Education and Science tedmem

Vol 41 (2016) No 183 47-67

Modeling Processes of Primary School Students: The Crime Problem

Neslihan Şahin [1], Ali Eraslan [2]

Abstract

In recent years, mathematics educators have frequently stressed the necessity of instructing students about models and modeling approaches that encompass cognitive and metacognitive thought processes, starting from the first years of school and continuing on through the years of higher education. The purpose of this study is to examine the thought processes of 4th-grade primary school students in their modeling activities and to explore the difficulties encountered in these processes, if any. The study, of qualitative design, was conducted in the 2013-2014 academic year at a Foundation School operating under the auspices of a state university located in a central city in the Black Sea Region of Turkey. A five-week preliminary study was first implemented with designated 4th grade students, after which the criterion sampling method was used to select three students that would be recruited into the focus group. The focus group that was thus formed was asked to work on the model eliciting activity of *the Crime Problem* and the entire process was recorded on video. A written transcript was made of the video recording, after which the recording and the students' worksheets were analyzed using the Blum and Ferri modeling cycle. The results of the study revealed that over the course of the process, the students tested the hypotheses related to daily life that they had set up, generated ideas of their own, verified their models by making connections with real life, and tried to make their models generalizable. On the other hand, the students had difficulty with understanding the problem and interpreting the qualitative data.

Keywords

Primary school students
Model eliciting activity
Mathematical modeling
Modeling process
Crime problem

Article Info

Received: 02.10.2016
Accepted: 27.01.2016
Online Published: 17.02.2016

DOI: 10.15390/EB.2016.6011

Introduction

In the technology-based age of information in which we live today, daily life is under the influence of constantly changing dynamics and complex systems, particularly in fields which make concentrated use of mathematics and technology (engineering, architecture, medicine, statistics, economics, etc.) and these complexities make it necessary to create more flexible, creative and even more complex solutions for the problems that may be encountered (Lesh & English, 2005). Educating individuals that will be able to interpret these complex systems and who have the skills to identify, explain, construct, verify, conjecture, predict, and engage in analytical thinking and working in a team

[1] Ondokuz Mayıs University, Faculty of Education, Department of Elementary Education, Turkey, shn.neslihan@gmail.com
[2] Ondokuz Mayıs University, Faculty of Education, Department of Elementary Education, Turkey, eraslanali@gmail.com

has become one of the most important goals of education today (English & Watters, 2004; Eraslan, 2012). Since it is not possible to know when and which kind of difficulties people will encounter in their daily lives or predict what type of needs they will have, each individual in society, in order to cope with complex daily problems, needs to be accustomed, beginning in childhood, to confronting challenging problems that are closely connected with real life (English, 2011). *Modeling activities* offer students new and enriched opportunities that are introduced to them in the effort to educate individuals who will be able to use mathematics effectively in their lives, make the connection between mathematics and life situations, cope with challenging problems, produce different solutions for problems encountered, and engage in analytical thinking (Blum & Niss, 1991; English & Watters, 2005; Eraslan, 2012; Lesh & Doerr, 2003). Besides seeking to develop mathematical concepts, the primary school program in Turkey also targets the development of some important skills and emphasizes in its program description the significance of the skills of problem-solving, communicating, reasoning and making connections: "Students learn to solve and analyze problems, share their ideas, explain and present arguments, make connections with mathematical concepts both within the field itself and also in relation to other disciplines, thus effectively enriching their store of mathematical concepts as they study mathematics." (MoNE, 2009, p. 8) The program openly states that problem solving is an integral part of the mathematics course and points to its significance and place in mathematics instruction.

That Turkey is behind other countries in educating students that are able to develop the higher order skills underlined above has been revealed in the report of the International Association for the Evaluation of Educational Achievement (IEA). In international assessments such as TIMSS (The Trends in International Mathematics and Science Study) and PISA (Program for International Student Assessment), the average performance of Turkish students is much lower than their OECD (Organization for Economic Cooperation and Development) counterparts (MoNE, 2005, 2007, 2010, 2013; OECD, 2003). In particular, according to the results of PISA-2012, mathematics proficiency level of Turkish students in the sixth stage, which measures the ability of mathematical modeling, is 1.2 % (MoNE, 2013). This rate is far below the OECD average of 3.3 %. For this reason, introducing young pupils to modeling activities that portray complex real-life situations, particularly from the early days of primary school, and equipping them with high order skills may be an effective method of preparing individuals for the age of technology-based informatics (English, 2011; Şahin, 2014).

A look into the international literature on modeling activities conducted at the primary school level reveals that such practices: (a) give students the opportunity to repeatedly express their thought processes and to test, review and change their ideas (English, 2011); (b) significantly improve students' use of mathematical language, skill in working in a group, engaging in social interaction, reading data on a table and using graphs (Watters, English, & Mahoney, 2004); (c) develop metacognition and analytical thinking skills (English & Watters, 2004); (d) ensure the elimination of deficiencies of conceptual knowledge in young children (English & Watters 2004); and (e) help students to identify the main ideas and processes of a problem, prioritize the elements of a problem, discover the relationships between its parameters and make mathematical calculations by quantifying qualitative data (English, 2007). On the other hand, it has been determined that some students have difficulty with (a) interpreting and understanding data given to them in various representative formats (English & Watters, 2004), (b) transforming data into different representative formats (English, 2012), (c) making systematic presentations of their most recent models (English, 2003), and (d) determining the appropriate parameters (Doerr & English, 2003). An investigation into the national literature in the field shows that there are a limited number of studies on modeling activities and that these have been mostly designed for academic levels that start from middle school up to the last year of university (Delice & Kertil, 2015; Doruk & Umay, 2011; Eraslan & Kant, 2015; Kal, 2013; Sandalcı, 2013; Tekin Dede & Bukova Güzel, 2013). In this context, only one study was seen in the literature that treats the modeling processes of students at the primary school level (Şahin, 2014). The author of this study has investigated modeling processes related to a modeling problem selected for 4th grade primary school pupils and examined the difficulties encountered in this process. This qualitative study has shown that students work successfully with modeling activities but have trouble with understanding the problem and the construction of the model. It is important that research continues so that the gap in instruction related to modeling can be filled at the primary school level and it can be determined how well primary school children are prepared for middle school, high school and for later in life in terms of the task of solving the real-life problems that they will inevitably come across in their professions or as ordinary citizens. Meanwhile, in line with the new education system of 4+4+4, mathematical modeling has taken its place in the current primary (1-4) mathematics curriculum as one of the six basic mathematics skills (MoNE, 2015). In particular, the new curriculum emphasizes that primary school students are able to solve the problems in their everyday life in using their own mathematical knowledge with the help of mathematical modeling (MoNE, 2015). In addition, during the process of modeling, students are able to (a) simplify complex problems in making predictions and assumptions, (b) identify quantities in the real-life problems, (c) represent relationships among quantities using tables, graphs, and formulas, and (d) analyze relationships in order to make interferences (MoNE, 2015). It is for this reason that this work seeks to review the modeling processes carried out by primary 4th grade pupils and to set forth the difficulties that are encountered in this process while at the same time contributing and adding depth to the currently limited literature on this subject.

Theoretical Framework

While *modeling* is the process of creating models through interpreting events and problems (identifying, explaining or constructing) and finding patterns and using different schemes to arrange, coordinate, systematize and organize the problem in one's mind, *models* are conceptual systems that exist in the student's or problem solver's mind and encompass the equations, diagrams, computer programs or concretized representations in the media that they use to solve problems (Lesh & Doerr, 2003). The relationship between a model and modeling is likened to the relationship between a product and a process (Sriraman, 2005). *Mathematical modeling* in this context is a systematic process whereby a mathematical or non-mathematical condition of real life is expressed as it can be expressed mathematically, by using numerous metacognitive activities such as analysis, synthesis and interpretation (Swetz & Hartler, 1991). Lesh & Doerr (2003) have defined mathematical modeling as a stage in the process of creating modeling activities, or rather as a process that is realized during the course of modeling activities. For this reason, in its broadest sense, *Modeling Activities*, differing from traditional problems, consist of problems devised to allow pupils to work in small groups where group members are asked to produce creative solutions to construct a generalizable model of a problem that relies on more than one hypothesis-based solution, contains possible alternative solutions, is non-routine and can be associated with real life (Lesh & Doerr, 2003).

