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Fostering mathematical thinking and social interaction: Third graders' reflections on modeling tasks

Mustafa Açıkgöz[1] and Zeynep Yıldız[2]

[1]Yıldız Technical University, Istanbul, Türkiye (ORCID: 0000-0001-8552-2251)
[2]Yıldız Technical University, Istanbul, Türkiye (ORCID: 0000-0002-1439-3592)

Corresponding Author: Zeynep Yıldiz, zeyildiz@yildiz.edu.tr

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Abstract

The purpose of this qualitative study is to investigate third-grade students' perspectives on the mathematical modeling process. The study employed a qualitative research design, and nine students enrolled in a public primary school in Istanbul were selected through purposive sampling. Prior to conducting individual interviews, a preparatory phase lasting six weeks (18 hours in total) was implemented. A semi-structured interview form developed by the researchers was utilized as the data collection instrument. The collected data were analyzed through content analysis, which yielded three themes—Mathematical Modeling Process, Affective Impact, and Social Relationships—organizing the categories and codes derived from student interviews and structuring the findings that follow. The analysis revealed that students perceived mathematical modeling problems as more challenging and requiring more intensive thinking compared to routine problems. However, as the process progressed, students reported finding mathematics lessons easier and demonstrated improvement in their problem-solving skills. In terms of affective outcomes, the modeling process contributed to the development of positive attitudes toward mathematics, helped students establish connections between mathematics and daily life, and encouraged collaboration within groups. Students also expressed a desire for the continuation of such activities. Regarding social outcomes, the process enabled students to express their ideas freely, and encountering different opinions promoted behaviors such as self-monitoring, revision, and comparison. Furthermore, it was found that the process strengthened group cohesion.

Keywords: Mathematical modeling; Primary school students; Student perspectives; Qualitative research

1. Introduction

In the 21st century, where the demand for accessing, utilizing, and generating knowledge has been continuously increasing, nations have shifted their focus toward the notion of global citizenship, moving away from the concept of individualism. Accordingly, one of the fundamental objectives of countries has been to cultivate students who possess the competencies required by the contemporary era in order to become global citizens (Ministry of National Education [MoNE], 2024). Educational approaches have evolved accordingly, emphasizing high-level thinking skills such as communication, information and technology literacy, problem-solving, collaboration, critical thinking, creativity, analytical reasoning, metacognitive awareness, and financial literacy (Assessment and Teaching of 21st Century Skills [ATC21S], 2012).

Mathematics is a fundamental discipline that not only directly impacts daily life but also serves to help individuals make sense of the world (Bukova-Güzel, 2018). However, many individuals perceive mathematics merely as a school subject, failing to recognize its deep connection to real life. Contrary to this belief, mathematics cannot be separated from real-world contexts; it involves formulating hypotheses, reasoning, and reaching logical conclusions (Baki, 2015).

Accordingly, the primary objectives of mathematics education are to develop students' abilities to understand and explain mathematical concepts and systems, test hypotheses, analyze relationships between data, and construct new connections (Thomas & Hart, 2010). Within the education system, mathematics plays a critical role in fostering individuals who can solve problems, generate creative ideas, and think analytically. The primary school years, in particular, are crucial for laying the foundation for these skills (English & Watters, 2004). Advancements in knowledge, science, and technology have reshaped countries' expectations of individuals, leading to significant shifts in perspectives on mathematics education and prompting substantial curriculum reforms (National Council of Teachers of Mathematics [NCTM], 2014).

The curriculum in Türkiye was revised in 2005, 2018 and 2024 in order to raise individuals with these skills. The mathematics course in the primary school curriculum aims to raise individuals who can make sense of what they learn both at school and outside of school, construct their own meanings, and apply the meanings they construct to situations they encounter in their daily lives (MoNE, 2024).

However, international large-scale student assessments provide important indicators that reveal the strengths and weaknesses of countries' education systems. Among these, TIMSS evaluates mathematics and science achievement at the 4th- and 8th-grade levels, whereas PISA measures the mathematics, science, and reading competencies of 15-year-old students (OECD, 2019; Mullis et al., 2020). The performance of Türkiye in these assessments has followed a fluctuating trend. In TIMSS, Türkiye remained below the international average for many years but surpassed it for the first time at the 4th-grade level in 2019, and in 2023 reached 553 points, which is well above the international average of 503, ranking 8th among 59 countries (Martin et al., 2024). At the 8th-grade level, Türkiye also scored 509 points. In PISA, although progress was observed in 2012, a significant decline occurred in 2015, followed by a partial recovery in 2018; however, in 2022 mathematics score of Türkiye remained at 453, below the OECD average of 472 (OECD, 2023). This overall picture highlights the need for sustainable improvement and innovative approaches in mathematics education. Recent studies further emphasize that mathematical modeling activities make significant contributions to the development of students' problem-solving skills and higher-order thinking abilities (Krawitz et al., 2025; Tasarib et al., 2025).

Therefore, mathematics education has turned towards activities in which meaningful connections between mathematics and daily life can be established and developed (De Corte, 2004). Due to the increasing importance of the relationship between daily life and mathematics, mathematical models and modeling processes have emerged in mathematics learning and teaching processes (Lesh et al., 2007). It has been observed that students engaged in modeling activities develop a deeper understanding of solving complex, multi-component problems that elicit ideas (English, 2006). Therefore, exposing students to mathematical modeling activities involving authentic real-life problem situations from the early years of primary school has become increasingly important (Carlson et al., 2016).

However, a review of the international literature reveals that most mathematical modeling studies have been conducted at the upper primary or secondary education levels (English & Watters, 2005; Doruk, 2010; Leiss et al., 2010; Tekin Dede & Bukova-Güzel, 2013; Tekin, 2012). Similarly, national studies focusing on modeling processes at the primary level are scarce, and existing research predominantly targets fourth-grade students (Şahin, 2014, 2019; Şahin & Eraslan, 2016, 2017, 2018; Ulu, 2017).

