



UPPER-SECONDARY STUDENTS' PROBLEM-POSING AND MATHEMATICAL MODELING SKILLS IN THE CONTEXT OF STEM EDUCATION AND 21ST CENTURY SKILLS

Ümit Karabıyık

Necmettin Erbakan University, Türkiye

E-mail: ukarabiyik@erbakan.edu.tr

Abstract

Mathematical problem-posing and modeling are essential skills in developing students' analytical thinking and problem-solving abilities. This study aims to examine correlation between 9th-grade students' problem-posing and mathematical modeling skills within the learning domain of numbers and algebra. Additionally, it evaluates students' mathematical modeling skills in relation to their 8th-grade mathematics scores from the Upper-secondary Entrance Examination (LGS). The research employs a quantitative approach, utilizing the relational survey technique. The study sample consists of 24 ninth-grade students from a private Upper-secondary school affiliated with the Ministry of National Education of the Republic of Turkey, selected through an accessible sampling method. The data were obtained from the students' examination results, problem-posing activities, and mathematical modeling questions. The data were examined using t-tests, Kruskal-Wallis tests, correlation analysis, and regression analysis. The findings indicated a significant relationship between ninth-grade students' problem-solving skills and mathematical modeling abilities. This relationship was found to be positive and moderate. The simple regression analysis of correlation between the two skills showed that the scores obtained from the problem-posing activities significantly predicted the scores obtained from the mathematical modeling questions. It was observed that problem-solving skills positively influenced mathematical modeling skills. In addition, it was concluded that there was no significant difference between students' LGS mathematics scores and their mathematical modeling skills, and that students with different mathematics score ranges showed similar performance in modeling questions. As a result, this study offers practical suggestions for improving education from the perspective of STEM education and 21st century skills.

Keywords: mathematics education, STEM education, algebraic thinking, problem-posing, mathematical modeling

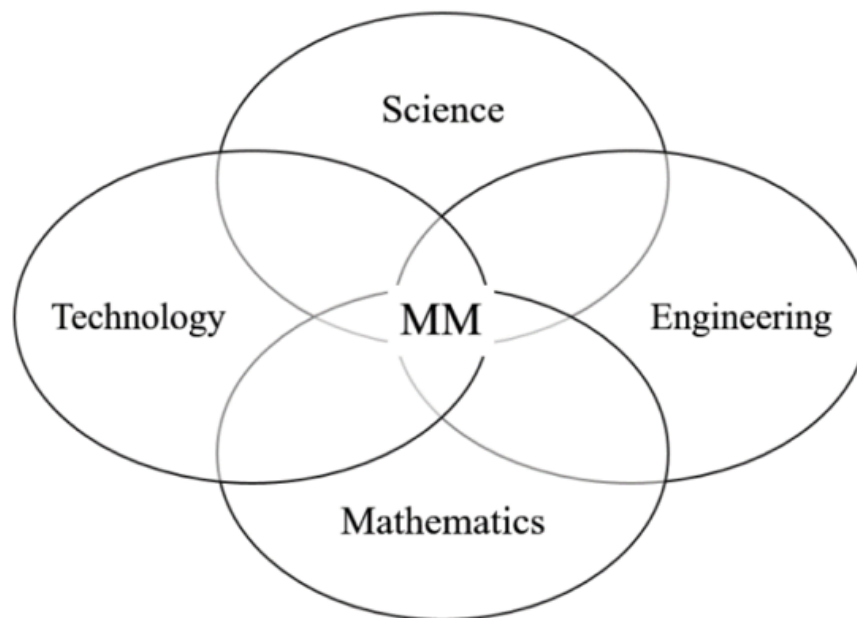
Introduction

In response to the demands of the 21st century, education systems have been undergoing significant transformations, with STEM (Science, Technology, Engineering, and Mathematics) education emerging as a key driver of this change. Modern societies encounter intricate challenges, such as optimizing traffic light sequences for safety or estimating when a landfill will reach full capacity. Tackling these issues enables students to apply their STEM knowledge and mathematical modeling skills, deepening their comprehension of the surrounding world. Previous studies have emphasized the critical role of these competencies in enhancing problem-solving abilities and facilitating real-world applications (Bybee, 2013; Williams & Goos, 2013). STEM education aims to develop not only scientific and technical knowledge but also problem posing, problem-solving, critical and creative thinking skills (Bybee, 2013). In this context, problem-posing and mathematical modeling skills stand out as fundamental components of