Lesh & Doerr (2003) have emphasized that modeling activities give students the opportunity to turn a real-life problem into a mathematical problem, decide on how the problem is to be solved and on how to develop ideas, plan, revise and make a decision about whether or not more comprehensive thinking is necessary, whether the student's thoughts meet the conditions and hypotheses of the problem, thus developing the student's investigative and exploratory skills. Students who are confronted with modeling activities must discuss the content of the problem in order to be able to reach their goal of solving it (Doyle, 2006). Students spend most of their time in this atmosphere of discussion, developing different ways of thinking about related relationships, structures and data. In this process, what they change or transform during the course of the activity represents their characteristic way of thinking about data. These characteristic ways of thinking, it is stressed, lead students into metacognitive thinking about the procedures during the modeling activities and direct them into thinking beyond the procedures (Lesh, Lester, & Hjalmarson, 2003). In effect, students working with modeling problems influence each other's thinking patterns and become involved in a learning process in which metacognitive thinking processes evolve in different environments of thought, urging the student to consider more than one multi-faceted alternative and cycle. In this process, to which there are critical approaches, the students are also provided with the opportunity to give each other feedback about the different models constructed.

The goal of the modeling activities is not only to develop models that students will find beneficial in their effort to conceptualize their mathematical thoughts and processes, but also to reveal their understanding of the problem itself. Lesh & Doerr (2003) have reported that modeling activities allow children to make mathematical descriptions, explanations, find the reasons behind the explanations and develop their arguments. The models arrived at as a result of these activities are constructed on the basis of significant mathematical structures, patterns, arrangements and require multiple cycles of interpretation, description, hypothesizing, explanation and reaching conclusions, all necessitated by the nature of the progress of the problem-solving (Lesh & Doerr, 2003). One of the cycles is represented by the modeling cycle developed by Blum and Ferri (2009) that was used in the analysis performed in the study:

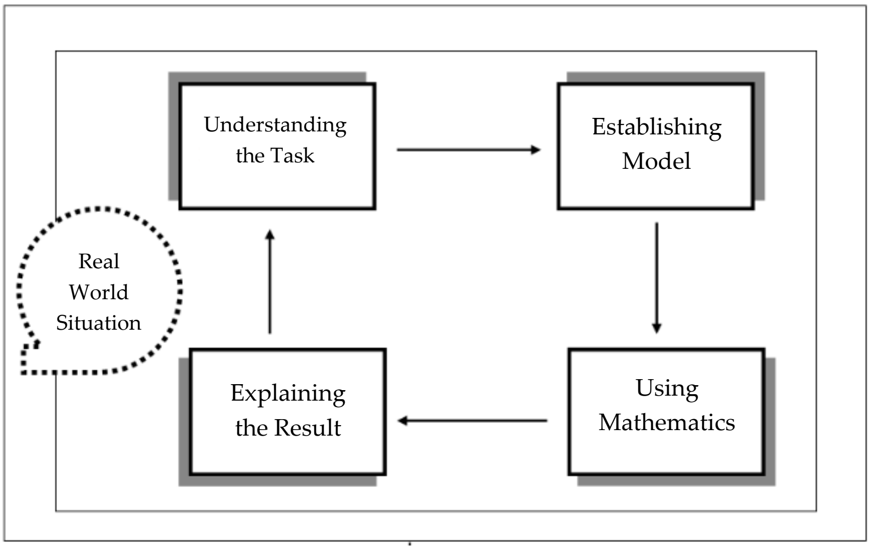


Figure 1. Blum & Ferri's (2009) Four-phase Solution Plan for Modeling Problems

Emphasizing that these steps do not have to occur in linear fashion in a particular order, Blum & Ferri (2009) explain the four phases of the modeling cycle as follows: At the *understanding the task* phase, in order to understand a problem that has been taken out of the context of daily life, the student performs tasks such as reading, imagining, drawing and reading tables that have been designed to bring simplification to the problem at hand. In *establishing models,* students create the data needed, find and recognize the relationship and rules, become aware of the patterns and form a hypothesis. In the *using mathematics* step, the students are expected to determine the appropriate mathematical concepts, perform the suitable mathematical operations and thus reach a mathematical solution at the end of these operations. The cycle ends with the students' checking the accuracy of what they have done, verifying the validity of the model by comparing the result with real life and reporting the solution, all of which make up the *explaining the results* phase, the last in the cycle. The order above is not a linear order (understanding the problem, setting up the model, mathematizing, explaining the result) but is the order of the thinking processes of the students in the study as they analyze the data.

Method

This is a qualitative study that was conducted to use modeling activities to examine modeling processes in primary school 4th grade students and to identify the challenges faced in this process, if any, along with the reasons for the difficulties. The research design was a case study, using a single group and in-depth review and analysis (Merriam, 2013). The case in this study consists of a focus group of three individuals who were chosen in the effort to determine thinking processes.

Study Group

The study was conducted in a classroom of eighteen 4th grade students in the 2013-2014 academic year at a Foundation School operating under the auspices of a state university located in a central city in the Black Sea Region of Turkey. A preliminary application was performed before the actual study commenced. The researcher took an active role as a practitioner-teacher in the process while the classroom teacher was observer in the whole process. In this preliminary study, six groups of students of three individuals each who were chosen from among the students' own group of friends, were given the task of creating a different model every week for five weeks and the students were asked to work together on these activities. At the end of the study, each group presented their conclusions to the other groups and explained how they had determined the structure of their models. Later, a focus group of three students was selected through the sampling technique of criterion sampling to take part in the actual study. The criteria below were used to select the groups: care was taken to ensure that (a) the students would be able to work in harmony for five weeks; (b) the problem could be solved "as a group"; (c) the students had high self-confidence and the ability to freely express and verbalize their thoughts. Instead of selecting the students one by one, the actual application was carried out by choosing the group that best provided the criteria.

Data Collection Instruments

After the preliminary study, the study group of three students that was selected from the class with the purposive sampling method was asked to work on the modeling activity of *the Crime Problem.* The Crime Problem was adapted from the study of Doerr and English (2003), and translated into Turkish language. Care was taken to ensure that statements in the problem were appropriate to the age level of children. This problem consists of a table of data belonging to different crimes occurring in twelve cities. The six crimes in the table are divided according to the annual average crime rates of *crimes of violence* and *crimes against goods and property*. Additionally, another column in the table shows the *increasing or decreasing* trend exhibited in the crime rate in the last 5 years. The students are asked to use the data in the table to develop a method which can help them decide on whether the city they live in is the safest among the cities displayed and then write a letter explaining how they found this method. In particular, they are asked to devise a system that can be used to determine if a particular city (e.g., Antalya) on the list of cities is "safe enough" or warrants increased expenditures for the police budget. It is expected that although violent crimes against persons have lower overall rates, they would be considered more important for decisions about safety than property crimes. Then, the students can take this difference into account when assigning new scores or coefficients to each city according to its frequency of highest crime ratings among the remaining cities and they can develop a generalizable model.

In the *Crime Problem*, the students are expected to use the experience they attained from the preliminary study and simplify the quantitative data, interpret it, put it in order, analyze and combine it, and then make a connection between the qualitative and quantitative data. Moreover, the problem is a modeling activity that gives students the opportunity to present the data in different representative formats, create a generalizable model that can be derived from different hypotheses and one that can be used in other situations. It gives them the chance to prepare a written report on the analyzed data, work in a group and share the results of their work, using their skills to make a presentation in written and verbal form (Doerr & English, 2003).

In the focus group session, which took a total of 90 minutes, a video recording was made and then transcribed; the students then engaged in qualitative analysis, relying on their worksheets and observation notes to perform this task. Before the focus group session started, the students and their families were given information about the study, told that their performance in the activity would not be evaluated with a grade in any way, and that their real names and images would not be used. They were additionally informed that the study would make an important contribution to developing and changing the primary school mathematics curriculum. During the work, no dialogue was carried out with the student to advise them or interact with them for any reason.