In order to achieve the objectives of Turkish national education and mathematics education, it is considered essential to implement model-eliciting activities in the early years of primary education. However, it is noteworthy that studies focusing specifically on the third-grade level remain limited in the national literature. Therefore, the aim of this study is to explore third-grade students' perspectives on the mathematical modeling process.

The study addresses three dimensions. First, students' views on the stages of the mathematical modeling process were examined. Focusing on these stages makes visible how students understand problem situations, develop solution strategies, and construct mathematical representations (Borromeo Ferri, 2018). Moreover, eliciting students' views on the stages of the process is emphasized as critical for understanding modeling competencies and improving instructional design (Çevikbaş et al., 2022). Second, students' perspectives on their affective experiences in the mathematical modeling process were investigated. In particular, it has been emphasized that factors such as motivation, interest, and anxiety directly affect the learning processes of young students (Hannula et al., 2019). Furthermore, systematic reviews have revealed that mathematical modeling activities can foster students' self-confidence, learning interest, and positive emotional experiences (Çevikbaş et al., 2022). For this reason, examining this dimension is of considerable importance. Third, the study explored students' perspectives on the social

dimension of the modeling process. Collaborative learning in younger age groups is regarded as a key factor in supporting both academic learning and social development (Gillies, 2016). Since mathematical modeling activities inherently rely on group work, they promote the development of students' communication, collaboration, and joint problem-solving (Doerr & English, 2003; Öztürk, 2025).

In conclusion, eliciting students' views on these three dimensions is important not only for understanding their experiences but also for improving curricula and classroom practices (Çevikbaş et al., 2022). In this respect, the third-grade mathematical modeling activities developed within the scope of this study are expected to contribute to the literature and serve as a guide for teachers and curriculum designers.

The research sub-problems are as follows:

RQ 1) What are third-grade students' views on the stages of the mathematical modeling process?

RQ 2) What are third-grade students' views on the affective outcomes of the mathematical modeling process?

RQ 3) What are third-grade students' views on the effects of the mathematical modeling process on social relationships and collaboration?"

At this point, it is important to examine how mathematical modeling processes are addressed in education and how students' cognitive, affective, and social experiences are discussed in the literature. Accordingly, the theoretical framework of this study is structured around the definitions and stages of mathematical modeling, followed by the affective dimension associated with modeling and the elements of social interaction.

2. Theoretical Framework

A model is a structure that encompasses cognitive constructions and their external representations, used to create, explain, or make predictions about complex systems based on known information (Lesh & Doerr, 2003a). In this context, models function both as cognitive structures formed in individuals' minds and as conceptual systems expressed through computer programs, diagrams, equations, formulas, graphs, tables, or other concrete representational media. In other words, models serve as representational tools that help make sense of and interpret complex systems, and they may also consist solely of spoken language, experiences, or drawings (Lesh & Doerr, 2003a). In essence, the concept of a model can be described as a simplified visual representation of an idea (Gilbert et al., 2000).

When examining the concept of modeling, it is evident that the same situation can be modeled differently by different individuals. Thus, models are representations reflecting the perspectives of their creators and cannot be considered universal systems (Dindyal, 2010). According to Sriraman (2005), modeling can be defined as the process of obtaining the outcome or the final product, namely the model, in response to a problem situation. Similarly, Güneş et al. (2004) describe modeling as a scientific form of thinking and inquiry involving decisions about how to use details and what paths to follow, comprising multiple stages.

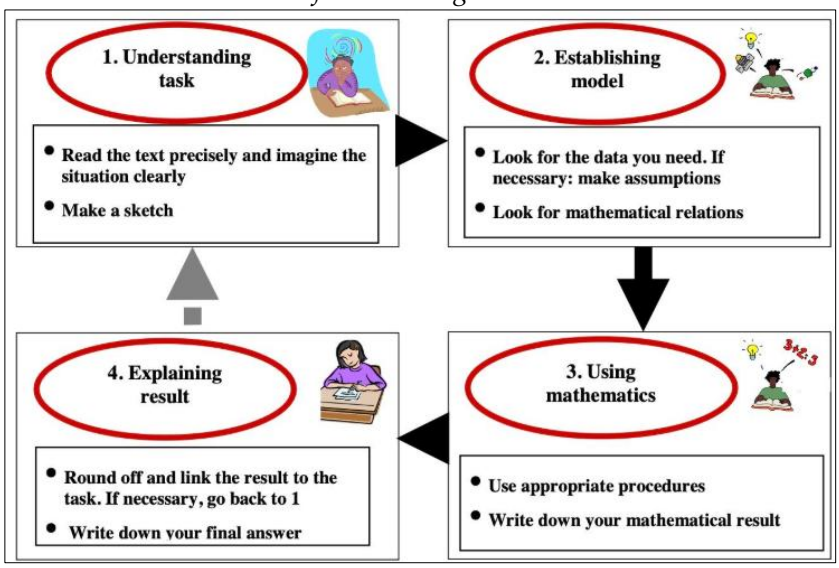
Mathematical modeling, in particular, is a process that connects real life and mathematics by utilizing mathematical skills and symbolic representations (Bukova-Güzel, 2018). According to Blum (2002), mathematical modeling encompasses both the transition from real-world contexts to mathematics and the entire process involved in this transition. Mathematical modeling is a cyclical process in which real-world problems are abstracted into mathematical language, the data are analyzed, and proposed solutions are subsequently tested (Haines & Crouch, 2010). Real-world situations are mathematically represented, and mathematical patterns are derived. Instead of routine, traditionally structured problems, students are presented with problems that involve complex, authentic real-life situations and have no single solution path through mathematical modeling activities. Additionally, the modeling process offers students the opportunity to generate and express their own ideas. Therefore, mathematical modeling activities make a significant contribution to the development of students' creativity skills (Blum, 2002; Blum & Borromeo Ferri,

2009).