STEM education. Problem-posing plays a central role in students' mathematical thinking and the development of solution strategies. Students' ability to identify and solve complex problems enhances their analytical and creative thinking skills (English, 2013). Problem-posing activities can contribute to students' effectiveness in problem-solving and problem-solving can positively influence problem-posing (Xie & Masingila, 2017). In addition, problem-posing provides teachers with information about students' mathematical learning and thinking (Arıkan & Ünal, 2015). Mathematical modeling is the process of representing real-world problems with mathematical symbols, which helps students to strengthen their abstract thinking skills. The creation of a solution plan that requires the use of assumptions, predictions and strategies created with mathematical structures in the process of solving the problem refers to mathematical modeling; the problem-posing process, which includes the creation of the solution plan, its adaptation to real life, interpretation and evaluation, refers to the mathematical modeling process (Çavuş Erdem, & Gürbüz, 2018). These two 21st century skills are crucial in STEM education. Problem-posing and mathematical modeling enhance students' ability to apply their knowledge and skills in different contexts, preparing them for their future academic and professional lives. In addition, the development of these skills supports students' other important skills such as critical thinking, collaboration and communication (Lesh & Doerr, 2003). This conceptual framework presents a research plan for examining each STEM discipline, aiming to identify the intersections of models, modeling, and mathematical modeling (MM) across different academic domains and content standards. It provides valuable insights for educators and researchers by highlighting the interdisciplinary nature of these elements. Additionally, it investigates the potential impact of these intersections on teaching and learning. The ovals in the diagram represent the ways in which models, modeling, and mathematical modeling are integrated within each discipline, while the central overlapping area emphasizes the common aspects of mathematical modeling in STEM education (Groshong, 2018).

Figure 1

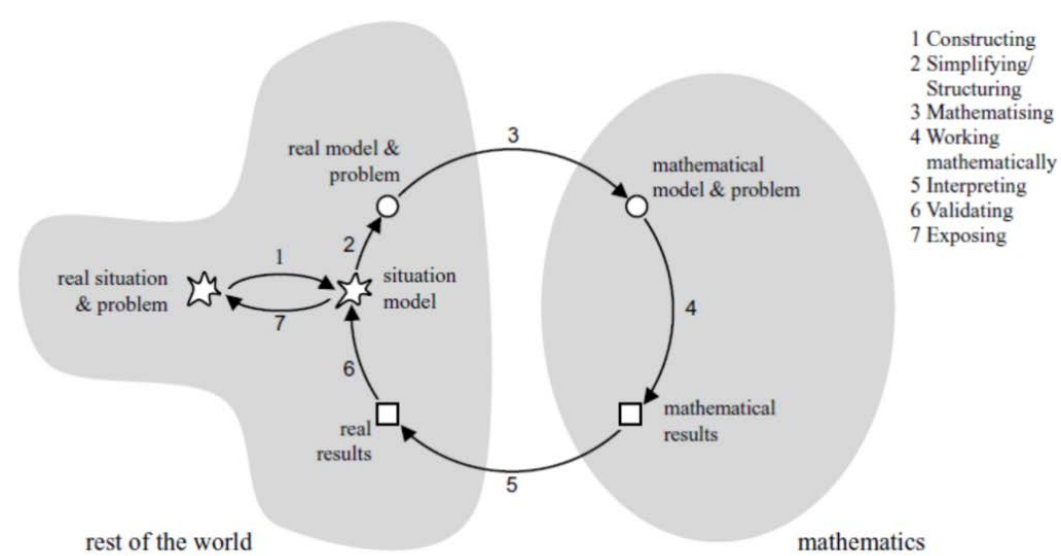
Integration of Models, Modeling, and Mathematical Modeling Across STEM Disciplines



Modeling and mathematical modeling, now widely used, are of interest not only in mathematics but also in many other disciplines. These skills involve real-life, open-ended problem-solving applications at all levels of education. The ability to use mathematics effectively in a variety of contexts and real-world problems is seen as a fundamental requirement of our age. Mathematical models and modeling can help students analyze the problems they face and develop effective solutions to those problems. The concepts of models and modeling, in addition to relating mathematics to real life, help students to understand more deeply the structures of mathematical concepts and to gain different perspectives on problem situations (Chamberlin & Moon, 2005).