Data Analysis

The mathematical thoughts developed by the 4th grade students in the study during the solving of the *"Crime Problem"* as well as their written responses were analyzed with the method of descriptive analysis. Descriptive analysis encompasses the stages of: (a) creating a framework for analysis; (b) working with the data according to a thematic framework; (c) identifying the results; and (d) interpreting the results (Yıldırım & Şimşek, 2011). For this reason, the thinking processes of the primary school 4th grade students in the focus group during the modeling activities were analyzed using the modeling cycle developed by Blum and Ferri (2009). To increase the internal reliability or credibility of the study, in order to achieve a longer span of interaction with the study group, the researcher attended the class as an observer for two weeks before beginning the preliminary study, participating in the classroom discussions and interacting with the students. The preliminary study was then implemented; this was a five-week period of modeling activities prior to the actual modeling activities, conducted to establish an environment of trust in the classroom. To ensure credibility, the observation notes taken during the process were evaluated along with the students' worksheets, the video analysis and the results reports to create a diversity of data. Furthermore, two colleagues of the researcher with doctoral degrees in education and experience in qualitative research from the same university were asked to review the processes and categories of the modeling so that a consensus could be reached. At the same time, to make sure that the results obtained could be transferred to other similar settings, the researchers benefited from the methods of detailed description and purposive sampling (Yıldırım & Şimşek, 2011). In detailed description, the setting and the participants are identified in rich and intensified detail while results are identified and supported by references to the participants' discussions, research notes and documents (Merriam, 2013).

Results

Modeling Processes

The modeling processes of the focus group students in their attempt to construct a model by revealing and writing down their mathematical thoughts are described below. The boys in the group were given the fictional names of Anıl, Berk and Mahmut.

Using mathematics: After the modeling activity was passed around to the students, the researcher read through the problem with them and the students reviewed the data table. Of the students reviewing the data table, Berk expressed his thoughts in this way:

Berk: *We'll add them all together and see.*

Researcher: *Why are you adding?*

Berk: *Sir, I'll add up all the crimes there are here. If I do half of these, I'll find the one with the lower crime rate. I'm going to add them all up. I'm going to look at how much burglary has occurred.*

In the excerpt above, Berk says that he will first find out "*how many crimes there are*", and then "*add up*" all the numerical values given in each category, thus starting the mathematizing step of the process.

Establishing the model: After Berk's above thoughts, Mahmut expressed his ideas as below as he started to calculate the sum of the crimes in all of the cities in the table (Figure 2):

> ***Mahmut:*** *What I will do is go over all the crimes... In this order. I'll add up Rize's. I'll do them all this way. I'll add up all the cities in this order (pointing to the crimes of violence column). Then I'll compare them all. The one that's the lowest is the safest. I'll do the same for the other rows too. Then I'll add up the whole row. Then I'll look at the increases (pointing to the crime trends for the last five years column). There's very little crime in one city but the crime has increased over the last five years. Then that city will drop to the second level, to the third level. But if it's decreasing in a city, if its even twice the one before, if it has decreased in five years, then that one will fall down to the second level and be the same as the other ones.*

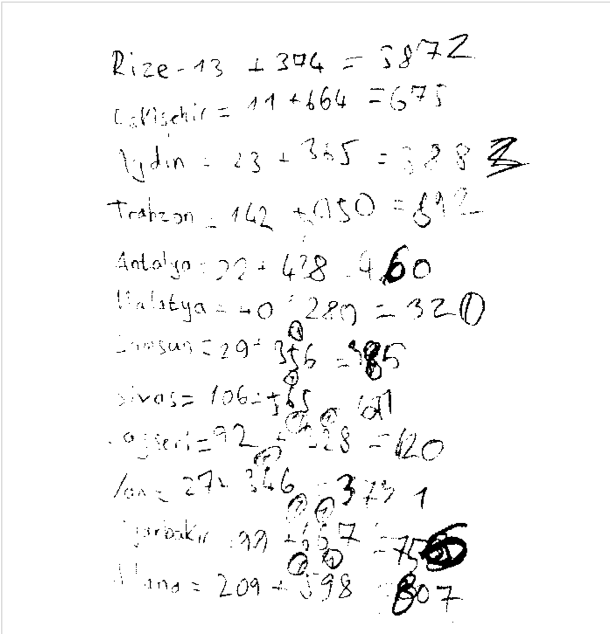


Figure 2. Calculating the Total Crime Rates for Each City

In the excerpts above, Mahmut tries to develop a model by considering more than one factor in his calculation. He says first that he will "*add up*" all of the crime rates in Rize, which is at the top of the *Cities* column and then says that he *"will do the same with* all [the cities*],"* showing that his approach is similar to Berk's. Mahmut also "*adds"* the data for the crimes of violence and "compares" them to find *"the city with the lowest number"* of crimes, setting forth the hypothesis that that city is *"the safest"* and evaluating each of the crimes in the main category separately. Besides this, *adding the crime trends in the last five years* column to the process, he says that if a city has an increased crime trend even though the *crime rate* is low, he will take it "*down to the second level,"* in other words, assess it as a less safe city, thus explaining how this factor will find a place in the model he is creating. On the other hand, even if the crime rate is "*twice*" that of another province, if there is a decrease in the *crime trend*, he says it will be treated in the same order as the other city, thus emphasizing the importance of the "*crime trend*" factor in the model he is constructing.

Understanding the task: As Mahmut was trying to develop the model, Anıl was in the process too and asking the researcher the concepts he did not understand in the problem:

> ***Anıl:*** *Sir, I'm going to guess but there's a place I don't understand. It says increasing, decreasing (pointing to the crime trend in the last five years column), I didn't understand what that means.*
>
> ***Researcher****: That crime in five years...*
>
> ***Anıl:****But how much did it increase, how much did it decrease?*
>
> ***Researcher****: It has shown an increasing trend. We don't know how much it has increased or decreased.*

In the excerpts above, Anıl says that he has difficulty understanding the expressions "increasing" and "decreasing" in the *crime trend in the last five years* factor. Instead of solving the issue with his friends in the group, he has asked the researcher directly "*how much of an increase*" or "*how much of a decrease*" there has been. In this stage, it was observed that instead of working together on the problem, the members of the group acted independently, trying to find their own individual solutions.

Establishing the model: After overcoming the difficulty he encountered in the understanding the problem step, Anıl described the model he developed in this way:

> ***Anıl:*** *For instance, Antalya's hasn't changed (pointing to the crime trend in the last five years column). Then I'll first add Antalya's. Then I'll add the other cities. Because Antalya hasn't changed. There are others that are increasing-decreasing. Antalya hasn't changed, so I'll put a 1 on Antalya. I'll add all of the good ones and find which one had a lesser crime rate in the last five years first. Then I'll find the one that had more.*

In the excerpts above, Anıl first starts to think about the data on the *crime trends in the last five years*. In the data for the *crime trends* in the last five years, besides *increases or decreases,* he also "added" the data on *Antalya,* the city where there were no changes and used the total crime rate of this city as a reference point (median). Thus Anıl categorized the cities that had a decreasing crime trend as "*good*." After adding the *crime rates* of the cities designated as "good," Anıl said he would put these in order according to the increase and decrease in Antalya, stating that this way he would find the city with the lowest crime rate. At this time, Berk was saying that the city of *Samsun*, which had been mentioned in the problem, was not "*the safest city*" and so he discussed with Mahmut the matter of how to interpret "*crime trends*" as follows:

> ***Berk:*** *Samsun is not the safest city, sir. See, it has shown an increase (pointing to the increasing crime trend).*
>
> ***Mahmut:*** *No, but this is how we're going to find this. It says annual average values here. We'll multiply this by five (pointing to the crime trends in the last five years column). Let's say we'll multiply the total of these in Rize (pointing to the crimes in the Rize row) by five. Then we'll find the increase in five years. If there is no increase, we'll divide it by five.*
>
> ***Berk:****How's that? That's very silly. Why would you divide it? If there's no increase, it'll remain the same.*
>
> ***Mahmut:*** *No! But it decreases over the five years...*
>
> ***Berk:*** *No, it doesn't. It does. I don't think that makes any sense...*
>
> ***Mahmut:*** *Why are you multiplying here for instance? If the annual average value increases this much, in five years--you'd have to multiply it, in other words. If it didn't change (pointing to the crime trend in Antalya) we'll still multiply. Why would we multiply? It hasn't changed in five years. Over the five years.*
>
> ***Anıl:*** *Do you have a calculator?*
>
> ***Berk:*** *That's very illogical, right? It's already a lot, if you multiplied by five, it would be even greater. Why would you have to multiply it?*
>
> ***Mahmut:*** *You divide it at the same time.*
>
> ***Berk:*** *What do you mean--at the same time? You don't know how much it's decreased.*
>
> ***Mahmut:*** *OK, so divide it by 5.*
>
> ***Berk:*** *Has it decreased by 40%, 95%? How can I find it by dividing by five?*
>
> ***Mahmut:*** *Yes, that's right, every year isn't the same.*
>
> ***Berk:*** *When you multiply by five and then divide by five, you get the same answer!*