Modeling activities take place in the form of a cycle. Blum and Ferri (2009) proposed a modeling cycle consisting of four stages. Although these stages are numbered, this does not imply that individuals engaged in modeling must strictly follow the given sequence. In other words, the modeling cycle is a non-linear process. As modelers progress through these stages, they also reflect the difficulties they encounter and their thinking processes to the practitioners. From this perspective, the cycle provides significant support for practitioners in identifying the challenges and cognitive processes that modelers experience during the mathematical modeling process. Figure 1 below presents the cyclical solution plan developed by Blum and Ferri (2009) for solving modeling problems, which consists of four stages.

Figure 1

Four-Phase Solution Plan for Modeling Problems



Source: Adapted from Blum and Ferri (2009).

In the first stage of the four-step solution plan, understanding the problem, students try to comprehend the real-life problem by reading it, visualizing it in their minds, and drawing. They also examine tables and graphs related to the problem. In the second stage, establishing a model, they analyze the relationships between the data, look for mathematical connections, and construct a model. In the third stage, using mathematics, they apply appropriate mathematical operations to obtain results. In the final stage, interpreting the results, the outcome is presented as a report and evaluated from various perspectives. When this four-step plan is examined, it becomes evident that students experience a process in which they interact multidimensionally with each other, engage in multiple trials and cycles, use metacognitive thinking skills, and provide critical feedback to one another.

Mathematical modeling, by its very nature, influences students' learning processes in multiple ways through its cognitive, affective, and social dimensions (Blum & Leiss, 2007; Maaß, 2006). To better understand this multidimensional structure, it is necessary to focus not only on instructional outcomes but also on students' own perspectives regarding their experiences. Considering student perspectives in educational research contributes to a deeper understanding of learning processes and provides a strong basis for improving instructional practices (Cook-Sather, 2006; Mitra, 2018). The literature emphasizes that incorporating student perspectives into research plays a critical role in revealing the quality of learning experiences and transforming pedagogical approaches (Fielding, 2004; Lundy, 2007). Therefore, examining students' perspectives on cognitive, affective, and social dimensions enables a more holistic understanding of the effects of mathematical modeling and serves as a complementary element of the theoretical framework. This theoretical background forms the foundation for the procedures outlined in the method section.

3. Method

3.1. Research Design

In this study, a qualitative research design, specifically a case study, was employed. The case study design was considered appropriate as the research aimed to provide an in-depth understanding of third-grade students' perspectives on the mathematical modeling process within a natural classroom context. Through this design, the study sought to capture students' authentic views, experiences, and interpretations regarding the modeling tasks. Case studies are particularly valuable when the goal is to explore a contemporary phenomenon within its real-life context (Creswell & Poth, 2023; Merriam & Tisdell, 2016). In this respect, the selection of this design allowed for a more detailed analysis of the data and contributed to developing a comprehensive understanding of students' experiences in the mathematical modeling process. Furthermore, it provided a methodological basis for generating findings that may inform both the literature and educational practice.

3.2. Study Group

The study group of this research consisted of nine third-grade students enrolled in a public primary school located in Istanbul during the 2022-2023 academic year. These participants were selected through purposive sampling from a class of 32 students, based on the prior observations of the classroom teacher. From this perspective, purposive sampling is useful for both the exploration and explanation of events and phenomena (Yıldırım & Şimşek, 2011). Studying all cases that meet predetermined criteria is referred to as criterion sampling. These criteria may be compiled in a list prepared in advance or developed by a researcher (Yıldırım & Şimşek, 2011). Therefore, the researcher identified specific criteria and aimed to conduct an in-depth examination based on these criteria. These criteria included selecting students who could work in harmony with their peers, demonstrated an interest in mathematics, were self-confident, and were capable of generating original ideas as well as expressing and defending them freely. Based on these criteria, nine students were selected to form the study group. In accordance with ethical principles, pseudonyms were used instead of real names to protect the students' identities.

3.3. Research Process

In the first phase of the research process, a total of six mathematical modeling activities were implemented by the researchers over six weeks (18 hours in total), with one activity conducted per week. These activities aimed to provide participants with hands-on experience in mathematical modeling. The activities were conducted during mathematics lessons in order to preserve the students' natural learning environment and to ensure that the experiences gained were directly connected to classroom practices. The activities carried out during this process are as follows:

Week 1: Jacket Problem: In this task, students were presented with a table containing ten different jackets characterized by variables such as the number of pockets, presence of a hood, lining, thickness, price, and warranty period. Students were asked to construct a mathematical model to determine the most suitable jacket in terms of price-performance ratio.

Week 2: Book Selection Problem: Students were asked to develop a mathematical model to decide between two books available on online shopping platforms. A table was provided that included variables such as book prices, shipping times, user ratings of the platforms, shipping costs, and total sales figures.

Week 3: Crop Selection Problem: In this problem, students were tasked with constructing a mathematical model to advise a farmer on selecting the most suitable crop—garlic, corn, or potatoes—to plant in their field. A data table covering the years 2018–2022 was presented, which included variables such as storage durability, profit margins, and yield quantity for each crop.

Week 4: Runner Selection Problem: Participants were asked to identify the most suitable athlete for a 100-meter hurdles race by developing a mathematical model. The table provided included data on athletes' participation in previous Olympic or championship events, their finishing times, and whether they were eliminated or advanced in those competitions.

Week 5: Racehorse Problem: In this task, two tables were presented, each containing data on three different racehorses and the distances they ran over time after consuming two types of feed. Based on this information, students were asked to create a mathematical model to determine which type of feed was most appropriate for each horse.