The literature presents various definitions of models, mathematical models, and mathematical modeling. Lesh and Doerr (2003) describe mathematical modeling as the process of generating solutions to real-world problems by converting them into mathematical formulations. It is a process in which these mathematical solutions are interpreted by making a connection to real life. Furthermore, Greefrath and Vorholter (2016) explained mathematical modelling as "a representation of the real world that is simplified but faithful and allows the application of mathematics". Mathematical modeling is defined as the process of simplifying the problem and transforming it into a mathematical language after evaluating all kinds of situations that occur in real life (Gürbüz et al., 2018). The model demonstrates the result of the modeling process. Several frameworks describe the process of mathematical modeling, including the development of new models and the analysis, application, and evaluation of existing ones. This process involves representing essential elements of complex real-world situations using mathematical symbols, language, and structures. Once formulated, the mathematical model is manipulated, and the results are analyzed in relation to the original context (Basmadjian, 2003; Gravemeijer, 2007). According to Blum (2011), Blum and Niss (1991), and Diefes-Dux et al. (2008), mathematical modeling follows a cyclical structure comprising seven distinct stages.

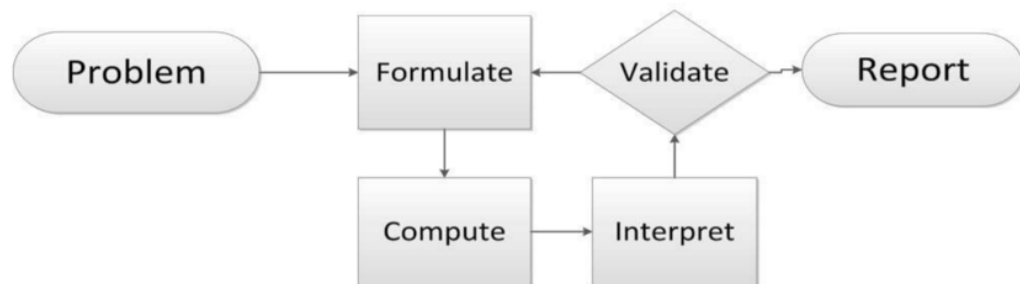
Figure 2
The Cyclical Structure of Mathematical Modeling with Seven Distinct Stages



The Common Core State Standards for Mathematics (CCSSM) highlight the significance of mathematical modeling in addressing real-world challenges. It treats modeling as an independent topic and categorizes it as one of the essential practices for students proficient in

mathematics (NGA & CCSSO, 2010). The standards outline a structured approach to guide students through the modeling process. First, students define the problem, identifying the relationships, variables, and constraints involved. Next, they create a mathematical representation of the problem, using tools like graphs, diagrams, or tables. In the third step, students perform calculations and modify the model to derive a solution. Then, they interpret the results within the context of the original problem. Finally, students assess the model's accuracy by determining how well it explains or predicts the situation. If the model is inadequate, students revisit earlier steps to refine it before documenting and presenting their findings.

Figure 3
Mathematical Modeling Process



Problem-posing and problem-solving are both crucial student-centered methods, though they serve different purposes and functions. Problem-solving focuses on understanding and applying a given concept. In this process, students must devise a strategy to find a solution based on the information provided within the problem's context. In contrast, problem-posing involves creating new mathematical questions or reimagining existing ones in novel ways (Kojima et al., 2015; Retnowati et al., 2018). Traditional problem-solving exercises in schools often reinforce certain patterns and limit students' ability to apply mathematics in real-life situations. However, non-routine problems, particularly those involving mathematical modeling, aim to enhance students' skills in solving real-world problems (Lesh & Doerr, 2003). This approach encourages students to develop problem-solving strategies for challenges they might face in both academic and everyday contexts. Although problem-solving is a core component of mathematics education, focusing on problem-posing can further enhance students' engagement with and understanding of mathematical concepts. Problem-posing enables students to generate new problem situations by analyzing existing ones or by examining the results and solutions of current problems. Research has shown that problem-solving and problem-posing skills are interrelated and support each other (Cai & Hwang, 2002; Stoyanova, 2003). Students proficient in problem-posing are often better at problem-solving, and those with strong problem-solving abilities tend to excel in posing problems (Cai, 1998; Chang et al., 2012; Chen et al., 2013). Recent studies provide valuable insights into effective methods and strategies for teaching problem-posing skills and highlight how these can be developed within the learning process. Several reviews also suggest that combining problem-posing with mathematical modeling offers significant benefits (Hansen & Hana, 2015; Hartmann et al., 2021). Problem-posing is essential not only in mathematics education but also as a key element in the mathematical modeling of real-world scenarios (Dowton, 2013; Christou et al., 2005). It involves creating new problems or restructuring existing ones, and can occur at any stage in the problem-solving process (Silver, 1994). Walkington and Hayata's (2017) teaching experiment emphasized problem-posing activities, which encourage students to view mathematical topics from different