In the excerpts above, Berk has said that *Samsun* isn't the safest city because of the increase in the crime trend. Upon that, Mahmut stresses that on the basis of the "*annual average value*," in cities that have had an increase in the crime trend over the last five years, the total crime rate should be "*multiplied by 5*" and in cases where there is a decrease, it should be "*divided by five"*. Insisting on his opinion, Mahmut continues to explain why he multiplied, pointing to the *"annual average value"* and the *trend in the last five years*. Berk doesn't share Mahmut's opinion and tries to make the point that if a city's annual average value is greater than another's, when it is multiplied by five, *"it will be greater*" and this will not do anything but make the values larger. Then Berk says that because the magnitude of the falling trend in the table is unknown, it should not be divided by five, and convinces Mahmut that multiplying or dividing by five comes out "*the same*," thus causing Mahmut to give up his model. The approach of totaling of each crime rate multiplied by five is an application of the primitive form of weighted mean. At this stage, Mahmut has created the *mean* and *weighted mean* concepts on his own during the process and, pointing out what mathematical calculation he will perform, tries to express the concept of *trend*.

Using mathematics: At the end of the discussions, the group is unable to reach a joint decision about a model and continues to discuss the situation in this way:

Anıl: *To me, I think the best idea coming out from these discussions is mine. I think we should get everybody's idea. Then we'll choose the most appropriate among them. Let us all find the answer first. But let's not do it one-on-one!*

Mahmut: *We're doing them one-on-one now but we'll talk about it.*

Berk: *I've already eliminated Aydın's. There are too many crimes. Even if it fell (a decline in the crime trend), there are still crimes.*

Berk: *And I eliminated Trabzon.*

In the above excerpts, Anıl said that his model was the *"best idea*" and pointed out that to choose "*the one that is the most appropriate,*" everybody had to offer their opinion. The other members of the group started to do the calculation of finding the total crime rates by using the model that Berk had developed, *"adding every value in each column"* and finding the answer that way. During all of this, Berk, who evaluated the crime rates and compared these with the cities for which he had calculated results, said that *Trabzon* and *Aydın* "*had too many crimes*" and should be eliminated.

Establishing the model: Each group member added the total crime rates for the cities and then discussed how to put the crimes in order of importance:

Anıl: *Sir, let me ask you something. Crimes of violence; crimes against goods and property...*

Mahmut: *Damage to property is better because the others involve taking a person's life. You can say "Better property than a life." That means let crimes of violence be very little. Let there be a lot of crimes against property and goods; I'll choose those. I'll choose these first because they're safe; these (pointing to crimes of violence) are a worse crime. Robbery is even worse...*

Berk: *Right. For instance, they burn up parks all around Turkey; they tear the swings apart. That's less. But if someone chopped somebody up with an ax, I wouldn't prefer that to anything else.*

Anıl: *For instance, fights break out in the stadiums. They burn down the bleachers; they burn the grass...*

Researcher: *What are you trying to say?*

Berk: *Violence is worse than that!*

Anıl: *For instance, there's a Galatasaray-Fenerbahçe match. And Galatasaray wins by, let's say, 12-1. The Galatasaray fans tear up the grass. That's a crime too...*

Mahmut: *But they don't put them in jail. They just interrogate them and then they leave, swinging their arms.*

Berk: *Molestation is a very bad thing. People use force and they can tie people in a corner or they can shoot them. Since we don't know this, this is the most important crime (pointing to the crime of homicide).*

Mahmut: *I'm throwing this out (pointing to the crime of homicide). There is no safety in that. The city of Aydın, for example, is good. There's a homicide there only once in a while.*

The excerpts above show that at this stage, the students try to categorize the crimes in the data table and evaluate the cities accordingly. In evaluating *crimes of violence* and *crimes against goods and property*, the students have stressed the importance of "*human life*" and have declared that crimes against goods and property are "*more acceptable*" than crimes of violence. Thus the students said that *crimes of violence* "*should be less*" and that *crimes against goods and property*, although they might signify more of a monetary value, if that city has *"the lowest number" of crimes of violence,* then that city will be declared safer. To determine the degree of importance of the crimes in these two categories, the students associated the situation with their different daily life situations and evaluated the sub-categories of these two categories (*Homicide, Robbery, Assault&Battery, Burglary, Theft, Auto Theft)* in order of their importance. The students defined *homicide* as the most important crime and then turned to the table and identified the city of Aydın as "*good*" or safe because *homicide* occurred there only *"once a year"*.

Using Mathematics: Starting off from the model they developed, the students examined the homicide rates in the cities and went on with their discussions as below:

Mahmut: *Let's first eliminate Adana. We can eliminate Diyarbakır, and also Trabzon...*

Anıl: *Samsun and Malatya have the same total!*

Mahmut: *What are you doing (asking Anıl)? Are you adding these (pointing to the column of crimes of violence)?*

Anıl: *Yeah!*

Mahmut: *But Berk is doing the same thing.*

Berk: *76, 99…*

In the excerpts above, Mahmut has stated that he has "*eliminated*" the cities with the highest crime rates in the *homicide* category, which are *Adana*, *Diyarbakır* and *Trabzon*. Despite the discussions above, Anıl has continued to try to calculate the total crime rate in the cities in the model the students previously devised. Because his approach was the same as Berk's, the other members of the group have ignored him.

Establishing the model: The members of the group evaluated and categorized the crimes in the table (*Homicide, Robbery, Assault&Battery, Burglary, Theft, Auto Theft*), starting their discussion and classifying *crimes against goods and property* in this way (Table 1):

Mahmut: *Is Auto theft better than burglary?*

Berk: *Automobile theft.*

Mahmut: *Because in burglary, you could steal something that's worth 130 billion. But purse snatching is worse... Because the purse might have a card in it, a house key, a car key. If a thief came and snatched a purse, the whole house and the car might go.*

Berk: *How will he know which house it is?*

Anıl: *But the credit cards have passwords.*

Mahmut: *Couldn't you tell which car it is from the car keys?*

Berk: *Nope, there are so many Nissans. There's Nissan qushquia. Which one are you going to find? Are you going to try the ignition of every car?*

Mahmut: *Auto theft is worse because I looked (at the table) and this has been done less (pointing to the auto theft column), and so has this (pointing to the purse-snatching column).*

Berk: *Because this is harder (pointing to the auto theft column). This one is easier (pointing to the purse-snatching column).*

Mahmut: *I think auto theft is the first one, this one (burglary) is second, and this one (purse-snatching) is third...*

Berk :*Is this one (pointing to auto theft) important?*

Mahmut: *Yes!*

Berk: *Why?*

Mahmut: *This is more important... It's very rare.*

Berk: *Because it's hard to do. Now, would you go steal a car as you're just casually walking down the street?*

Mahmut: *They steal them at night.*

Table 1. Classifying Crimes Against Goods and Property

ŞEHİRLER	ŞİDDET İÇEREN SUÇLAR (Yıllık Ortalama Değerler)			MÜLKE (EŞYAYA) ZARAR VEREN SUÇLAR (Yıllık Ortalama Değerler)			SUÇ EĞİLİMİ (Son 5 Yıl İçinde)
	Cinayet	Gasp (Güç Kullanarak Soygun)	Darp (Saldırı- şiddet-taciz)	Ev Hırsızlığı	Hırsızlık (Kapkaç)	Otomobil Hırsızlığı	Artan ↑ / Azalan ↓
Rize	4	3	6	56	304	14	↑
Eskişehir	2	2	7	134	498	32	↑
Aydın	1	2	20	50	299	16	↓
Trabzon	18	32	92	186	497	67	↓
Antalya	2	4	16	90	325	23	Değişmedi
Malatya	4	16	20	60	162	58	↑
Samsun	3	10	16	83	257	16	↑
Sivas	9	53	44	103	367	95	↑
Kayseri	5	8	79	125	177	26	↓
Van	2	3	22	62	271	13	↓
Diyarbakır	15	23	61	185	421	61	↓
Adana	24	107	78	131	315	152	↑

karşılaştır

The excerpts above show that the students divided the category of *crimes against goods and property* according to "*importance*" under the crime sub-categories of *burglary, theft (purse-snatching), and auto theft*. During their discussion, the students expressed their thoughts and formulated their arguments frequently by making associations with their daily lives. When Mahmut looked at the table and classified the crimes by assuming that "*less committed crimes*" or "*rarely committed crimes*" are harder to carry out, he qualified them as one being "*worse* than another. He then put the three categories in order, starting from the most difficult to the easiest: *auto theft, burglary* and *purse snatching*. Although the students defined the crimes in the sub-category according to "*importance*" as being *auto theft, burglary* and *purse snatching*, they did not use this new model but instead continued to calculate the total crime rates according to city as in the previous model. Mahmut became uneasy when the others ignored the model that he had come up with and continued the discussion by saying,