Week 6: Healthy Saving Problem: In this activity, students were required to develop a mathematical model to help a student manage their school allowance in a way that enabled both healthy nutrition and saving money to purchase a desired backpack in the shortest time possible. A table was provided that listed items sold in the school canteen, including their nutritional content and prices.

3.4. Data Collection Tool

Within the scope of this study, a semi structured interview form was used as a qualitative data collection tool. The main purpose of the interview was to reveal the individual's feelings, beliefs, and thoughts about the subject under investigation (Çepni, 2009). The semi structured interview form was developed by the researchers based on a review of the relevant literature. Then, the interview questions were revised by two experts, one in the field of mathematics education and the other in qualitative research, and inappropriate questions were removed. The interview form consisted of three main categories: stages of mathematical modeling, affective impact, and social interaction, with a total of 13 questions related to these categories. First, the necessary legal permissions were obtained, and the interviews were conducted face to face in a room within the school where the participants would feel comfortable. In addition, the participants' responses were audio recorded with their consent, then transcribed, and finally played back to the participants for verification. Each interview lasted approximately 20 minutes.

3.5. Data Analysis

The data obtained in this study were analyzed using a qualitative content analysis approach. According to Merriam and Grenier (2019), content analysis is a process that requires a detailed examination of the data collected during the research process and the identification of concepts, categories, and themes that can explain these data. In this context, the analysis of data collected through documents, observations, or interviews proceeds through four stages (Miles & Huberman, 1994): (i) coding of the data by the coders, (ii) identification of a code list, categories, and related themes based on the codings, (iii) revision and organization of themes, categories, and codes, and (iv) description and interpretation of the findings obtained.

The data were analyzed based on the responses given to the questions under the three main categories included in the semi-structured interview form. The responses within each category were coded, and codes with similar meanings were grouped together to form categories. Through this process, the data concerning students' reflections on the mathematical modeling process, their affective experiences, and their social interactions were systematically organized.

To enhance the reliability of the analysis process, the researchers initially conducted independent coding, and inter-coder agreement was calculated using Miles and Huberman's (1994) formula, yielding a concordance rate of 85%. Since this rate exceeds the acceptable threshold for qualitative research, the reliability of the analysis was ensured. In addition, the coding process was reviewed by a field expert, and to strengthen the credibility of the findings, direct student quotations for each category were provided.

3.5.1. Coding process

The student responses obtained in this study were analyzed in a general-to-specific sequence. First, the data were grouped under the three sections of the semi-structured interview form; subsequently, categories were identified for each section, and finally, codes were generated based on student statements. In the presentation of direct quotations, students were referred to with abbreviations such as S1, S2, and S3, corresponding to Student 1, Student 2, and Student 3, respectively. Examples illustrating the formation of codes and categories for each section are summarized below. In this way, each category is supported by a representative code and a student

quotation, ensuring transparency in the development of categories and codes.

Section 1: Mathematical Modeling Process. Four categories were identified within Section 1 (Mathematical Modeling Process): Comparing problems with others, encountering new situations, impact on mathematics lessons, and easy and difficult aspects.

- For example, the code "Different" in the first category emphasizes that students perceived modeling problems as different from traditional problems. A supporting student statement is: "These problems were different because they required more complex calculations and deeper thinking." (S1)
- The code "Encountered" in the second category highlights that students faced new experiences during this process. One student remarked: "I had never seen a problem with so much information. This was the first time I encountered such a problem." (S9)
- The code "Facilitated" in the third category reflects that the process made mathematics lessons more understandable for students. As one noted: "I think it made mathematics easier." (S4)
- The expression "Eliminating data" under the fourth category, "Challenging parts," indicates that students particularly struggled during the data selection stage. A supporting student quotation is: "It was difficult to separate the data. I couldn't analyze the data in the table." (S2)

Section 2: Affective Impact. Four categories were identified within Section 2 (Affective Impact): Thoughts about mathematics lessons, the relationship between mathematics and daily life, the affective impact of group work, and continuation of modeling activities.

- The code "I liked the lesson more" in the first category reflects students' development of positive attitudes toward mathematics. For instance: "I started to like mathematics more." (S4)
- The code "I made a connection with real life" in the second category shows that students realized the link between mathematics and everyday life. One student commented: "I didn't know mathematics existed so much in daily life, but now I have learned." (S6)
- The code "Collaboration facilitated the process" in the third category indicates that group support made the process easier. As one student explained: "… I could not solve some problems alone… If my result was wrong and my friend's was right, I would find the correct answer thanks to my friend. This made me feel good." (S2)
- The code "It develops us" in the fourth category shows that students believed the activities contributed to their personal development. For example: "We improve ourselves more in mathematics with these activities." (S7)

Section 3: Social Relations. Five categories were identified within Section 3 (Social Relations): Expressing thoughts within the group, agreeing, disagreeing, when the line of reasoning is incorrect, and the effect on friendships.

- The code "I felt comfortable" in the first category emphasizes that students could freely express themselves within the group. One noted: "I could openly express my opinions, I could speak comfortably." (S1)
- The code "I was glad, I thought I was right" in the second category indicates that agreement among peers gave students confidence. For example: "We thought the same, so I was glad, thinking we were doing it right." (S7)
- The code "I respect" in the third category highlights tolerance toward different opinions. As one stated: "Everyone has different opinions, and I respect everyone's decisions." (S4)
- The code "I would warn" in the fourth category emphasizes the tendency to correct a peer's incorrect reasoning. For example: "I would warn them. Together with my groupmates, we would explain it to them." (S4)
- The code "Friendship bonds strengthened" in the fifth category reflects that the process had a positive effect on social relations. As one student expressed: "We bonded more closely." (S5)

3.5.2. Validity and reliability

In qualitative research, it is more appropriate to use the concept of trustworthiness instead of

validity and reliability. To enhance the trustworthiness of the study, four criteria have been identified: credibility, transferability, confirmability, and dependability (Lincoln & Guba, 1986, as cited in Arastaman et al., 2018). In line with these criteria, several practices were carried out to increase the level of trustworthiness in this study. First, prolonged engagement with the participants, who served as data sources, was established to build a relationship of trust, thereby creating an environment in which participants could behave more sincerely and respond to interview questions more genuinely. In addition, observations related to the phenomenon under investigation were conducted throughout the process, and all interviews were audio recorded and archived. At the end of the interviews, the data obtained from participants' statements were reviewed together with the participants to verify their responses. Moreover, the findings obtained during the research process were also coded by an independent researcher, and intercoder agreement was ensured. The findings collected during the research were reported in detail, and the results obtained from the study were presented systematically to allow for future verification.

