Kuram ve Uygulamada
SOSYAL BİLİMLER DERGİSİ
Social Sciences: Theory & Practice
ISSN: 2619-9408
Geliş/Received: 03.07.2024 ***Kabul/Accepted:*** 02.12.2024
***Makale Türü*:** Araştırma

Ortaokul 7. Sınıf Öğrencilerinin Matematiksel Modelleme Süreçlerinde Problem Çözme Stratejilerinin İncelenmesi*

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ÖZ

Bu araştırmanın amacı, matematiksel modellemede 7.sınıf öğrencilerinin problem çözme stratejilerinin incelenmesidir.Araştırmada, nitel araştırma yöntemlerinden durum çalışması kullanılmıştır. Durum çalışmasında katılımcılara altı hafta boyunca toplam 22 ders saati süren model oluşturma etkinlikleri uygulanmış ve 6 hafta sürmüştür. Katılımcılar; 15 tane yedinci sınıf öğrencisi arasından amaçlı örnekleme yöntemiyle seçilmiş sekiz öğrencidir. Araştırmada gözlem yöntemi kullanılmıştır. Verilerin analizinde betimsel analiz kullanılmıştır. Öğrencilerin matematiksel modellemede en fazla kullandıkları strateji "Denklem veya Eşitsizlik Kurma"dır. Öğrenciler "Geriye Doğru Çalışma"yı hiç kullanmamışlardır.

Anahtar kelimeler: Matematiksel modelleme, problem, problem çözme stratejileri

The Investigation of Problem Solving Strategies in Mathematical Modelling of Middle School Seventh-Grade Students

ABSTRACT

This study is aimed at investigating the problem solving strategies of seventh-grade students in mathematical modelling. This study was carried out using case study method which is one of the qualitative research methods. In case study, model eliciting activities lasting a total of 22 lesson hours were implemented for six weeks Participants were eight students who were selected among fifteen seventh-grade students by purposive sampling method. Observation method was used in the research.Descriptive analysis was used for data analysis. The most commonly used strategy in mathematical modelling was "Establishing Equation and Inequality". The participants never used "Working Backward.

Keywords: Mathematical modelling, problem, problem solving strategies

Atıf Bilgisi: Sırmacı, N., & Uyar, Z., E. (2024). Ortaokul 7. sınıf öğrencilerinin matematiksel modelleme süreçlerinde problem çözme stratejilerinin incelenmesi. *Kuram ve Uygulamada Sosyal Bilimler Dergisi*, *8(2),* 427-445. Doi: 10.48066/kusob.1509945

*Bu çalışma yüksek lisans tezinden üretilmiştir, VI. International "Başkent" Congress on Physical, Social And Health Sciences kongresinde sözlü bildiri olarak sunulmuştur.

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Introduction

Problem solving and mathematical modelling are of great importance in teaching mathematics. These two concepts are related to each other. Since the models created by students are a special representation of the real world (Greefrath & Vorhölter, 2016), creating the appropriate model in the problem solving process is important in reaching the appropriate result. Problem-solving strategies can help in the development of an appropriate mathematical model by providing a different perspective on the problem (Noble, 1982). In order to gain a better understanding, the following information is provided with the expectation that it may be useful to know the connections between mathematical modelling and problem solving.

Mathematical Modelling

According to Vygotsky (as cited in Esteban-Guitart & Moll, 2014), an education apart from the real world is as meaningless as breathing in an oxygen-free fire or a vacuum. Based on this assertion, a curriculum should be structured for students in line with the needs of society, in which real life should be integrated into education. It is contemplated that mathematics teaching practices should be modalized in this direction in order to come up with solutions to real life problems.Mathematical modelling, which emerged incidental to the aim of integrating daily life into mathematics lessons in order to cope with real life problems (Maaß, 2006), has become the focus of attention of mathematics educators (Mousoulides, Christou & Sriraman, 2008) and has taken its place in the mathematics curriculum of many countries. Mathematical modelling takes on a task as a systematic tool that can demonstrate how mathematics is used in daily life (Lingefjärd, 2007). Mathematical modelling provides students with vast opportunities to perform important processes such as creating, explaining, verifying, predicting, coordinating data, organizing and inferring from data (English & Watters, 2005).Mathematicalmodelling begins in the real world(Han & Kim, 2020).

Mathematical modelling can be conceived of as a projection of real life on mathematics. Because there are processes of transforming a real-life problem into a model as a representative image, solving the problem by interpreting the model, and interpreting this solution in the context of real life. According to Haines and Crouch (2007), mathematical modelling is a cyclical process in which the real-life problem is transferred to the mathematical world and mathematicized, resolved, and the solution is evaluated and verified by creating a set of models.

Classification of Mathematical Modelling Problems

According to Berry and Houston (1995), model eliciting activities, in which students develop mathematical models, or in other words, mathematical modelling problems, are splitted into four types as experimental modelling, theoretical modelling, simulation modelling and dimensional analysis modelling as they differ in variety in terms of the presentation of the data of the problem or the difference in the solution process, Experimental Modelling: Experimental modelling is a type of modelling that is based on real-life data and can generally be expressed based on graphical representation (Berry & Houston, 1995). In the experimental modelling type, the most appropriate model is developed for the solution of the problem by using the existing data given in the problem statement, by establishing relations between the data, and in this way, predictions for the future are made (Thomas, Weir & Giordano, 2004). For example, it is within the scope of empirical modelling to determine how much unemployment will occur in any given year by means of presenting a table of unemployment rate that is annual based with respect to real-life data. Because, a model is attained by establishing a correlation between the available data.