perspectives, helping them understand concepts more deeply and connect mathematics with real-world applications. These activities also promote self-regulation and cognitive awareness in students (Brown & Walter, 1990).

Problem-posing activities not only enhance students' metacognitive abilities but also boost their interest and attitudes toward mathematics (Silver, 1994; Walkington, 2017). For instance, when students are presented with a math problem and tasked with creating similar problems, they must first examine the problem as a whole and comprehend the underlying dynamics (Priest, 2009; Silver, 1994). After constructing the problems, students should comprehend the logical relationships between problem texts, question sentences and solution processes. During these processes, students develop their metacognitive skills by continuously self-regulating and self-regulating the problem-posing stages (Arikan & Ünal, 2015; Cankoy & Darbaz, 2010; English, 1997; Kopparla et al., 2019; Priest, 2009). In addition, Altun (2002) stated in his study that achieving success in problem-posing skills would help students reduce their negative feelings, thoughts and anxieties towards mathematics course.

Research explores the impact of mathematical modeling and problem-posing tasks on student achievement and identifies effective teaching strategies for enhancing problem-posing skills. Studies on mathematical problem-posing and solving processes in secondary education highlight the methods employed to develop students' problem-posing abilities and their role in education. Investigations into how innovative teaching methods foster problem-solving and construction skills examine the correlation between the teaching strategies used and student performance. Research on the development of problem-posing skills in mathematics education reviews evidence-based effective teaching practices and synthesizes recent studies on problem-posing and problem-solving in mathematics classrooms. These studies introduce new approaches and strategies aimed at improving student outcomes (Bakker & Gravemeijer, 2021; Mousoulides & Leikin, 2022; O'Neill & Robson, 2023; Rasmussen & Marrongelle, 2022; Sullivan & Lilburn, 2021).

The importance of this study stems from the fact that the number of studies examining mathematical modeling and problem-posing skills together is higher than the number of studies examining these skills in the context of number and algebra learning. The number of studies examining problem-posing or mathematical modeling skills in relation to number and algebra learning is limited in the literature. Most of the studies cited in the introduction focus on the correlation between problem-solving and mathematical modeling, or between problem-solving and problem-posing. Given the relevance of problem-posing and mathematical modeling skills in daily life, the significance of this study becomes more apparent. The aim of this study was to examine the correlation between mathematical problem-posing and mathematical modeling skills. Within the scope of the research, the following research questions (RQ) have been addressed:

- RQ1. What is the level of students' success in problem-posing in the numbers and algebra learning domain of mathematics course?
- RQ2. What are the students' mathematical modelling skill levels?
- RQ3. Do students' mathematical modelling skills and problem-posing success levels differ significantly according to their LGS mathematics scores?
- RQ4. Is there a significant correlation between students' problem-posing success levels in the learning area of numbers and algebra and their mathematical modeling skill levels?
- RQ5. To what extent do students' problem-posing success levels in the learning area of numbers and algebra predict their mathematical modelling skill levels?

Research Methodology

Research Design

The study is based on a correlational survey design, which is one of the quantitative research approaches. It was conducted during the first semester of the 2024 academic year at a public high school in Konya, Turkey. A total of 24 ninth-grade students, selected through purposive sampling, participated in the study. The participants were aged between 13 and 15, with 13 male and 11 female students.