4. Results

4.1. Findings on the First Sub-Problem

The first sub-problem guided the analysis, and the *mathematical modeling process* was identified as the initial section. Within this section, categories and codes were systematically developed. The resulting categories, codes, and their frequencies, derived from students' views, are presented in Table 1.

Table 1
Categories, Codes, and Frequencies within Section 1: Mathematical Modeling Process

Categories and sub-categories	*Codes*	*Frequencies*
Comparing mathematical modeling problems with other types of problems	Different	9
	Not different	0
Encountering a situation for the first time in this process	I encountered it	2
	I did not encounter it	7
The impact of this process on mathematics lessons	It made it more difficult	1
	It made it easier	8
The easy and difficult aspects of this process		
Easy aspects	Comparison	1
	Model Eliciting	1
	Mathematical Operations	3
Challenging aspects	Eliminating irrelevant data	3
	Understanding the problem	3
	Explaining the result	1

While presenting the findings, direct quotations from the interviews conducted with the study group were included alongside the table of categories, codes, and frequencies in order to provide more detailed and in depth information. To determine students' perceptions regarding the stages of the mathematical modeling process, they were first asked the question, "What can you say when you compare the content of the problems given in this process with those given in other times?" All participants responded by stating that the mathematical modeling problems were different from the problems they usually solved. A few of the students' responses supporting this view are provided below.

S1, who emphasized that the questions were different from those encountered in regular mathematics lessons and required more thought, stated, "These questions were different from the ones we solve in class. These required more operations and more thinking. We had to think more to solve them. The ones in class were simpler."

Student 3 (S3), who emphasized the difference in terms of group work and the difficulty of the operations, expressed this view as follows:

> They are different. For example, in some places you work alone, but in mathematical modeling you work as a group. The difference is that the operations in mathematical modeling seem harder to me, but in math class there is nothing like that. You just do addition, subtraction, or division, something like that.

Similarly, Student 7 (S7), who described the process as more confusing, difficult, and mentally demanding, stated, "Well, it's different. I mean, what we solve in class is easier, but what we did here is more confusing, more difficult, our brain gets a bit tired."

An analysis of the participants' responses to the first question reveals that they emphasized that the content of the problems presented during this process differed from the problems they usually encountered. This difference was reflected in their individual statements, in which they described mathematical modeling problems as more difficult, more confusing, more mentally demanding, requiring more operations, and necessitating deeper thinking.

To explore participants' perceptions regarding the stages of the mathematical modeling process, students were asked whether there was anything in the mathematical modeling problems that made them feel as if they were encountering something for the first time. The majority of students stated that they had not previously encountered this type of problem situation.

S2, who emphasized that the problems required a great deal of thinking, stated, "We hadn't solved problems that made us think this much." In contrast, Student 3 (S3), who stated that there was nothing unfamiliar in the mathematical modeling problems, explained this view with an example from daily life:

> No, nothing like that for me. Because I've done this kind of thing a lot in my life. Like when I'm buying chocolate, and there are three different kinds in front of me. I compare them, their prices and ingredients, and then choose.

Student 9 (S9), who emphasized that he had never encountered a problem containing so much data before, stated, "Yes, I had. I hadn't seen a problem with this much information before; it was the first time."

An analysis of the participants' statements indicates that students commonly described mathematical modeling problems as unfamiliar due to the amount of information they contained and the level of thinking they required. While some students stated that they had not previously solved problems that made them think this much or included so much information, S3 noted that such situations were familiar from daily life experiences, such as shopping, and therefore did not consider them new or unfamiliar.

To further examine participants' perceptions of the mathematical modeling process, students were asked whether this process made mathematics lessons easier or more difficult. Most students stated that the process made mathematics easier. S1, who emphasized that such problems improved their comprehension skills and therefore made mathematics easier, stated:

> I think it became easier. Because when we solve these, we understand the hard ones, and we can understand the simple ones even more easily. So I think math became simpler. These problems we did in math improved my understanding ability, so the other problems got easier.

Student 4 (S4), who initially struggled with the problems but later observed progress in their thinking skills, stated, "I think it made it easier, because at first we couldn't do the hard questions here, but then we thought about them and did them, so we started to understand the ones in class more easily."

Student 8 (S8), who emphasized that solving such problems improved both thinking and comprehension, stated, "It made it easier. Modeling problems are harder and they open our minds. Because we work hard to understand and solve the problems, and our minds get better."

Student 3 (S3), however, stated that the process partially made mathematics more difficult due to disagreements experienced during group work:

> The hard part is when you're working in a group, and your idea is different from the others. Like you say A, the other says B, and another says C—then it gets confusing and that makes it a bit hard. The easy part is that you learn other things and life gets easier. It helped me grow; we learned new things.

The analysis of participant responses suggests that the mathematical modeling process generally contributed to making mathematics lessons easier. This was largely attributed to repeated exposure to complex, multi-variable, and cognitively demanding problems, which supported the development of students' mental skills such as comprehension, analysis, reasoning, and prediction. On the other hand, as reflected in S3's statement, disagreements during group work and the confusion caused by differing opinions were identified as aspects of the process that made mathematics more challenging.