Mahmut: *Hey, you're adding these up now. Aren't you both doing the same thing? You know what we should do? Anıl and I will look at these. You're fast;, you do these. Burglary is very rare. Auto theft is very rare. Let's find the one that's important, let's find the city where it's rare. Let's look at the other crimes in that city. Are the others rare too? If they're not, let's look at the next rare one. If they're all good, let's choose this one as the safest city.*

Berk: *That's what we're doing.*

Mahmut: *So which is the rarest (asking Anıl)?*

Mahmut: *Aydın I think is a very nice city. Rize is good too.*

Mahmut: *Aydın is the best in homicide, the best in robbing. The best in battery...*

***Researcher**: What does "the best" mean?*

***Mahmut:** That homicide is very rare. Homicide in the last 5 years; it's also in second place in battery and it has decreased over the five years...*

***Anıl:** I think it's Rize! But Rize's is increasing.*

***Mahmut:** So there are two rare ones. This one (pointing to Aydın) has three or four. This one (the province of Aydın) has four rare ones.*

***Berk:** Mahmut, you do these calculations here. The grand totals. And let me think a bit.*

***Berk:** Mahmut is right. First of all, Rize isn't the rarest (looking at the table).*

***Mahmut:** It's not the rarest because this one (Aydın province) has four rare ones.*

***Berk:** Wait a minute, wait a minute. Aha--"13". How did you find Rize (in the auto theft column)? Didn't you see the "13"? Van! That's (14) wrong. "160" in burglary and purse snatching is right! Yes, and so is this (pointing to the burglary column). This is right (looking at the third column) too. This one could be too (marking Eskişehir in the second column)... Yes, he's right. Aydın is the best.*

Mahmut, who assigned the jobs to the others in the excerpts above, emphasized that the "*important*" crime was the one that was the "*rarest*" meaning that their task was to find the city where these "*important crimes*" were committed *the least*. Then, looking at the crime rates in the other categories, he asserted that in "*the other crimes,*" they would choose the "*rarest"* one as the safest city. The students then made a verbal comparison of each city in terms of the crime rates in each category and sub-category according to which one was "*the best"* where *robbery* and *battery* were *rarest*, in other words, naming *Aydın* as the city with the lowest crime rates. Also, Mahmut stated that the reason for this was that in the sub-categories of *homicide* and *assault&battery*, since its crimes had the lowest rates (respectively, homicide:1 and battery:2), and *crime was on a downward trend in the last five years, Aydın* was the safest city. Anıl however, was hesitant about *Rize* because although it was found to be the safest city, it had a *rising crime rate*. Mahmut pointed out that *Aydın* had *"three rare crimes"* (*homicide*:1, *robbery*:2 *burglary*:50) and that three of the six sub-categories in this city represented the least number of crimes. As a result of these discussions, Berk calculated the total crime rates of both main categories, and then left his calculations to go back to the table. He stressed that he agreed with Mahmut and said that *Aydın* was "*the best*" meaning that the students had now chosen this city to be the safest. Additionally, a review of Table 1 given above shows that the *crimes of violence* and *crimes against goods and property* have been placed in order of importance and that the most important crimes are *"crimes of violence"*. The crimes in the sub-categories have also been placed in order of importance, designated by the values 1, 2 and 3.

Explaining the results: In the report they wrote about the model they had developed (Figure 3), the students explained their model as follows:

***Berk:** The best city here is Aydın because it has the least number of homicides compared to the other cities.*

***Mahmut:** It has the fewest number of crimes...*

***Berk:** There are fewer assaults and fewer burglaries and there has been a decrease in total over the five years. When you add up all of the crimes, I'll think about the average. Where's my calculation sheet? If you look at the average, Aydın... Wait, let me calculate it first. Mahmut, you haven't added these up. Add it up and let me do the calculation. Let me explain on this (pointing to the data table). For example, homicide is less here and that's why Aydın has won. Robbery is less and burglary is less and they have decreased. But in Samsun, the police commissioner has said it's the safest but it's not. It's one of the three best but not the best. It's very bad here--there's a "4", a "2", a "3", an "8". It's way behind (Samsun). With "16" it's not terribly behind but it's in the middle, "83" is the same too. In the middle, that is.*

***Anıl:** Samsun has a "257"--how can you call it in the middle?*

***Berk:** There's a "177". Look, it's second.*

Anıl: *But you're saying it's in the middle.*

Berk: *OK, it's in second place, it's in the middle.*

Anıl: *There's nothing higher than "257."*

Berk: *"451", "497", "299", "499", "304".*

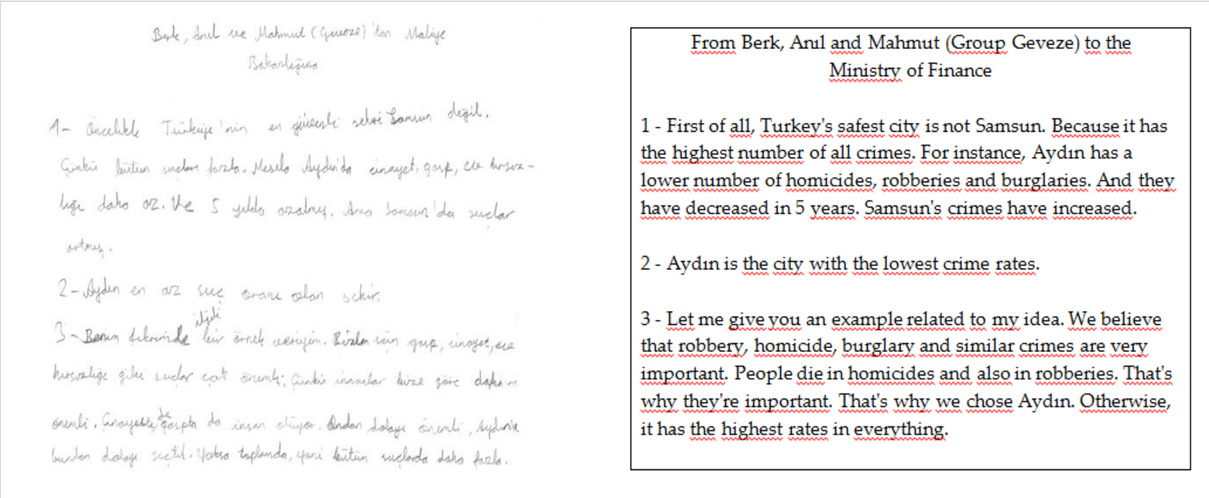
Anıl: *Is "299" more?*

Berk: *Yes.*

Anıl: *Then it's more than "257." Because there's not much difference between "257" and "299."*

Berk: *But look at the other figures, there's a difference. Now let's put these in order (the total crimes in the cities on the worksheet). According to the sum, Aydın is in 3rd or 4th place but homicide, robbery, etc. is more important for us. The crimes here are more. The important crimes are less in Aydın. Here, for example, Adana is "107" (the crime of robbery) but let's look at Aydın--it's "2." There's "105" of a difference between them.*

Mahmut: *Homicide, for example, is "1". The crime rate is decreasing, for instance (pointing to the rate in the city of Aydın). Who knows? Maybe the next time it will be zero (homicide rate).*



Berk, Anıl ve Mahmut (Geveze)'dan Maliye Bakanlığına

1- Öncelikle Türkiye'nin en güvenli şehri Samsun değil. Çünkü bütün suçlar fazla. Mesela Aydın'da cinayet, gasp, ev hırsızlığı daha az. Ve 5 yılda azalmış. Ama Samsun'da suçlar artmış.

2- Aydın en az suç oranı olan şehir.