Correlation and regression analyses were employed to analyze the data. Correlation analysis was used to assess the direction and strength of the relationship between two or more variables, while regression analysis aimed to determine the effect of variables on each other and their predictive power. As part of the research process, students were first given problem-posing activities in the learning area of numbers and algebra, followed by mathematical modeling problems. The data were analyzed using quantitative methods, and the findings were interpreted within the theoretical framework. The results were evaluated based on these interpretations. Before conducting the study, informed consent was obtained from both the participants and their parents. The identities of the students were kept confidential, and all data were analyzed anonymously in accordance with ethical principles. The study primarily aimed to examine the relationship between ninth-grade students' problem-posing and mathematical modeling skills.

Data Collection Tools

In this study, the data collection tools developed by the researcher were the LGS Results Information Form, the Problem Forming Activity, and the Mathematical Modeling Questions. The LGS Results Information Form contained questions about students' LGS math scores to determine their personal interests. The Problem Forming Activity data tool, prepared by the researcher, includes questions about algebraic expressions, equations, and inequalities (Appendix-A). Before the study, the researcher developed a form consisting of 15 questions covering the sub-learning area of equations and inequalities under the 9th-grade Numbers and Algebra learning area, which included semi-structured problem-posing activities.

In the semi-structured problem-posing approach, students are encouraged to generate problems grounded in their prior mathematical knowledge and experiences. This is achieved by providing open-ended event patterns in various formats, such as equations, verbal expressions, graphs, pictures, or tables. These event patterns are designed as open-ended prompts that do not have a predefined question, and students are expected to create unique and inventive problems based on these constructs (Stoyanova, 2003).

The results of the item analysis of the Problem-posing Activity are presented in Table 1 with item difficulties and discriminations.

Table 1
Item Analysis Results of Problem-posing Activities

Item No	Item Difficulties	Item Discriminations
1	.67	.57
2	.75	.59
3	.49	.47
4	.71	.62
5	.81	.34
6	.73	.41
7	.51	.44
8	.68	.47
9	.67	.44
10	.52	.45
11	.57	.42
12	.79	.46
13	.73	.43
14	.83	.57
15	.45	.42

Expert opinions were sought to determine the content validity of the problem-posing activities. An associate professor working in the Department of Mathematics Education and two Upper-secondary mathematics teachers working in the Ministry of National Education provided their opinions and suggestions on the clarity and comprehensibility of the questions in the problem-posing draft, the extent to which they included the learning outcomes, and their suitability for the students' level. After ensuring the content validity, this problem-posing activity was applied to the students.

As a result of the Turkish literature review on mathematical modeling, mathematical modeling problems that require the use of Upper-secondary level algebra and can be completed in two class periods were identified. The four selected questions were taken from the 9th grade modeling activity book of the Turkish Ministry of National Education, General Directorate of Secondary Education. These questions are as follows: "How should I spend my energy", "Green cities", "Coronavirus", and "Healthy weight loss" (Appendix-B). Based on these activities, the final form of the mathematical modeling data collection tool was created.

Data Collection and Experimental Procedures

In this study, national and international studies on problem-solving, problem-posing and mathematical modeling were extensively reviewed through Google Scholar, YÖK Thesis, Dergipark and ERIC databases. In order to collect the implementation data of the study, "LGS Result Information Form", "Problem-posing Activity", and "Mathematical Modeling Questions" data collection tools developed by the researcher were applied to the study group.

At the end of the school semester, during the final week when all classes were completed, a two-stage face-to-face implementation process was planned with the participation of the students. In the first phase, problem-posing activities lasting four class hours (160 minutes in total) were carried out, specifically in the last week of the semester, after the completion of regular lessons. Before these activities, students were given preliminary information about

problem-posing and solved a sample problem for one class hour. The aim of this phase was to improve students' problem-posing skills and increase their mathematical thinking skills. In the second stage, mathematical modeling problems lasting four class hours (160 minutes in total) were applied to the students who participated in the problem-posing activities. Prior to the mathematical modeling activities, students were provided with preliminary information about modeling and mathematical modeling for one class hour and a sample mathematical model was made. At this stage, students' ability to solve everyday problems using mathematical models was assessed.

As a result, all data were collected and analyzed using these methods. The results of the study provide important clues for improving students' mathematical modeling and problem-posing skills. This process has provided rich learning experiences for students and is expected to help educators develop effective teaching strategies.