Students were also asked whether there were any parts of the process they found difficult or easy. Their responses showed variation across individuals.

Student 3 (S3), who stated that making comparisons was easy but understanding the problem was challenging, explained, "One of the things that was easy was making comparisons. Because we do comparisons all the time. The hard part was understanding. Like, understanding what was inside was hard for me." S2, who indicated that they struggled with analyzing data, stated:

> The part that was hard for me in the process was eliminating the choices. Like, I couldn't analyze the data in the table, but as I kept doing it, it started to get easier. After solving a few questions, I learned more about analyzing data and started to understand it better.

S4, who also had difficulty analyzing data but found implementing the model easier, stated, "For example, I had trouble eliminating the information we were given. The easy part was putting plus and minus, because once I understood it, it got easier." S5, who noted that the mathematical operations were easy, stated, "At first, I thought about it a lot, planned it out in my head. I drew and erased. The mathematical operations part was easy." S7, who found explaining the result and presenting the report difficult, stated, "The part where we explained the result was a bit hard for me. The mathematical operations part was easier."

An examination of participants' responses reveals that individual differences became evident during the mathematical modeling process. While most participants found the mathematical operations easier, the stages they struggled with were mainly related to understanding the problem, analyzing data, explaining results, and presenting the report. Considering the responses to the previous questions as well, it can be stated that the nature of mathematical modeling problems, which involve multiple variables, various solution paths, and diverse outcomes, posed challenges for students particularly in terms of problem comprehension, data analysis, and explaining results. However, students' statements also indicate that these difficulties tended to decrease as the number of activities increased.

4.2. Findings on the Second Sub-Problem

This section presents the findings related to the second sub-problem of the study. Based on this sub-problem, the analysis focused on students' views regarding the affective outcomes of the mathematical modeling process, and *affective impact* was identified as the second section. Within this section, categories and codes were systematically developed. The resulting categories, codes, and their frequencies, derived from students' views, are presented in Table 2.

To explore the affective impact of mathematical modeling processes on students, students were first asked whether the process had any effect on their thoughts about mathematics lessons. The majority of students stated that the process made them enjoy mathematics more.

S4, who stated that mathematics became their favorite subject as a result of the process, expressed, "I started to like math lessons more. Math became my favorite subject." Similarly, S8, who reported developing a more positive perspective on mathematics due to personal development through the process, stated, "It was positive because I improved myself." S2, who noted that the process helped them realize the connection between mathematics and real life, explained this view as follows:

> I mean, we're actually doing this in real life. Before, I used to think there wasn't math in real life or in some things we do. But as I solved these problems, I understood that math is really in everything.

Table 2
Categories, Codes, and Frequencies within Section 2: Affective Impact

Categories and sub-categories	*Codes*	*Frequencies*
Thoughts About the Mathematics Lesson	I liked the lesson more	7
	I made a connection with real life	1
	In-class applicability	1
The Relationship Between Mathematics and Daily Life	Math is everywhere	3
	I didn't know there were so many connections	6
Affective Impact of Group Work	Helping each other made the process easier	7
	Confusion	1
	Friendship bonds became stronger	1
Continuation of Modeling Activities	It helps us improve	8
	It challenges us	1

S3, who became curious about whether such activities would continue in regular mathematics lessons, stated, "It changed. I wondered if these kinds of questions would appear in regular math class."

Both the frequency values presented in Table 2 and the direct quotations from the participants suggest that the mathematical modeling process had affective effects on students' perceptions of mathematics lessons. It appears that the process contributed to students' developing more positive attitudes toward mathematics, enjoying the subject more, believing that mathematics became easier, and recognizing the connection between mathematics and real life.

To further examine the affective effects of the process, students were asked to compare their thoughts on the relationship between mathematics and daily life before and after the process. Most participants stated that they had not previously realized there was such a strong connection between mathematics and real life.

S6, who previously believed that mathematics was not frequently used in daily life, stated, "I didn't know there was so much math in daily life, but I learned it." Similarly, S3, who emphasized that they came to realize the presence of mathematics in every moment of life, stated, "Now I understand that math is everywhere—while walking, while playing, math is there."

In contrast, S8 indicated that they had already been aware of the presence of mathematics in daily life, stating, "I used to think that before, too, because math is everywhere." Likewise, S5 expressed prior awareness of the connection between mathematics and real life by providing an example: "Like when we go to the market and buy apples, if one kilo is 10 lira, when we buy two kilos, we do addition."

Based on the quotations above and the frequency values in Table 2, it is evident that the majority of participants reported that the modeling process helped them establish a stronger connection between mathematics and daily life. Through this process, students came to realize that mathematics is an indispensable part of everyday life.

To further investigate the affective impact of mathematical modeling processes, students were asked how doing this kind of group work in mathematics class made them feel. The majority of participants stated that group work made the process easier because it allowed for mutual support.

S2, who experienced difficulties during the process but overcame them through collaboration with peers, stated:

> It made me feel really good because I couldn't do some problems on my own and couldn't come up with different answers. I compared my answers with my friends' answers. That made me feel good. If my answer was wrong and my friend's was right, for example, I would find the right one thanks to them. That made me feel good.

S5, who believed that working in a group made the tasks easier and quicker to complete,

expressed, "It was a very nice feeling. Because we were thinking together with our friends. Like, if one person did it, it would feel very hard. But if many people do it, it finishes quickly."

In contrast, S3 stated that group work caused some confusion: "It added a bit of confusion. One person says A, another says B, and another says C." S4, who emphasized that group work strengthened friendships, stated, "It felt nice because in group work we were always talking and agreeing on things together. And this also affected our friendships; our friendship grew stronger."

An examination of the student statements presented above, along with the frequency values in Table 2, indicates that the group work implemented during the mathematical modeling process had positive effects on participants. Group work allowed for mutual support and idea exchange, which not only helped students recognize their personal mistakes or gaps in understanding but also contributed to making the process easier and completing tasks more efficiently. Moreover, group work appeared to strengthen participants' friendships, as reflected in their responses.