Theoretical Modelling: Although it is different from experimental modelling types, there is no data for the solution of the problem in the problem statement. Creating the model in the problem solving

process is based on problem-oriented theories of problem solvers rather than data (Berry & Houston, 1995). Although the problem statement does not contain data that allows the solution of the problem, the problem solver can create his/her own data in modelling based on theory. For example, the model eliciting activity of Borromeo Ferri (Act., Bukova Güzel, 2016) asking "How much space will be left between the mother and father lying on a circular bed with a diameter of 210 cm" is an example of theoretical modelling. Knowing the diameter of the bed is not enough to solve the problem. In order to solve the problem, students have to make estimations about the width and height of the mother and father rather than the data and solve the problem through their theories. In addition, the result may vary depending on the data received in the problem.

Simulation Modelling: In some problems where algebraic expressions cannot be established and modelling cannot be done while eliciting mathematical models, probabilities can be simulated using computers and this modelling is called simulation modelling (Hıdıroğlu, 2012). In order to examine the air flow in a newly designed aircraft, a smaller model of this aircraft with similar proportions is designed and the behavior of the model in the aerodynamic test tunnel is set as an example of simulation modelling (Berry & Houston, 1995).

Dimensional Analysis Modelling: Modelling in which mathematical relationships are reached through effective grouping of variables using the physical quantity called dimension is called dimensional analysis modelling (Berry & Houston, 1995). According to Berry and Houston, mass, time and length dimensions, which are defined as basic dimensions, are used to develop appropriate models by making use of the relations between variables. For example, in order to find the oscillation period of a simple pendulum, developing a formula in terms of the acceleration due to gravity, the length of the pendulum's string, the mass of the object suspended on the end of the string, and the angle of the object with the vertical is an example of dimensional analysis modelling (Berry & Houston, 1995). In order to find the oscillation period of the simple pendulum, the length dimension for the length of the pendulum's string, the mass dimension for the mass of the object at the end of the string, the time dimension for one full rotation of the pendulum, and other physical quantities and dimensions are used to develop a model from the relations between the variables.

Mathematical Modelling and Problem Solving

Researchers have different views on problem solving and mathematical modelling. While some researchers consider mathematical modelling as a form of problem solving(Özturan & Sağırlı,2010) and a subset of the problem solving process(Noble,1982), some researchers state that mathematical modelling includes problem solving(Keskin, 2008; Lesh & Doerr,2003b)Mathematical modelling is beyond problem solving, which includes the solution of symbolically defined verbal problems, in terms of improving students' mathematical competencies and thinking skills (English, 2003). The fact that it supports the interpretation of real-life situations and the use of multiple solution approaches for these situations makes mathematical modelling different from traditional problem solving (English & Watters,2004). Certain principles must be followed in order to design mathematical modelling problems (Lesh et al., 2000). There is no specific design principle for other problems that are solved with the conventional method.

Problems solved by conventional problem solving method are presented symbolically apart from the context. While the application of mathematical skills rather than the context of the problem is essential in conventional problem solving, mathematical modelling focuses on the problem itself (Ang, 2009). According to Ang, conventional problem solving allows for the development of mathematical skills, while mathematical modelling provides a rich context in which mathematical skills can be applied in a real-life situation.Quite a number of national and international studies have been conducted on mathematical modelling. Doruk(2010) and Sandalcı(2013) determined that mathematical modelling

activities have a positive effect on transferring and associating mathematics with daily life. Some researchers have examined the effect of mathematical modelling on attitude (Kal, 2013; Ünveren, 2010). In his study, Kal(2013) concluded that mathematical modelling activities positively affected the problem-solving attitudes of 6th grade students. In some studies (Sağıroğlu, 2018; Taşpınar & Şener, 2017; Tekin, 2012) the model eliciting activity design processes of mathematics teachers or prospective teachers were examined. In these studies, it was determined that the activities designed by teachers or teacher candidates did not comply with some of the design principles of model building activity.Jacobs and Durandth(2017), in their prominent study examining the attitudes of 50 pre-service teachers working on model eliciting activity reached the conclusion that pre-service teachers had a positive attitude towards modelling.

In his study, Ang(2010) exemplified how technology can be used in mathematical modelling without reducing students' knowledge and experience on four model eliciting activities. When the studies on mathematical modelling are examined, few studies have been conducted on the strategies used in mathematical modelling(Stender, 2019; Stender & Kaiser, 2017; Zawojewski & Lesh, 2003)In this sense, it is thought that examining the problem solving strategies used by students in mathematical modelling will contribute to the literature.Thanks to the fact that mathematical modelling is carried out with small groups of students, students can create many strategies for the solution of the problem and share them with their group friends, evaluate which strategy is more suitable for the solution and reach the appropriate solution. Problem solving strategies help students develop, revise, modify and expand their ideas in mathematical modelling(Lesh & Doerr, 2003). These strategies can support the formation of different ideas and approaches by providing flexible thinking(Woodward et al.2012)Based on this idea, another aim of the research is to reveal the strategies used in mathematical modelling and to serve to popularize the use of these activities in mathematics teaching. The main problem in order to realize the aim of the research is determined as follows"Which problem-solving strategies do students use in mathematical modelling?"Sub-problem of the study is specified as follows:

1.Which problem-solving strategies do students use most in each model-eliciting activity in mathematical modelling?