Data Analysis

In the research, all data collected for the study were first transferred to a computer in Excel file format. This step is critical for organizing and analyzing the data systematically. Within the framework of the problem-posing activity, each student was coded as S1, S2, S3, ..., S24 before the problem drafts created by the students were analyzed. The following scoring system was used to evaluate the problem-posing activity:

- The problems constructed by the students were scored 0 points if they were incorrectly written or left blank.
- If the problems constructed by the students were partially appropriate to the desired situation or partially correct, 1 point was awarded.
- If the problems constructed by the students were completely appropriate and correct for the desired situation, 2 points were awarded.

According to these scoring criteria, the maximum score a student could receive from the problem-posing activity is 30 and the minimum score is 0. The scoring of the problem-posing activity was done independently by a mathematics teacher and a faculty member from the Department of Mathematics Education and then compared. As a result of the coding, it was found that there was disagreement between the experts on 68 of the 360 questions. The reliability coefficient of the coding was calculated using Miles and Huberman's "Agreement / (Agreement + Disagreement)" formula and was found to be .811.

Within the mathematical modeling activities, scoring was done as follows:

- 0 points if students' mathematical modeling expressions were completely incorrect,
- 1 point if the mathematical modeling statements were partially correct,
- If the statements were completely true and appropriate for the given situation, they were scored 2 points.

According to this scoring system, the highest score a student can get from mathematical modeling activities is 8 and the lowest score is 0. Statistical software was used to analyze the data. First, the normality distribution of the data was evaluated, and the results of the skewness, kurtosis, and Kolmogorov-Smirnov tests were checked.

Table 2
Kurtosis and Skewness Analysis

Activity Type	Kolmogorov- Smirnov	Kurtosis	Skewness	Reliability
Problem-posing activity	.200*	.151	-.391	.804
Mathematical modeling problems	.000	-.325	-.287	-

Table 2 shows that the skewness and kurtosis values of the data related to the problem-posing activity and mathematical modeling problems are in the range of ± 2 . This indicates that the scores obtained from the scales are normally distributed, and the results of the Kolmogorov-Smirnov test show that the total scores of both scales conform to the normal distribution. Due to the normal distribution of the data, it was determined that it would be appropriate to use parametric tests for the analyses to be performed.

In addition, in the later stages of the study, the nonparametric Kruskal-Wallis test was used to determine whether the problem-posing activity and mathematical modeling questions differed according to LGS mathematics scores. The Pearson correlation test was used to determine the significant differences between the total scores obtained from the problem-posing activity and the mathematical modeling questions. In addition, a regression test was conducted to determine the extent to which the total scores obtained from the problem-posing activity affected the total scores obtained from the mathematical modeling questions.

Research Results

Students' Performance in Problem-Posing Activities within the Numbers and Algebra Learning Area

To assess the students' success level in problem-posing within the mathematics course, specifically in the area of numbers and algebra, the means and standard deviations of the individual questions and the total scores from the problem-posing activities were calculated. The results are shown in Table 3.

Table 3
Arithmetic Means and Standard Deviations of Problem-posing Activities

Problem-posing activities	N	M	SD	Kurtosis	Skewness
P1	24	1.45	.686	-.239	-.887
P2	24	.95	.825	-1.518	.098
P3	24	1.05	.759	-1.754	-.086
P4	24	.75	.786	-1.151	.496
P5	24	1.05	.825	-1.518	-.098
P6	24	1.15	.812	-1.399	-.295
P7	24	1.1	.852	-1.617	-.204
P8	24	1.7	.470	-1.241	-.945
P9	24	1.5	.686	.541	-1.283
P10	24	1.3	.732	-.833	-.553
P11	24	.8	.716	-.825	.417
P12	24	1.6	.68	1.17	-1.513
P13	24	.9	.788	-1.307	.186
P14	24	1	.794	-1.366	0
P15	24	1.65	.489	-1.719	-.681

As can be seen in Table 3, students in activities numbered P2, P4, P11, and P13 had difficulties in constructing problems. On the other hand, in activities numbered P3, P5, P6, P7, P10 and P14 only half of the students participating in the study were able to construct problems as desired. In activities P1, P8, P9, P12, and P15 most students were able to construct problems as desired.