3- Benim fikrimde ilgili bir örnek vereyim. Bizler için gasp, cinayet, ev hırsızlığı gibi suçlar çok önemli; Çünkü insanlar bize göre daha önemli. Cinayette de gaspta da insan ölüyor. Ondan dolayı önemli, Aydın'ı bundan dolayı seçtik. Yoksa toplamda, yani bütün suçlarda daha fazla.

From Berk, Anıl and Mahmut (Group Geveze) to the Ministry of Finance

1 - First of all, Turkey's safest city is not Samsun. Because it has the highest number of all crimes. For instance, Aydın has a lower number of homicides, robberies and burglaries. And they have decreased in 5 years. Samsun's crimes have increased.

2 - Aydın is the city with the lowest crime rates.

3 - Let me give you an example related to my idea. We believe that robbery, homicide, burglary and similar crimes are very important. People die in homicides and also in robberies. That's why they're important. That's why we chose Aydın. Otherwise, it has the highest rates in everything.

Figure 3. Results Report in Turkish and English

In the excerpts above, the students try to explain the written report that they have been working on. The students explain that in their order of the total crimes in the cities, *Aydın* is in *"3rd or 4th place"* but since Aydın has the least crime rates in the *"most important crimes"* model that they developed, they state that they chose Aydın as the safest city. *They put the crimes of homicide, robbery* and *burglary* in order verbally in relation to the other cities and they chose the province of *Aydın*, the city that had the lowest rates in these crimes. The students also took into consideration the *crime trends in the last five years* factor and saw that the city of *Aydın* is *"1"* in *homicide* but that this trend had decreased and because of this decrease, homicide *"could be zero"*, proving that Aydın is the safest city. *By not choosing the city of Samsun* as the safest province, they stress that this city is *"somewhere in the middle."* Although during the calculations they say they will*"think of"* taking the *"average"* of the crimes, they do not actually do this in their calculations.

Summary Analysis of the Modeling Process

In their process of creating a mathematical model for *the Crime Problem,* the group of 4th grade students, Berk, Anıl and Mahmut, first of all start with reading the problem and trying to understand it. After the reading, the idea that all the data must be collected was introduced and the students start off with the first step of *mathematizing*. Two out of the group act on this thought and start to add the *annual average crime rates* of each city while their friend Mahmut, another member of the group, does not carry out this operation, trying to develop another model. He evaluates the three main categories on the data sheet (*crimes of violence, crimes against goods and property and crime trends)* separately, stating that, having added all the data for the *crimes of violence*, the city with the lowest rate will be the safest city. Mahmut says he will do the same for the *crimes against goods and property* and after determining the cities with the lowest total crime rates, he states that he will have to also look at the crime trends. He says that if there is an increase in the *crime trend* of the city that is first among the cities with the lowest total crime rates, the first choice will be another city with a decreasing *crime trend* and the lowest crime rate. At this point, Anıl interrupts his addition calculation and says that he is having difficulty developing a model because he does not understand the category of *crime trends*. Instead of discussing this in the group, he asks the researcher questions and tries to understand the problem in that way. After he is satisfied, Anıl also takes into consideration the changes in the *crime trend* in addition to any increases and decreases there might be (in the city of Antalya) and accepts this city's total crime rate as an *average*. By taking into consideration only those cities whose crime trends have decreased, in other words, Anıl has ignored the cities with increasing *crime trends* and after finding the total crime rates of these cities, has put the cities with decreasing crime rates in order with reference to Antalya.

Mahmut joins the discussion with another idea and, referring to the fact that the data are annual values, says that in the case of an increase in the *crime trend of the last five years*, the values should be *multiplied by 5* and when there is a decrease, they should be *divided* by 5. Berk opposes this idea and says that when we talk about *crime trends*, we cannot know for sure the amount of increase or decrease and so directly multiplying *averages* by five is not right and serves no purpose other than to increase the magnitude of the values. Although concepts such as *arithmetic mean* and *weighted averages* have not been taught to this age group, it was these mathematical concepts that were in effect being explained by the students during the model constructing activity. In other words, the student was expressing a notion that had actually not yet been learned, namely that a *weighted average* should be used, showing that the student had already created his own conceptual system. Berk continued to explain, asserting that multiplying and dividing by the same number would yield the same result, convincing Mahmut to give up on his model.

In the continuation of the discussions, the students go on with finding the total of the cities' annual average crime rates and, because of its high total crime rate and despite the decrease in the *crime trend*, the students eliminate the cities of *Aydın* and *Trabzon*. During these calculations, Anıl starts a different discussion and all of the group members express their opinions. The students evaluate the two main crime categories (*crimes of violence* and *crimes against goods and property*) according the degree to which these crimes are damaging for people. In this case, to choose the safest city, they say, *crimes of violence* must be at the lowest level and so they treat this as the primary assessment criterion. In determining the degree of importance of the crimes in these two categories, the students associate the situation with their different daily life situations and evaluate the sub-categories of these two categories (*Homicide, Robbery, Assault&Battery, Burglary, Theft, Auto Theft*) in order of their importance. Assigning scores to the crimes, starting from those that are *the most* damaging to human life to the ones that are *the least* damaging, they choose *homicide* as the most important (No. 1) crime. Thus, they return to the table and choose *Aydın* as the safest province because homicide occurs in that city only once a year. Accordingly, they first eliminate the cities in the provinces column (*Adana, Trabzon* and *Diyarbakır*) that have the highest crime rates as compared to *homicide*. Mahmut however has tried to develop their model to categorize the sub-categories of the category of *crimes against goods and property*, that is *burglary, theft (purse-snatching), auto theft* to classify them separately according to their degree of importance. During their discussion, the students frequently make a connection with their daily lives, expressing their thoughts and arguments. In addition, the students examine the sub-categories of the category of *crimes against goods and property* (*burglary, purse-snatching, auto theft*) according to the magnitude of the numerical values. The students look at the annual averages and because the crime of auto theft is lower than the other values, they assess this crime as a crime that is hard to carry out and thus put the crimes in the sub-category in order of importance as *automobile theft, burglary* and *purse-snatching*. Although the students have set up a different model, they do not use the new one and continue to search for the total rates of the crimes in the cities in their previous hypothesis.

Uncomfortable with this process and because the model he set up was ignored, Mahmut states that they would have to find the city where the crimes of *homicide, robbery, and assault* that were determined as important crimes were at the lowest level. Making a verbal comparison of each province in terms of the crime rates in each category and sub-category, they name *Aydın* as the best city, where crimes of *robbery* and *assault* are at the lowest levels. Also, Mahmut states that the reason for this is that in the sub-categories of *homicide* and *assault&battery*, since its crimes had the lowest rates (crime rates respectively 1 and 2), and *crime was on a downward trend in the last five years, Aydın* is the safest city. While Anıl however is hesitant about *Rize* being the safest province (in 4th place among the cities with the lowest total crime rates) because of the increase in *its crime trend*, Mahmut points out that in three of the six sub-categories (*homicide*:1, *robbery*:2, *burglary*:50), the crimes with the lowest rates were in *Aydın*. As the end of these discussions, Berk calculates the total crime rates in both main categories and then leaves his calculations to go back to the table. He says that he agrees with Mahmut that *Aydın* is the safest city. Thus, the students do not consider the total crime rates and reject these models, deciding that according to the criteria they determined, *Aydın* is the *safest city* despite the fact that its total crime rate does not make it the city with the lowest crime rates (it lies in 5th place). At the end of the process, the group wrote the letter requested of them explaining why *Samsun* was not the safest city and how they chose *Aydın*, thus completing their results report.

It was observed that during the process, the students gave themselves frequent breaks, drifted away from the subject at hand many times while they were making associations with daily events, left the group to work independently during the discussions as they were mathematizing or tried to quiet down the group members in this period. The researcher therefore had to step in frequently and try to get the distracted group members back into the process without influencing them in any way. In the moments when the students strayed away from the topic, the researcher asked questions to get the students to concentrate. Because of the length of time the work took, from time to time the students were given a break so they could return to a more productive process.

