in Mathematizing and Working Mathematically steps and got a "0" in the Validating step. Yavuz Mumcu and Baki (2017) stated, in their study conducted with high school students, mean scores of the students have decreased throughout the study and that the students scored the lowest at the Validating the solution step.

Another finding therein was that the mathematical modeling problem in which the groups were mostly successful was the Whitewash Problem. For the purpose of the Whitewash Problem, students were asked to calculate the amount of paint needed and the cost to be incurred to paint the walls of their rooms. The Whitewash Problem is a Model-Eliciting Activity (MEA) that meets the criterion of being close to the realities of life as stated in the literature since it refers to a problem that pre-service teachers may come up with in real life and will be curious to solve (Tekin Dede, 2018). Pre-service teachers were asked to paint the rooms where they spent majority of their time and to prepare a poster describing this process. Pre-service teachers used mathematics while planning to paint their rooms. Thus, they reached the conclusion that "Mathematics Everywhere" in life. While deciding on the color and amount of paint to be used and calculating the cost to be incurred, pre-service teachers assumed the responsibilities that were otherwise performed by their parents. Accordingly, they took a decision through an independent judiciary. In addition, pre-service teachers became a part of social life by doing research outside of school (Tekin Dede, 2018). While calculating, pre-service teachers considered the walls of their rooms in three-dimensions and then moved the assumptions onto a two-dimensional floor while preparing the poster. Thus, they used their spatial orientation skills. They reached mathematical solutions by making use of the drawings and subsequently interpreted the mathematical solutions by adjusting them to real life conditions. Furthermore, pre-service teachers who solved the Whitewash Problem experienced the relationship between mathematics and real life and reached the conclusion that mathematics is actually a part of our lives. Thus, they also developed a positive attitude towards mathematics. For these reasons, the Whitewash Problem differs from other Model-Eliciting Activities (MEAs). The assessment with regard to the posters prepared by the groups revealed that one group prepared an 8-page poster while another group prepared a slide. Such a result indicated that the primary school teachers candidates did not know what the poster actually meant. Model-Eliciting Activities (MEAs) allowed determining missing information of the primary school teachers candidates on other subjects. These deficiencies may further be eliminated through interdisciplinary studies.

The mathematical modeling problem that the groups except for the fourth group failed was the Tooth Brushing Problem. The Tooth Brushing Problem is a Fermi Problem. The Fermi Problem can be defined as the type of exercises in which students are not provided sufficient information for deriving a solution however that leads them to think more creatively (Taplin, 2007). Yanbıyık (2016), in the study aiming to reveal the modeling skills of primary school teachers candidates using Fermi Problems, similarly revealed that the modeling skills of pre-service teachers in Fermi Problems were not at the expected level. We further recommend to incorporate activities that require meta cognitive skills such as open-ended questions and non-routine problems in the classwork in order to improve the competencies of primary school teachers candidates in Fermi problems. The problem that the fourth group solved most successfully was the Tooth Brushing Problem. The competence to solve mathematical modeling problems may not be attributed to academic success. Students with lower academic success may get an outstanding success in mathematical modeling problems. Mathematical modeling problems may be a significant opportunity for students with different academic achievements.

As a result, it has been observed that primary school teachers candidates could not attain an increasing progress in mathematical modeling problems. While pre-service teachers did not have sufficient modeling competence at the beginning of the study, they attained an acceptable level of modeling competence as the study progressed. However, it was observed that some groups could not get the expected success in modeling problems and could not attain the expected modeling competence at the end of the study. This may be attributed to the structure of mathematical modeling problems. Pre-service teachers who had not worked sufficiently with mathematical modeling problems may have difficulties in solving these problems. Or the limited term of such a research/training may also affect the expected success. For this reason, it is argued that an increasing progress can be achieved with longer-term trainings.

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