Students' Mathematical Modeling Achievement Levels

The second research question was to determine the mathematical modeling proficiency levels of 9th grade students. To answer this question, the students' scores on the mathematical modeling questions and the means and standard deviations of the total scores they received on these questions were calculated. The results of these calculations are presented in detail in Table 4. This analysis provides an important basis for understanding the students' skills in mathematical modeling and how widespread these skills are. Table 4 provides an overall assessment of students' modeling skills, with both mean scores and standard deviations.

Table 4
Arithmetic Means and Standard Deviations for Mathematical Modeling Questions (MQ)

Mathematical modeling questions	N	M	SD	Kurtosis	Skewness
M1	24	1.45	.686	-.239	-.887
M2	24	.95	.825	-1.518	0.098
M3	24	1.05	.759	-1.754	-.086
M4	24	.75	.786	-1.151	.496

According to the data in Table 4, some significant differences were observed in the students' performance in the mathematical modeling activities. In particular, in the mathematical modeling questions M2 and M3 it was found that almost half of the students participating in the study were able to formulate these questions as desired. This indicates that these two questions were better understood by the students and the analysis was more successful. On the other hand, most of the students had difficulty with the mathematical modeling question M4; the number of students who were able to construct this question in the desired way remained below half. This suggests that question M4 was more complex or challenging for the students. However, during Activity M1, it was observed that most students answered the mathematical modeling question as expected. This suggests that question M1 was easier for students to understand and solve successfully.

Relationship Between Students' Mathematical Modeling Achievement Levels and LGS Mathematics Scores

The Upper-secondary Transition System exam in Turkey is organized by the Ministry of National Education every year for 8th grade students in secondary schools. This exam is conducted to place students in Upper-secondary system and consists of two sessions: verbal and numerical. Mathematics is one of the most important components of the numerical session. In the LGS exam, there are 20 questions from the math course. These questions are designed to measure students' mathematical reasoning, problem-solving, and mastery of mathematical concepts.

In recent years, the average mathematics scores in the LGS (Upper-secondary Transition Examination) in Turkey have generally remained at a low level. In 2020, the average mathematics score was 4.89, and in 2021, it was 4.20. In 2022, this average rose to 4.74 but fell again to 3.92 in 2023. In 2024, the average was 4.21. The performance of students according to their math scores on the LGS exam in recent years can be divided into four categories: poor, average, good, and very good. According to this categorization, the poor level is defined as 0-4 score, the average level is 5-8 score, the good level is 9-13 score, and the very good level is 14-20 score.

Table 5
Students' Scores on Mathematical Modeling Questions According to their LGS Exam Mathematics Scores

Mathematical modeling questions	N	Mathematics scores	Kruskal-Wallis test	p
M1	3	0-4	.856	.648
	6	5-8		
	3	9-13		
	12	14-20		
M2	3	0-4	2.60	.270
	6	5-8		
	3	9-13		
	12	14-20		
M3	3	0-4	.878	.682
	6	5-8		
	3	9-13		
	12	14-20		
M4	3	0-4	2.52	.284
	6	5-8		
	3	9-13		
	12	14-20		
General Average			1.20	.545

As shown in Table 5, the results of the Kruskal-Walli’s test conducted based on the LGS mathematics scores indicate that there is no statistically significant difference between the M1, M2, M3, and M4 groups in terms of the total scores they received from the mathematical modeling questions ($p = .545, p > .05$).

This result shows that there is no significant difference between the LGS mathematics scores of different groups and their mathematical modeling skills. In other words, students' mathematics scores in the LGS exam do not have a significant effect on their scores in mathematical modeling questions. It was concluded that students with different mathematics score ranges were not significantly different from each other in terms of mathematical modeling skills and performed at similar levels.

Correlation Between Students' Problem-Posing Achievement in Numbers and Algebra and Their Mathematical Modeling Skills

A Pearson correlation analysis was conducted to examine the relationship between students' problem-posing achievement in the learning area of numbers and algebra and their mathematical modeling skills. The correlation between the scores obtained from problem-posing activities and mathematical modeling questions was analyzed. The results, presented in Table 6, provide insights into the extent of this relationship.

Table 6
Correlation Analysis of Problem-Posing and Mathematical Modeling Scores

Problem-posing activity	<i>p</i>	<i>r</i>
Mathematical modeling problems	.0001	.540**

Table 6 shows that the *p* value is .0001, indicating a statistically significant relationship between 9th-grade students' algebra problem-posing scores and their mathematical modeling scores. This finding confirms a meaningful correlation between problem-posing activities and mathematical modeling performance.