Discussion and Conclusion and Suggestions

This study was carried out with a focus group of primary school 4th grade students who worked on a *Crime Problem*, striving to reach a result in a nonlinear cyclical process which showed how they used many of their cognitive and metacognitive thinking processes. During the problem-solving process, at each stage, the students tried out hypotheses that they associated with everyday life, produced ideas, tested the accuracy of their models by making associations with real life and even tried to generalize the models through that association. Moreover, the *crime problem* forced the students to communicate and also created an atmosphere in which they could explain their own mathematical thoughts, share and relate how they could use their models, defend the justification of their own opinions, try to convince the other members of the group of that justification and refresh their thoughts by sharing ideas with the others in the group. For the length of the process, the students considered many hypotheses and tried to find patterns, mathematize relationships and principles while also engaging in higher level mathematical thought processes in order to explain, analyze, construct and reason. On the other hand, it was seen that the students encountered some difficulties in the process.

In the first step of the modeling process, *understanding the task*, the students had difficulty interpreting the qualitative data in the data table that described the *crime trend* factor, one of the main categories of the problem, in terms of symbolic increases and decreases. In particular, they could not understand how the magnitude of the *increases* and *decreases* could be determined nor the concept of *trend*. Similarly English and Watters (2004) stress in their study that students find it hard to understand and interpret various formats and representations. At this point, another noteworthy result was that the students decided to move into the mathematical calculations directly without fully understanding the problem. A study by Şahin (2014) too has reported that students focused on solving a problem without understanding its wording. The reasons for this difficulty have been suggested as stemming from the fact that students do not usually find an environment in or outside of school to work together on these types of activities where they can generate new ideas and gather experience in defending their arguments (Blum & Ferri, 2009; Eraslan & Kant, 2015; Şahin, 2014). This is because these types of activities are, contrary to the single-solution routine problems presented to them in the curriculum, focused on urging them to think in depth on what they have already learned so that they may understand, generalize and develop solutions.

Especially at the beginning of the group work, as in Şahin's (2014) study, the students experienced difficulty with focusing and had to have frequent breaks. It was seen that some students could not focus during the group discussion, that they wanted the group to be quiet, and that they left the group to go to another corner of the classroom to work on their own. In these situations, the researcher stepped in frequently, asking the students to focus on the problem and stressing the importance of generating ideas by working and reaching a solution together. The students were encouraged to express their ideas more explicitly and write their thoughts down. While the students were working together, the difficulties they experienced slowed down the process and delayed the development of the modeling. It was seen that primary school students displayed the need for more interventions compared to students at higher levels; similar results have been reported by the instructors in the study of Watters et al. (2004).

In the *establishing model* step, the students produced many different hypotheses and were successful in developing suitable models based on the hypotheses, creating a model that could be generalized to apply to all data, producing a valid model that made the connection between real life and mathematics. Instead of using customary mathematical operations to reach the result, the students assigned meanings to the data and decided upon which factors were important and of more value in their process of modeling. Many hypotheses were explored throughout the process, the unsuitable models were eliminated and the model that was developed was reviewed and a nonmathematical, subjective method was used to obtain a generalizable model. As in the study by Doerr and English (2003), the students realized that the model should be generalizable and so they used the required strategies to achieve this. In parallel to the results attained by Şahin and Eraslan (2014), the students frequently associated their hypotheses with their daily lives in an attempt to verify their models and make them more meaningful.

In the *using mathematics* step, the students developed their model, reviewing their data by performing simple mathematical operations such as addition, multiplication, and putting into order on the basis of quantity. The students, as in the study by English (2007), identified the important factors in the problem in order of priority, explored the relationship between the factors, put the data in order and, differing from the mentioned study, put the factors in order on the basis of a *scoring system*. Moreover, although the concepts of *arithmetic mean* and *weighted average* had not been taught previously, as in the studies of Doerr and English (2003) and English and Watters (2004), the students explained these concepts in their discussion and created their own conceptual system. When the students of this age group were working on a generalizable model, contrary to students at higher levels, they could not have been expected to formulate their model mathematically but instead to express themselves verbally or write up each step of their mathematical thought process. In this study, the focus group did verbally explain their models and how they used the mathematical concepts.

As to the *results explaining* step, the students successfully reported in the letter they wrote the factors they considered in developing their model, how they assessed these factors and the cause and effect relationship involved in their ascertaining why the city they lived in was not the safest city. At the same time, it was seen in the report that although there was no mathematical demonstration of the model they developed, they had been able to express the steps in the creation process verbally.

When the task of modeling is given to students of younger ages, we see that this experience gives them the opportunity to develop their ideas, try out hypotheses, review their ideas and rearrange them, use the data with different methods and observe that they attempt to solve a problem using different approaches and then are able to explain the different methods they used. It is because of this that a discussion environment inevitably ensues and it is seen from the study data how students are influenced by each other's thoughts and proceed to develop their model. In studies that report similar results (English & Watters, 2005; English, 2007, 2010; Mousoulides & English, 2008), it has been asserted that the skills needed to succeed at modeling are some of the most characteristic qualities of professionals in real life and are the qualities that experts seek in fields such as engineering, economics, industry and business administration. It is emphasized that to be most effective, these skills need to be developed early on in life. For this reason, students gain valuable experience if they are introduced to modeling activities in a learning environment that can help them to use the language of mathematics to interpret real life situations at early ages. Modeling activities may thus be included in primary and middle school programs in an uninterrupted fashion. It can be seen that there are no activities in the present curriculums that are conducive to creating such environments. It may be suggested therefore that the elective *applied mathematics* course in the middle school first year program be extended to encompass years 1-4. Also, in order to ensure that students realize the relationship between mathematics and other disciplines, the use of interdisciplinary modeling activities starting from primary school may offer students the opportunity to develop a positive attitude toward mathematics (English, 2013). If, in the time that the elective *applied mathematics* course is spread out into all of the primary school years, each unit in the primary school mathematics textbook could be revised with the addition of at least one modeling activity, students may be given the chance to gain experience in this respect. Providing students with instruction in mathematical modeling at early ages will contribute greatly to their creativity, high level thinking skills, their communication skills as well as to their social development.

The results of this study are limited to the modeling activity on the thought processes involved in solving the *Crime Problem* tackled by a focus group of three primary school 4th-grade students. New research on mathematical modeling activities conducted to broaden the presently limited volume of Turkish literature on the subject should be expanded to include students in pre-school and all levels of primary school. Modeling processes should be examined, how knowledge on modeling develops and changes over time should be investigated, and the ways in which modeling may help to change negative thoughts and opinions about mathematics should be explored.

References

Blum, W., & Ferri, B. R. (2009). Mathematical modeling: Can it be taught and learnt? *Journal of Mathematical Modeling and Applications*, *1*(1), 45-58.

Blum, W., & Niss, M. (1991). Applied mathematical problem solving, modeling, application and links to other subjects-state, trends, and issues in mathematics instruction. *Educational Studies in Mathematics*, *22*(1), 37-68.

Delice, A., & Kertil, M. (2015). Investigating the Representational Fluency of Pre-Service Mathematics Teachers in a Modeling Process. *International Journal of Science and Mathematics Education*, *13*(3), 631-656. doi:10.1007/s10763-013-9466-0

Doruk, B. K., & Umay, A. (2011). The effects of mathematical modeling on transferring mathematics into daily life. *Hacettepe University Journal of Education*, *41*, 124-125.

Doyle, K. M. (2006). *Creating mathematical models with structure.* Paper presented at the 30th Annual Meeting of the International Group for the Psychology of Mathematics Education. Prague, Czech Republic.

Doerr, H. M., & English, L. D. (2003). A modeling perspective on students' mathematical reasoning about data. *Journal for Research in Mathematics Education*, *34*(2), 110-136.

English, L. D. (2003). Mathematical modeling with young learners. In Lamon, S. J., Parker, W. A., & Houston, S. K. (Eds.), *Mathematical modeling: A way of life* (pp. 3-18). Chichester, UK: Horwood Publishing.

English, L. D., & Watters, J. (2004). *Mathematical modeling with young children*. Paper presented at the 28th Annual Conference of the International Group for the Psychology of Mathematics Education. Bergen, Norway.

English, L. D., & Watters, J. (2005). *Mathematical modeling with 9-year-olds*. Paper presented at the 29th Annual Conference of the International Group for the Psychology of Mathematics Education. Melbourne, Australia.

English, L. D. (2007). Interdisciplinary Modeling in the Primary Mathematics Curriculum. In J. Watson, & K. Beswick (Eds.), *Mathematics: Essential research, essential practice* (pp. 275-284). Hobart, Australia: MERGA.

English, L. D. (2010) *Promoting student understanding through complex learning*. Paper presented at the 32nd Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education. Columbus, Ohio.