Method

Research model

Research model is case study. According to Gliner, Morgan, and Leech (2015), the main aspect in case study is to develop an understanding by accessing rich data about the researched situation or phenomenon. Observational case study, one of the case study types, was used. The method used in this research is the observation method.

Participants

The participants are seventh grade students The research was initated with a total of 15 students. Nine of these students are girls and six are boys. In order to help students get used to the mathematical modelling process, four model-eliciting activities were applied to 15 students as a warm-up activity. However, purposive sampling method was used in the selection of the participants in the main study to be conducted after the warm-up activities, due to the narrow and unfavorable physical conditions of the classroom, the difficulty of some students in adapting to the mathematical modelling process, the noisy implementation process of the activities, and the inability of the researcher to make a more in-depth analysis due to the large number of groups. For the selection of the participants, criteria such as being able to freely express their feelings and thoughts, being willing to participate in model-eliciting activities, acting in accordance with the integrity of group work, coming to school for weekend activities,

and students' interests and behaviors in warm-up activities were considered in the selection of the participants in the study.

At first, when forming groups in the main study, the students were determined as four girls and four boys. Other names were used instead of students' real names. Because, they have a right to privacy. Students were given the names Dilek, Durmuş, Doğan, Filiz, Hüsnü, Haluk, Lale and Sahra. Students named Dilek, Durmuş, Doğan, Filiz, Hüsnü, Haluk, Lale and Sahra were chosen as volunteer students to participate in the research. However, the student named Hüsnü later stated that he could not attend the study on the grounds that he could not come to school at the weekend, and a student named Sevde was included in the study instead. Thus, the students to participate in the main study were determined as three boys and five girls

Data Collecting Tools and Process

In this research, datas are obtained from video transcripts of model building activities and solution papers for each group's four model eliciting activities. Moreover, while the students were solving the model eliciting activities, the researcher closely observed the groups in order to better understand their problem solving processes and asked the students to explain their thinking processes by asking questions. Before starting the data collecting process, model eliciting activities (mathematical modelling problems) to be used in the research were determined and a pilot application was made. After the pilot application, necessary corrections were made in the model eliciting activities and they were made suitable for the research. Eight mathematical modelling problems were used in the research. One of the problems that required mathematical modelling used in the research(Time Problem) was designed by the researcher by Two mathematics educators were consulted in terms of the compatibility of the designed problem with the principles of model eliciting activities. For other problems that require mathematical modelling, permission was obtained from the researchers who prepared the problems and eight modelling problems. The type of the problem was included in the research by being presented to the opinion of three mathematics educators in terms of learning areas and suitability for the level of the student.

Mathematical modelling problems were selected as four experimental and four theoretical, by consulting the opinions of two mathematics educators. While deciding on the type of the problem, the modelling types of Berry and Houston(1995) were taken into account and it was paid attention to whether the problem statement provided sufficient data for the solution of the problem. While the problems in which the models are developed by using the data in the problem statement are considered as experimental modelling problems, the problems in which the problem statement does not provide sufficient data for the solution of the problem and the problem solver develops models by creating data based on some assumptions or theories are considered as theoretical modelling problems. Other types of mathematical modelling problems (simulation modelling and dimensional analysis modelling) were not included in this study, considering that the students' lack of computer skills and knowledge of computer programs, and the inability to use most of the computers in the school, would adversely affect the research.

Table 1. Types of Mathematical Modelling Problems and Learning Domains

Mathematical Modelling Problem	***Mathematical Modelling Type***
Time Problem	*Experimental*
Hay Bale Problem	*Theoretical*
Pineapple Problem	*Theoretical*
Pharmaceuticals Industrialists Golden Award Problem	*Experimental*
Travel Problem	*Experimental*
Bigfoot Problem	*Theoretical*

Long Jump Problem	*Experimental*
Mattress Problem	*Theoretical*

The “Hay Bale” problem is derived from the work of Hıdıroğlu and Hıdıroğlu (2017), which he adapted from the work of Borromeo Ferri. “The Pineapple Problem” is adapted from the work of Ludwig and Xu (2010). "Pharmaceutical Industry Golden Award Problem", "Travel Problem", "Bigfoot Problem" and "Long Jump Problem" are derived from Doruk's (2010) work. “The Mattress Problem” was obtained from Bukova Güzel (2016).The first four problems in Table 3 (Time, Hay Bale, Pineapple and Pharmaceutical Manufacturers' Gold Award Problem) were determined as warm-up activities for students to get used to the structure of mathematical modelling problems. The next four problems (Travel, Bigfoot, Long Jump and Mattress Problem) were selected for use in the main study. A total of four experimental and four theoretical modelling problems, two of which were experimental and two of which were theoretical modelling problems, were determined according to Berry and Houston (1995).