To further examine the affective effects of the mathematical modeling process, students were asked whether they would like modeling activities to continue regularly. All participants except one responded positively. S1, who stated that although the process was initially difficult and tiring, it became easier over time and they would like it to continue, expressed:

> Yes, I would. I used to get tired, but I would still want it. It was nice. I mean, I got tired because at first the questions seemed hard, and that's why I got a little tired, but later I stopped getting tired.

S2, who emphasized that the process helped them improve, also wanted it to continue: "Yes, I would. Because it helps develop our minds, we improve ourselves, and in that way we also improve in mathematics."

Similarly, S7, who found the process mentally challenging but stimulating, stated, "Yes, I would. Because it makes you think, and I like that. It opens our minds, we deal with difficult things, and that makes it enjoyable and fun." In contrast, S9 found the process difficult and did not want the modeling activities to continue, stating, "No. Because it's hard."

Overall, the affective effects of the mathematical modeling process on participants were largely positive. According to their responses, the process contributed to greater enjoyment of mathematics, increased awareness of the relationship between mathematics and daily life, enhanced collaboration, strengthened friendships through group work, and supported cognitive development, which made students feel good.

4.3. Findings on the Third Sub-Problem

This section presents the findings related to the third sub-problem of the study. Accordingly, the analysis focused on students' views on the effects of the mathematical modeling process on social relationships and collaboration, and Social Relationships was identified as the third section. The categories, codes, and frequencies developed from students' views are presented in Table 3.

Table 3
Categories, Codes, and Frequencies within Section 3: Social Relationships

Categories and sub-categories	*Codes*	*Frequencies*
Expressing Ideas Within the Group	I felt comfortable	5
	I felt more comfortable later on	2
	I couldn't fully express myself	2
Agreement on Ideas	I was happy, I thought I did it right	8
	I got confused	1
Disagreement on Ideas	I make comparisons	7
	I show respect	1
	I stay silent	1
When the Way of Thinking Is Incorrect	I give examples and explanations	7
	I give warnings	2
Impact on Friendships	We had a good time	1
	We bonded	6
	No differences	2

To explore participants' perceptions regarding the effects of the mathematical modeling process on their social relationships, students were first asked about the extent to which they were able to express their thoughts within the group. Most participants stated that they were able to express themselves comfortably, while some noted that they became more comfortable over time. However, two participants indicated that they were unable to fully express their thoughts.

S1, who expressed feeling comfortable throughout the process, stated, "I could say my ideas clearly. I could speak comfortably. I could say something without hesitation." S8, who explained that they were initially unable to express themselves but became more comfortable later, stated, "At first, they didn't let me talk much. While they shared their ideas, I just sat and stayed quiet. I saved my thoughts for later, then I spoke." S5, who felt interrupted while speaking and mentioned issues related to turn-taking, stated, "When I first started speaking, my friend interrupted me and shared their idea. So, I couldn't say anything. Later, they allowed it. We started talking by taking turns." Similarly, S4 stated, "They were respectful of my ideas, but sometimes they blocked me. They gave different answers; I gave a different answer. I couldn't fully speak."

These responses suggest that most students felt comfortable expressing their thoughts during group work. Some students initially experienced difficulties but became more at ease as the process progressed. Only a few students reported continued discomfort. This may indicate that participants had limited prior experience with group work and were not yet fully familiar with collaborative learning culture.

To further examine the social effects of mathematical modeling, students were asked how they felt when their groupmates had the same idea as them. Almost all participants stated that having similar ideas made them feel happy and confirmed their thinking. Only one participant found this situation confusing.

S7, who expressed happiness about having shared ideas, stated, "I felt happy. Like, when we all had the same idea, I was glad. Because I thought I had done it right." Similarly, S9 stated, "I feel like I did it right. I feel smart." In contrast, S2 found the situation confusing and difficult to evaluate:

> When everyone found the same answer, I got confused because it could be right or wrong, I don't know. If everyone finds different answers, we can review and assess them. But when everyone gets the same result, I get confused because I can't evaluate it.

These responses indicate that agreement among groupmates generally made students feel happy and confident. Some students even interpreted shared ideas as an indication of being correct or smart. However, one participant viewed this situation as potentially misleading, noting that identical incorrect answers could remain unquestioned, whereas varied answers allowed for critical reassessment.

Students were also asked how they felt and responded when their groupmates had different ideas from their own. Most participants stated that they compared their own answers with those of their peers. One student emphasized showing respect, while another stated that they preferred to remain silent.

S1, who evaluated different responses in order to reach the correct answer, stated, "I thought more, like can I reach that answer, or can they reach mine? If they can reach what I did, mine is correct. If their answer is right, I ask how they did it. They help me." S2, who emphasized that different ideas could be discussed and compared to find the correct answer, explained:

> I felt like everyone had different ideas and found different things. So, in a group of three, we all shared our thoughts. Then we eliminated choices and found the one that made the most sense or seemed right to us.

S3, who preferred to remain silent to avoid disagreement, stated, "I prefer to stay quiet. I stay silent because they might oppose my idea." In contrast, S4 emphasized the importance of respecting differences, stating, "Everyone has different thoughts. I respect everyone's decisions." These responses suggest that differing ideas prompted most participants to compare, reflect on, and reassess their own answers. They also acknowledged that disagreement is a natural part of group work and should be handled respectfully.

To examine how students responded when they thought a groupmate's way of thinking was incorrect, participants were asked to explain their reactions in such situations. Most participants reported that they would explain their own thinking with examples, while two students stated that they would warn their peers.