English, L. D. (2011). complex modeling in the primary/middle school years. In G. Stillman, & J. Brown (Eds.), *ICTMA Book of Abstracts* (pp. 1-10). Melbourne, Victoria: Australian Catholic University.

English, L. D. (2012). Young children's metarepresentational competence in data modeling. In J. Dindyal, L. P. Cheng, & S. F. Ng (Eds.), *Mathematics education : expanding horizons* (pp. 266-273). Singapore: MERGA.

English, L. D. (2013). complex modeling in the primary and middle school years: An interdisciplinary approach. In G. A. Stillman, G. Kaiser, W. Blum, & J. P. Brown (Eds.), *Teaching mathematical modeling: Connecting to research and practice* (pp. 491-505). Dordrecht: Springer.

Eraslan, A. (2012). Prospective elementary mathematics teachers' thought processes on a model eliciting activity. *Educational Sciences: Theory & Practice*, *12*(4), 2953-2968.

Eraslan, A., & Kant, S. (2015). Modeling processes of 4th-year middle-school students and the difficulties encountered. *Educational Sciences: Theory & Practice*, *15*(3), 809-824. doi:10.12738/estp.2015.3.2556

Kal, F. M. (2013). *Matematiksel modelleme etkinliklerinin ilköğretim 6.sınıf öğrencilerinin matematik problemi çözme tutumlarına etkisi* (Unpublished master's thesis). Kocaeli University Institute of Science and Technology, Kocaeli.

Lesh, R. A., & Doerr, H. (2003). Foundations of a models and modeling perspective on mathematics teaching and learning. In R. A. Lesh, & H. Doerr (Eds.), *Beyond constructivism: A models and modeling perspective on mathematics teaching, learning, and problem solving* (pp. 3-34). Mahwah, NJ: Lawrence Erlbaum.

Lesh, R. A., & English, L. D. (2005). Trends in the evolution of models and modeling perspectives on mathematical learning and problem solving. *Zentralblatt Für Didaktik Der Mathematik*, *37*(6), 487-489.

Lesh, R. A., Lester, F. K., & Hjalmarson, M. (2003). A models and modeling perspective on metacognitive functioning in everyday situations where problem solvers develop mathematical constructs. In R. Lesh, & H. M. Doerr (Eds.), *Beyond constructivism: A models and modeling perspective on mathematics problem solving, learning and teaching* (pp. 383-403). Hillsdale, NJ: Lawrence Erlbaum.

Merriam S. B. (2013). *Nitel araştırma desen ve uygulama için bir rehber* (S. Turan, Trans.). Ankara: Nobel.

MoNE (Ministry of National Education). (2005). *PİSA 2003 Projesi Ulusal Nihai Rapor.* Retrieved from http://yegitek.meb.gov.tr/dosyalar/pisa/PISA_2003_Ulusal_Nihai.pdf

MoNE (Ministry of National Education). (2007). *PİSA 2006 Projesi Ulusal Ön Rapor [National PISA Project Preliminary Report]*. Retrieved from http://yegitek.meb.gov.tr/dosyalar%5Cdokumanlar%5Culuslararasi/pisa_2006_ulusal_on_raporu.pdf

MoNE (Ministry of National Education). (2009). *İlköğretim 1–5. Sınıflar Matematik Dersi Öğretim Programı [Primary Schools Grades 1-5 Mathematics Curriculum]*. Ankara: Talim ve Terbiye Kurulu Başkanlığı.

MoNE (Ministry of National Education). (2010). *PİSA 2009 Projesi Ulusal Ön Raporu [National PISA Project Preliminary Report]*. Retrieved from http://pisa.meb.gov.tr/wp-content/uploads/2013/07/PISA-2009-Ulusal-On-Rapor.pdf

MoNE (Ministry of National Education). (2013). *PİSA 2012 Projesi Ulusal Ön Raporu [National PISA Project Preliminary Report]*. Retrieved from http://yegitek.meb.gov.tr/meb_iys_dosyalar/2013_12/13053601_pisa2012_ulusal_n_raporu.pdf

MoNE (Ministry of National Education). (2015). *İlkokul Matematik Dersi (1–4) Öğretim Programı*. Ankara: Talim ve Terbiye Kurulu Başkanlığı.

Mousoulides, N. G., & English, L. D. (2008). *Modeling with Data in Cypriot and Australian Primary Classrooms*. Paper presented at the 32nd Annual Meeting of the International Group and the North American Chapter of Psychology of Mathematics Education. Morelia, Mexico.

OECD (Organization for Economic Co-operation and Development). (2003). *The PISA 2003 Assessment Framework.* Retrieved from http://www.oecd.org/edu/school/programmeforinternationalstudentassessmentpisa/33694881.pdf

Sandalcı, Y. (2013). *Matematiksel modelleme ile cebir öğretiminin öğrencilerin akademik başarılarına ve matematiği günlük yaşamla ilişkilendirmelerine etkisi [Effect of mathematical modeling on students' achievement in learning algebra and their associating mathematics with daily life]* (Master's thesis). Recep Tayyip Erdoğan University, Institute of Social Science, Rize.

Sriraman, B. (2005). *Conceptualizing the notion of model eliciting*. Paper presented at the Fourth Congress of the European Society for Research in Mathematics Education. Sant Feliu de Guixols, Spain.

Swetz, F., & Hartzler J. S. (1991). *Mathematical modeling in the secondary school curriculum*. NCTM: Reston, Virginia.

Şahin, N. (2014). *İlkokul 4. sınıf öğrencilerinin model oluşturma etkinlikleri üzerindeki düşünme süreçleri [Thought processes of primary school 4th grade students related to modeling activities]* (Master's thesis). Ondokuz Mayıs University, Institute of Educational Sciences, Samsun.

Şahin, N., & Eraslan, A. (2014). *İlkokul 4. sınıf öğrencilerinin model oluşturma etkinlikleri üzerine düşünme süreçleri ve karşılaşılan zorluklar [Thought processes of and problems experienced by primary school 4th grade students related to modeling activities]*. Paper presented at the XI. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi. Çukurova University, Adana.

Tekin Dede, A., & Bukova Güzel, E. (2013). Examining the mathematics teachers' design process of the model eliciting activity: Obesity problem. *Elementary Education Online*, *12*(4), 1100-1119.

Watters, J. J., English, L. D., & Mahoney, S. (2004, April). *Mathematical modeling in the elementary school*. Paper presented at the American Educational Research Association Annual meeting. San Diego.

Yıldırım, A., & Şimşek, H. (2011). *Sosyal bilimlerde nitel araştırma yöntemleri [Qualitative researcj methods in the social sciences]*. Ankara: Seçkin Yayıncılık.

Appendix

The Crime Problem: Samsun Police Headquarters told the Ministry of Treasure that the budget for the police department does not need to be increased. The polis chief said, 'Samsun is one of the safest cities in the country and our data proves it!'. However, Police Headquarters' critics do not believe him. They think that Samsun is not very safe compare to other cities and that the Ministry of Treasure should increase the budget for the police. The Ministry of Treasure has asked you to help them decide if Samsun is one of the safest cities in the country. You need to develop a method that the Ministry of Treasure can use to decide if Samsun is or is not a safe city. Tell the Ministry of Treasure what you decided and how you arrived at your decision.

The Polis Department's data table shows each city's average annual rates for six serious crimes: murder, robbery, assault, burglary, theft, and automobile theft for the latest five years for which data are available. These rates are per 100.000 people. The rates are divided into violent and property categories and a total rate for each of these categories is given below. The last column indicates the crime trend over the previous five years.

CITIES	VIOLENT CRIMES			PROPERTY CRIMES			CRIME TREND	
	Murder	Robbery	Assault	Burglary	Theft	Automobile Theft	Up ↑	Down ↓
Rize	4	3	6	56	304	14	↑	
Eskişehir	2	2	7	134	498	32	↑	
Aydın	1	2	20	50	299	16		↓
Trabzon	18	32	92	186	497	67		↓
Antalya	2	4	16	90	325	23	unchanged	
Malatya	4	16	20	60	162	58	↑	
Samsun	3	10	16	83	257	16	↑	
Sivas	9	53	44	103	367	95	↑	
Kayseri	5	8	79	125	177	26		↓
Van	2	3	22	62	271	13		↓
Diyarbakır	15	23	61	185	421	61		↓
Adana	24	107	78	131	315	152	↑	