Main study

The problems used in the main study are “Travel Problem”, “Big Foot Problem”, “Long Jump Problem” and “Mattress Problem”. A student named Hüsnü, who was one of the students who used problem solving strategies the most during the mathematical modelling process in the warm-up studies, participated in the main study voluntarily at first, but later wanted to leave the study for some reasons. Instead, a student named Sevde voluntarily participated in the research. A student named Sevde participated in all the exercises, including four warm-ups and four main exercises.In the main study, students were divided into two groups. The group names chosen by the students are Pinky (Blue) Smurfs and Terrible 3. While the students named Doğan, Filiz, Haluk and Sahra are in the Pinky (Blue) Smurfs group, the students named Dilek, Durmuş, Sevde and Lale are in the Terrible 3 group. Thus, the main study was conducted with a total of eight students consisting of two groups.There is no student absent from these activities. Students were divided into groups according to their grade point averages in mathematics and in-group harmony in warm-up exercises. It was tried to be grouped as heterogeneous within the group and homogeneous among the groups according to the grade point averages of the mathematics course. However, there was not much heterogeneity within the group since the mathematics course grade averages of the students were generally close to each other. While the model building activities were being solved, the students were seated on the benches so that they could see each other's faces, and the modelling process was carried out by placing a camera directed at each group.

While implementing the "Travel Problem", in order to prepare the students for the model building activity and to attract the attention of the students, after the conversation about the holiday, travel and the transportation vehicles that the students use while traveling, the model building activity sheet was distributed to the students and the process was recorded with the camera while the students were solving the problem as a group. While the students were engaged in model building activities as a group, the researcher observed the students and tried to understand their thinking processes by asking questions about how they carried out the process and how they thought. After solving the problem, the students wrote letters describing the solution process and explained the problem-solving processes by making presentations.

While conducting the "Big Foot Problem", "Another Human-Like Fossil Footprint Found in China!" and "Trace Dog Searches for a Woman Lost in the Mountain as She Traveled with Her Daughter" captioned newspaper news were distributed, and the attention of the students was drawn before the model eliciting activity. Afterwards, the researcher distributed A3 paper with a 38-meter-long and 12-meter-wide footprint to the students. The solution process of the problem was carried out similar to the "Travel Problem"While the "Long Jump Problem" was being solved, the students were asked whether they watched the Olympics and the long jumps, and after a short conversation, the worksheets

were distributed and the process was carried out similar to other model eliciting activities.In the "Mattress Problem", after watching a video of round bed models from the computer in the teachers' room, the students were asked questions such as what to consider when buying a bed and how people can fit. Afterwards, worksheets were distributed in the classroom and the process was carried out similar to other model building activities.

It took a total of 22 lesson hours to complete the model building activities, with 10 hours of warm-up and 12 hours of main study. In addition, after the model building activities were completed.

Data Analysis

In this research, descriptive analysis, one of the qualitative data analysis types, was used in the analysis of the data of model building activities. In descriptive analysis, the data obtained during the research process are summarized and interpreted according to the themes that were previously created (Özdemir,2010). Data obtained from video transcripts of model building activities and solution papers for each group's four model eliciting activities.; It has been evaluated and analyzed over 10 strategies: finding correlations, animating, establishing equations or inequalities, working backwards, reasoning, simplifying the problem, making systematic lists, drawing figures or diagrams, making tables, and estimating and controlling strategies

Problem solving strategies were created as follows:

In the literature, problem solving strategies have been explained by many researchers (Altun, 2002; Baykul, 2014; Posamentier & Krulik, 2016; Van De Walle, Karp & Bay-Williams, 2016;Yazgan & Arslan, 2017).When problem solving strategies are examined in the literature, it is seen that the same strategy is named in different ways. Problem solving strategies according to different researchers are given in Table1 by making a common denomination.

Table 2. Problem Solving Strategies According to Different Researchers

Problem Solving Strategies	Finding Relation	Animation	Establishing Equations and Inequalities	Elimination	Adopting a Different Perspective	Working Backwards	Using the Models	Reasoning	Simplifying the Problem	Making a Systematic List	Drawing a Shape or Diagram	Making a Table	Guessing	Guessing and Control
Altun (2002)	x		x	x		x		X	x	x	x	x	X	x
Baykul (2014)	x	x	x			x	x	X	x	x	x	x		x
Posamentier and Krulik (2016)	x	x			x	x		X	x	x	x	x		x
Van De Walle, Karp and Bay-Williams (2016)	x	x	x				x		x	x	x	x		x
Yazgan and Arslan (2017)	x	x	x			x		X	x	x	x	x		x

When Table 2 is examined, it is seen that the most used problem solving strategies in the literature are finding correlations, animating, establishing equations or inequalities, working backwards, reasoning, simplifying the problem, making systematic lists, drawing figures or diagrams, making tables, and guessing and checking.

Validity and Reliability

The research environment is described in detail. In addition, the research process has been tried to be explained in detail. Students were not limited in terms of time in problem solving, and the research process was tried to continue until there was no data to be obtained for each model building activity.To provide participant confirmation, The researcher stood nearby the groups alternately throughout the process and asked the groups "How did you think?" in order to understand how they acted in the process and allowed them to express their thoughts. In order to ensure reliability, the reliability coefficient between the two encoders was calculated for the model building activities. According to Miles and Huberman (1994), this coefficient is calculated with the formula consensus÷(consensus+disagreement) According to Miles and Huberman, the intercoder reliability should be above 70% and close to 80%.