S1 stated, "I would explain the correct answer to them. I explained the question I solved. If I found a different answer, I asked the teacher." S2, who described involving other group members for feedback and clarification, stated, "I told them my idea. If mine was right, I would also want another friend to tell theirs. Then our friend could assess our ideas, eliminate wrong ones, and find the right answer." S3 stated, "I would warn them. Politly, following manners." Similarly, S4 explained, "I would warn them. Together with my groupmates, we would explain it. Then they would understand and get it right." These responses suggest that students generally responded to perceived errors in a polite and constructive manner. They tended to explain their own reasoning, provide examples, and sometimes involve other group members to help guide their peers toward the correct solution.

Finally, students were asked whether the mathematical modeling process led to any changes in their relationships with their groupmates. Most students stated that the process helped them bond more with their peers. One student reported having a good time, while two students stated that there was no change in their relationships. S9 stated, "I had a better time with my friends." S6, who reported no major change in their relationships, explained, "I get along well with all my friends, so there was no real change." In contrast, S5 stated, "We bonded more," and S7 similarly expressed, "It helped us bond."

As a result, the mathematical modeling process appears to have had a positive effect on students' social relationships. Most students stated that they felt comfortable expressing their thoughts within the group, felt pleased when their ideas aligned with those of their peers, used differing opinions as opportunities to compare and reassess their own solutions, and tried to guide their groupmates constructively when they believed an approach was incorrect. In addition, the collaborative nature of the process contributed to strengthened peer relationships and helped students develop more positive interactions with their groupmates.

5. Discussion

In this study, the categories and codes obtained from the interview findings were discussed within the framework of the sections established within the scope of the study. Regarding the Mathematical Modeling Process, students perceived modeling problems as more demanding than traditional tasks multi- step, cognitively effortful, and information-dense (Lesh & Zawojewski, 2007; Mousoulides, 2007). Under the category comparing problems with others, this perception aligns with literature characterizing modeling as generating mathematical representations in authentic contexts rather than pursuing a single correct answer (English, 2006; Lesh & Zawojewski, 2007). In encountering new situations, students' initial difficulties in interpreting task demands and handling data are consistent with evidence that modeling diverges from routine problem types (Eraslan, 2011). In impact on mathematics lessons, students reported greater clarity and accessibility, consistent with work showing that modeling activities strengthen practices such as defining, explaining, and justifying (Lesh & Doerr, 2003b). In easy and difficult aspects, difficulties clustered around understanding the problem and sifting/analyzing data; here, recent assessment work conceptualizes and operationalizes "authenticity" in modeling items (Schlüter et al., 2024). Empirical studies of teacher-designed modeling tasks at the elementary level likewise indicate that connections to reality shape students' experiences (Turner et al., 2024). In parallel, instruments developed and validated for the elementary grades show that modeling processes can be monitored reliably (Turner et al., 2021a, 2021b), a line of work complemented by rubric design and validation spanning school levels (Toalongo et al., 2022). A systematic review further indicates that—when instruction is structured—modeling is teachable and can foster students' competencies in primary classrooms (Wei et al., 2022).

Findings related to Affective Impact indicate that students came to like mathematics more and

perceived clearer connections between mathematics and everyday life (Niss et al., 2007). These results converge with evidence that modeling instruction in the elementary grades can produce both immediate and durable gains in affective outcomes such as interest and self-efficacy (Vogelsanger-Holenstein et al., 2025). Classroom studies also suggest that culturally responsive modeling mitigates marginalization while strengthening participation and belonging, underscoring the social and cultural dimensions of affect (Turner et al., 2024). Consistent with the systematic review, attending to affective components alongside task and instructional design appears to enhance teachability and impact (Wei et al., 2022).

For Social Relationships, students reported that they could express ideas freely, that agreement bolstered confidence in the solution path, and that disagreement prompted checking, revising, comparing, and productive argumentation that helped correct errors (Zawojewski et al., 2003). This interactional pattern is compatible with findings that the teacher's argumentative guidance of the modeling cycle strengthens justification and comparison practices (Solar et al., 2022). Culturally responsive modeling designs further support collaborative meaning-making and the development of shared products, thereby deepening group interaction (Turner et al., 2024).

6. Conclusion and Recommendations

This study provided a comprehensive examination of third-grade students' perspectives on the mathematical modeling process across cognitive, affective, and social dimensions. The findings revealed that engaging students in modeling activities not only enhanced their mathematical thinking but also significantly strengthened their motivation, self-confidence, and social interaction skills. Students described modeling problems as more challenging, multi-step, and thought-provoking than traditional tasks, indicating that early exposure to modeling-based learning can effectively promote higher-order cognitive skills.

From an affective perspective, the modeling process fostered more positive attitudes toward mathematics and helped students recognize clearer connections between mathematics and real-life situations. Socially, modeling activities encouraged collaboration, communication, idea sharing, and empathy, naturally promoting discussion, comparison, and collective reasoning.

In conclusion, mathematical modeling emerges as a powerful pedagogical approach that supports both academic and social learning at the primary level. Therefore, it is essential to integrate modeling activities systematically into mathematics curricula, support teachers through professional development programs, and provide students with meaningful, real-world learning experiences. Future research should explore the long-term impacts of modeling across diverse contexts and develop evidence-based strategies to strengthen classroom implementation.

Taken together, the evidence supports systematic implementation of mathematical modeling across all elementary grades so that students cultivate positive attitudes toward mathematics from an early age, connect school mathematics to everyday contexts, and develop social competencies (Niss et al., 2007; Wei et al., 2022). To enhance quality, teachers should have access to professional learning that strengthens the authenticity and real-world connectedness of modeling tasks (Schlüter et al., 2024; Turner et al., 2024) and should employ valid, reliable tools suited to the elementary level to monitor processes and outcomes (Toalongo et al., 2022; Turner et al., 2021a, 2021b). Within this frame, in-service programs targeted at elementary teachers are critical for building awareness and raising the overall quality of implementation.

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