The data were analyzed only according to the determined 10 strategies, other strategies were not included in the analysis of the data. In the analysis of video transcripts, solution papers the intercoder reliability coefficient was 82.5%. When the reason for the disagreement was investigated, it was seen that one of the coders wrote some of the problem-solving strategies that came as a continuation of each other, instead of taking them as a single strategy. This error has been corrected and written as a single strategy.

Findings

1) Problem solving strategies used by students in "Travel Problem".

The frequency of the strategies used by the groups in the mathematical modelling of the "Travel Problem" is given in Table 3

Table 3. Frequency of Problem Solving Strategies Used by Students in "Travel Problem"

Problem Solving Strategies	Finding Relation	Animation	Establishing Equations and Inequalities	Work Backwards	Reasonnig	Symplifying the Problem	Making a Systematic List	Drawing Figures and Diagrams	Drawing a Table	Guessing and Control	**Total**
Terrible 3 Group	1	1	2	-	2	-	1	-	-	1	8
Pinky (Blue) Smurfs Group	1	1	1	-	-	-	1	-	-	-	4
Total	2	2	3	-	2	-	2	-	-	1	12

According to Table 3, the strategy most frequently used by students is "Establishing Equations or Inequalities". In modelling, students used the strategy of "Establishing Equations or Inequalities" three times, "Finding Relation" twice, "Animation" twice, "Reasoning" twice, "Making Systematic Lists" twice, and "Prediction and Control" once. Students did not benefit from four strategies (work backwards, simplify the problem, draw figures or diagrams, make tables) during the problem solving

process. The problem solving strategies used by the groups in the modelling are presented under separate headings.

a) Problem solving strategies used by the Terrible Three group in the "Travel Problem".

In order to solve the problem, the students, trying to determine the distance of the road between Ankara and Antalya, searched the distance of the road from the internet using the researcher's phone. Students who encountered more than one road on the Internet were hesitant about how many kilometers they would take as a distance. The students used the "Reasoning" strategy to determine which road distance to take.

Dilek: *483 by car. Which one is this?*

Durmuş: *549 km here...*

Lale: *Which one should we pick?*

Durmuş: *482.*

In Figure 1, an example of the "Establishing Equations or Inequalities" strategy used by the Terrible 3 group is given.

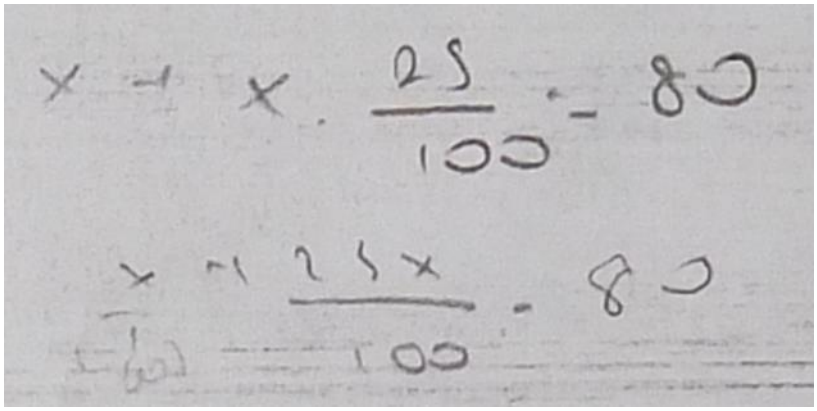

Figure 1. An example of the "Setting up Equation or Inequality" strategy used by the Terrible Three group to solve the "Travel Problem".

2) Problem solving strategies used by students in the "Big Foot Problem".

The frequency of the strategies used by the students in the mathematical modelling of the "Big Foot Problem" is given in Table 4.

Table 4. Frequency of Problem Solving Strategies Used by Students in the "Big Foot Problem"

Problem Solving Strategies	Finding Relation	Animation.	Establishing an Equation	Work Backwards	Reasoninig	Symplifying the Problem	Making a Systematic List	Drawşng Figures and Diagrams	Drawing a Table	Guessing amd Control	**Total**
Terrible 3 Group	6	1	3	-	4	1	-	-	-	-	15
Pinky (Blue) Smurfs Group	5	-	9	-	3	-	-	-	-	-	17
Total	11	1	12	-	7	1	-	-	-	-	32

According to Table 4, the strategy most frequently used by students in the solution process of the "Big Foot Problem" is "Establishing Equations or Inequalities". In modelling, the students used the strategies of "Establishing Equations or Inequalities" twelve times, "Finding Relation" eleven times, "Reasoning" seven times, "Animating" once and "Simplifying the Problem" once. Five strategies (working backwards, making systematic lists, drawing figures or diagrams, making tables, guessing and checking) were never used in the solution process of the problem.

b) Problem solving strategies used by the Pink (Blue) Smurfs group in the "Big Foot Problem".

The students in this group, like the students in the other group, tried to establish a relationship between height and foot length after reading the problem statement. The students in the group measured their own height and foot length and tried to find a solution to the problem by using the "Find a Relation" strategy:

Filiz: *"We also measure our feet with our own height, we make a guess... according to that. So I think that's the most logical one*

Haluk: *How will we measure it?*

Filiz: *Our teacher has a ruler or something. There were meters*

(The researcher gives the measuring tape to the students.)

Researcher: *How did you think about doing it by yourself?*

Filiz: *On ourselves? First, we measure our height, teacher, we look at the proportion of our feet and height. Then you measure the man's foot or something, or we determine his height accordingly* (he talks about the "Big Foot" print, which was given by the researcher on an A3 paper with a length of 38 cm and a width of 12 cm)

First, while Sahra and Filiz were measuring their height and foot lengths, the other group members took notes.

Filiz: *Write 1.58 for Sahra's height*

Sahra: *1,60*

Filiz: *1,60* (corrects accordingly)

Haluk: *Let's measure our feet*

(Students measure their foot lengths)

Filiz: *Now I'm going to measure my foot length. Measure with my shoes. Let me help. Come. Do I measure my own?*

Sahra: *Yes*

Filiz: *24*

The students tried to find a correlation between height and foot length from the data they obtained.

An example of the "Finding a Correlation" strategy used by the group in the solution is given in Figure 2.

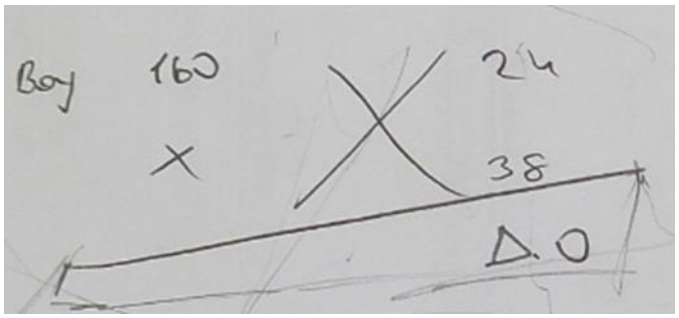

Figure 2. An example of the "Finding a Correlation" strategy used by the Pinky (Blue) Smurfs group to solve the "Big Foot Problem".

3) Problem solving strategies used by students in the "Long Jump Problem".

The frequency of the strategies used by the group in the mathematical modelling of the "Long Jump Problem" is given in Table 5

Table 5. Frequency of Problem Solving Strategies Used by Students in the "Long Jump Problem"

Problem Solving Strategies	Finidng a Correlation	Animation	Establishing an quation	Work Backwards	Reasoning.	Symplifying a Problem	Making a Systematic List	Drawing Figures and Diagrams	Drawing a Table	Guesssng and Controlling	**Total**
Terrible 3 Group	-	-	-	-	-	1	1	-	-	-	2
Pinky (Blue) Smurfs Group	-	-	-	-	1	-	1	-	-	-	2
Total	-	-	-	-	1	1	2	-	-	-	4

When Table 5 is examined, the students in the process of solving the problem; They used three strategies: "Reasoning", "Simplifying the Problem" and "Making a Systematic List". The strategy most used by the students in modelling was "Making a Systematic List" strategy. In the modelling of the "Long Jump Problem", students; They used the strategy of "Making a Systematic List" twice, "Reasoning" once, and "Simplifying the Problem" once. The students never used the strategies of "Find a Relation", "Animation", "Establishing Equations or Inequalities", "Working Backwards Strategy", "Drawing Figures or Diagrams", "Making Tables" and "Guessing and Control" in the process.

a) Problem solving strategies used by the Terrible 3 Group in the "Long Jump Problem".

After reading the problem, the students in the Terrible 3 group initially thought of calculating the arithmetic average of the lengths that each person jumped. They also examined the median of the data. They distributed tasks to find the arithmetic mean and median of each person in the question statement. They had other group members check their actions again. However, the fact that the student named Büşra in the question statement had the highest jump length created a question mark in the minds of some group members and they tried to find a solution to the problem by using the "Making a Systematic List" strategy.

Lale: *Dilek is 57You make the addition once again*

Dilek: *Sevde, can you make the addition once again?*

Sevde: *What?* (They make Sevde control the operations)

Durmuş*: I have made the additionç Şeyda is the 1st. Fatna is 22.35. Fatma, I have lost by only 2*

Dilek: *I think Büşra must go*

Researcher:*Why?*

Dilek: *Why?*(laughs) *Yes,why*

Durmuş: *It is a very good question*

Dilek: *Because she has become first for more than once*

Sevde: *Which one did you find?*

Dilek: *But she has once become 3rd*

Researcher: *Hıı*.

Dilek: *She has become 2nd as well*

Lale: *I think Şeyda must go*(She says based on the arithmetic mean they calculated)

Dilek: *It is her first time as being the 1st. But she became 1st twice* (She points at Şeyda), *she became 1st for three times*(She points at Büşra)

Dilek: *Büşra was first, Fatma was second, Şeyda was third. Büşra came first in the third race. Fatma came in third. How about her? She came second. Teacher, after that, Büşra*

Durmuş: *Came third*

Dilek: *Three four. In her fourth race, she came second, Fatma came first, and Şeyda came in third*

The group did this by listing the rank of the students given in the problem statement in all situations. An example of the "Systematic List Making" strategy used by the group in solving the problem is given in Figure 3.

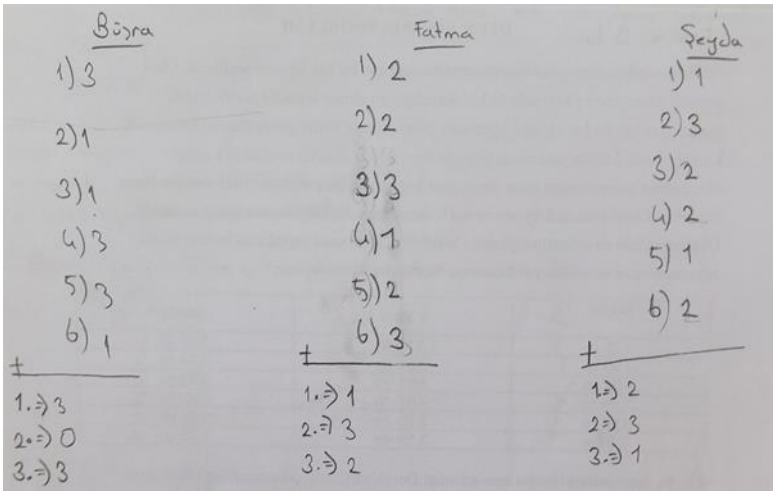

Figure 3. An example of the "Systematic List Making" strategy used by the Terrible 3 group to solve the "Long Jump Problem".

Table 6. Frequency of Problem Solving Strategies Used by Students in "Mattress Problem"

Problem Solving Strategies	Finding a Correlation	Animation	Establishing an Equation	Work Backwards	Reasoning	Simplifying a Problem	Making a Systematic List	Drawing Figures and Diagrams diagrams	Drawing a Table	Guessing and Controlling	**Total**
Terrible 3 Group	1	2	1	-	-	2	1	-	3	1	11
Pinky (Blue) Smurfs Grouğ	-	1	-	-	3	1	-	11	-	5	21
Total	1	3	1	-	3	3	1	11	3	6	32

When Table 6 is examined, it is seen that the strategy most used by students in mathematical modelling is "Drawing Figures or Diagrams". Students in modelling; “Drawing Figures or Diagrams” 11 times, “Prediction and Control” six times, “Animation” three times, “Reasoning” three times, “Simplifying the Problem” three times, “Making Tables” three times, “Find Connections” once They used the strategy of “Establishing Equations or Inequalities” once and “Making Systematic Lists” once. In the solution process of the "Mattress Problem", the students did not only benefit from the "Work Backwards" strategy.

b) Problem solving strategies used by the Pinky (Blue) Smurfs group in the “Mattress Problem”.

In order to solve the problem, the students thought to take into account the lengths of the arms of the parents. The students, who gave an estimated value for the father's height, tried to confirm their predictions by measuring the researcher's arm and tried to solve the problem based on the "Guessing and Control" strategy.

Filiz: *Let's think about it, shall we? If his height is 1.75, how wide will he be? It is not possible to add up the measurements from here*(What the student is talking about here is the width that the father can cover when he opens his arms.)

Haluk*: I also thought likewise*

Doğan: *Let’s say he is 1.72 instead of 1.75*

(Students measure the length of the researcher's arm and check their estimates)

Filiz: *Then we can say that. Yes. 70. The length of an arm is 70*

(They are reestimating father's arm length based on researcher's arm length)

Filiz: *To me, the length of the arm is 80*

Sahra:*80*

Filiz: *True, I agree.*

The frequency of the strategies used by the students in all four model eliciting activities in mathematical modelling is given in Table 7.

Table 7. Frequency of Problem Solving Strategies Used by Students in All Model Eliciting Activities

Problem Solving Strategies	Finding a Correlation	Animation	Equation	Work Backwards	Reasoning	Symlifying a Problem	Making a Syatematic List	Drawing Figures and Diagram	Drawing a Table	Guessing and Control	**Total**
Terrible 3 Group	8	4	6	-	6	4	3	-	3	2	36
Pinky (Blue) Smurfs Group	6	2	10	-	7	1	2	11	-	5	44
Total	14	6	16	-	13	5	5	11	3	7	80

When Table7 is examined, it is seen that the strategy most used by students in mathematical modelling is "Establishing Equations or Inequalities". In modelling, students were asked to “Establishing Equations or Inequalities” 16 times, “Find Relation” 14 times, “Reasoning” 13 times, “Drawing Shapes or Diagrams” 11 times, “Prediction and Control” seven times, “Animation” six times, and five times. They used the strategy of “Simplifying the Problem”,“Making Systematic Lists” five times and “Making Tables” three times. They have never used the “Work Backwards” strategy

Result

As a result of this research, in mathematical modelling, students' "Establishing Equations or Inequalities", "Finding Relation", "Reasoning", "Drawing Shapes or Diagrams", "Guessing and Control", "Animation", "Simplifying the Problem", "Making a Systematic List" ” and “Making Tables”strategies, but they never used the “Working Backwards” strategy. It was determined that students used different problem solving strategies in model eliciting activities. This result is similar to the study of Stender and Kaiser(2017),and it was concluded that different strategies were used in modelling activities, some of the strategies used were developed intuitively, and some of them resulted from the explanation of the previously introduced modelling cycle. It can be said that mathematical modelling provides an appropriate context for the use of different strategies. In this study, it was determined that the most frequently used strategy by the students was the "Establishing Equations or Inequalities" strategy. This result is consistent with Taşpınar's study(2011). In parallel with the beginning of abstract thinking, writing equations, which is used starting from the seventh and eighth grades, is one of the strategies used perfectly by students(Yazgan&Arslan,2017). Students may have preferred this strategy because they are familiar with the equation-building strategy.

Following the strategy of " Establishing Equations or Inequalities" in mathematical modelling, students mostly used the "Searching for Relation" strategy in modelling. This result is consistent with the findings of Çelebioğlu(2009) and Durmaz and Altun(2014). This may be due to the inclusion of the subject of patterns in the mathematics curriculum since the first years of primary education.

After the "Relation Search" strategy, one of the strategies most frequently used by students in the model creation process is "Reasoning". The solution process of all problems requires reasoning(Yazgan & Arslan,2017; Posamentier & Krulik,2016). Model eliciting activities can provide an appropriate context for the use of the “Reasoning” strategy. In this study, similar to studies of Verschaffel et al.(1999) and Yazgan(2007), one of the least used strategies by the students was the "Problem Simplification Strategy".One of the least used strategies by the students in the process was "Making a Systematic List" strategy. This result was reported by Arslan and Altun(2007) and Yıldız et

al.(2012) is inconsistent with the studies. The reason why “Systematic List Making” strategy is used less in modelling may be due to the structure of model eliciting activities. Because in some real-life problems, there are an infinite number of possible situations specific to the problem situation, and it may not be possible to list them.

Another strategy that the students used the least in the process was the "Drawing Tables" strategy. While this result is consistent with the study of Durmaz (2014), it is inconsistent with the study of Güler and Didiş Kabar(2017).One of the reasons why the results differed in terms of the use of the "Drawing Tables" strategy may be that the learning area of "Data Processing" was scheduled for a later term in the curriculum. This strategy may not have been used because the acquisition of the "Data Processing" learning area could not be gained by the student. Another reason for not using this strategy may be due to the type of modelling problems. In addition, the students did not make any use of the "Table Drawing Strategy" in their experimental modelling problems. While the students were editing the data they found in the experimental modelling problems, they took the easy way out and wrote the data in the empty spaces in the tables given in the problem statement. In experimental modelling problems, the presence of tables originating from the structure of the problem may be due to the "Table Drawing Strategy".Students benefited from this strategy only in theoretical modelling problems (Mattress problem).This may have arisen as a result of the inability of the students who collected data to solve the theoretical modelling problems to cope with the excess data.

Arslan and Altun(2007)stated that seventh and eighth grade students used some strategies informally in their pre-test before strategy teaching was given, but they never used the strategies of searching for correlations and working backwards. In this study, the problem solving strategies used by the students in the mathematical modelling process were examined without any problem solving strategy training, and when the problem solving strategies used by the students in all model eliciting activities were examined, it was observed that they never used the "Working Backwards Strategy".Similar to the findings of this study, in Yazgan's(2007) study, students could not adopt the "Guessing and Control Strategy" and "Working Backwards Strategy" in solving non-routine problems. According to Posamentier and Krulik(2016), it may be difficult for students to use this strategy professionally in solving problems. The fact that students do not use this strategy in model eliciting activities may be due to the structure of the problems. Since model eliciting activities are open-ended problem situations, it may not be possible to reach the initial state as in other problems.In addition, reasons such as the fact that some problems do not provide sufficient data for problem solving may have prevented the use of this strategy.Students can develop original strategies in real-life situations through model-eliciting activities that provide a context suitable for the use of different strategies. Model eliciting activities should be included more in mathematics teaching programs in order to enrich the strategy repertoire of students in accordance with real life situations.

It is recommended to carry out long-term studies to determine the problem solving strategies used in mathematical modelling and to use different modelling activities in these studies. Furthermore, it can be suggested to generalize the data by conducting experimental studies on the strategies used by the students in the mathematical modelling method.

Within the scope of this study, problem solving strategies used by students in experimental and theoretical modelling problems were examined. It is recommended to carry out studies on dimensional analysis and simulation modelling, since it will provide a more holistic view of students' problem-solving strategies. In addition, it is recommended to investigate which strategies the students use in the modelling steps of the mathematical modelling process

During the modelling process, students may be inclined to think about different strategies regarding the problematic situation and not to express them. In order to reveal different strategies, it is suggested to

reveal the strategies that students think about by designing a suitable environment for in-group interaction.

By including mathematical modelling problems in their lessons, teachers can enable students to develop problem-specific strategies. Therefore, in-service training on mathematical modelling should be given to teachers. Authors should also include problems involving mathematical modelling in their books. In addition to non-routine verbal problems, model-eliciting activities and the strategies that can be used in these activities should be included more intensively in the books prepared on problem solving strategies.

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Bu çalışmada, Yükseköğretim Kurumları Bilimsel Araştırma ve Yayın Etiği Yönergesi'nde belirtilen tüm kurallara uyulmuştur. Yönergede Bilimsel Araştırma ve Yayın Etiğine Aykırı Eylemler başlığı altında açıklanan eylemlerden hiçbiri gerçekleştirilmemiştir.

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Atatürk Üniversitesi Sosyal ve Be

şeri Bilimler Etik Kurulu Eğitim Bilimleri Birim Etik Kurul başakanlığı, 03.02.2022, Toplantı sayısı: 02 Karar no: 07

Yazarların Katkı Oranı

1. yazarın araştırmaya katkı oranı %60, 2. yazarın araştırmaya katkı oranı %40'dır

Çıkar Çatışması

Araştırmada herhangi bir kişi ya da kurum ile finansal ya da kişisel yönden bağlantı bulunmamaktadır.