The correlation coefficient obtained (*r* = .540) indicates that this relationship is positive and of moderate strength. In other words, as students' scores on problem-posing activities increase, their scores on mathematical modeling questions also tend to increase. This finding suggests that problem-posing skills may contribute to students' success in mathematical modeling processes.

Impact of Students' Problem-Posing Success in Numbers and Algebra on Their Mathematical Modeling Skills

To examine the effect of students' problem-posing success in algebra on their mathematical modeling skills, a simple regression analysis was conducted. This analysis aimed to determine the extent to which problem-posing scores predict students' mathematical modeling skill levels. The results, presented in detail in Table 7, provide valuable insights into how problem-posing skills influence success in mathematical modeling processes.

Table 7
Regression Analysis of the Predictive Relationship Between Problem-Posing Success and Mathematical Modeling Success

Independent variable	Dependent variable	<i>B</i>	<i>SD</i>	β	<i>t</i>	<i>p</i>	<i>R</i>	<i>R</i> ²	<i>F</i>	<i>p</i>
Problem Posing	Mathematical Modeling	.89	.023	.525	.293	.0001	.525(a)	.254	16.75	.001(b)

a. Predictors: (Constant), PT b. Dependent Variable: MT

Examining the results in Table 7 it can be seen that the level of problem-posing success in the learning area of numbers and algebra significantly predicts students' mathematical modeling skills. According to the results of the analysis, it was found that problem-posing success positively affected mathematical modeling success, and this effect was statistically

significant ($p = .0001 < .05$). This finding indicates that students' problem-posing skills play an important role in their mathematical modeling performance.

More specifically, it was found that problem-posing success explained 24% of the total variance in mathematical modeling success. This shows that problem-posing skills are an important factor in the mathematical modeling process and have a significant impact on students' modeling performance. The correlation coefficient ($R = .525$) indicates that there is a moderately strong relationship between problem-posing success and mathematical modeling success, while the coefficient of determination ($R^2 = .254$) indicates that problem-posing skills explain approximately 25% of the variation in mathematical modeling success.

Discussion

The aim of this study was to examine the correlation between 9th-grade students' problem-posing skills and their mathematical modeling abilities within the number and algebra learning area. The results of extensive analyses reveal significant insights, aligned with the study's objectives. These findings highlight the interconnectedness of students' problem-posing and mathematical modeling skills, their correlation with LGS mathematics scores, and potential differences among students. This provides valuable guidance for educators and policymakers on the key skills to prioritize in mathematics education.

Regarding the first research question, the findings suggest that students' success in posing problems within the number and algebra learning area varies depending on the type of activity. Specifically, difficulties encountered in some activities indicate the need to further develop problem-posing skills in the teaching process. To better equip students to handle more complex problems, teaching methods may need to be revised, and additional support should be provided. Moreover, creating more accessible and student-appropriate activities could contribute to the development of problem-posing skills across all students. These results underscore the importance of reassessing teaching strategies and activities for algebraic problems. Offering students a variety of appropriately leveled problem-posing activities can more effectively improve their problem-solving skills. A study by Çetinkaya and Soybaş (2018) found that 8th-grade students demonstrated moderate success in structured problem-posing activities, a finding consistent with the results of this study. The fact that similar studies over time have consistently shown moderate results suggests that students' problem-posing skills are generally below expectations. One possible reason for this may be that curricula in schools do not sufficiently emphasize problem-posing skills. Additionally, teachers' limited incorporation of problem-posing skills in their teaching may also contribute to this issue. Aykurtlu (2019) 9th-grade students' problem-solving and problem-posing skills on "fraction and percentage problems," revealing that the students were generally unsuccessful in both areas. In a similar vein, Xiu et al. (2020) explored problem-posing and mathematical thinking abilities of students at different grade levels in China, showing that as grade level increases, students tend to construct more complex problems.

In response to the second research question, the data revealed that students' mathematical modeling skills varied significantly based on the difficulty level of the activities. This highlights that mathematical modeling activities directly affect student performance. Students' performance changed when they faced questions of varying difficulty levels, with success decreasing as difficulty increased. This emphasizes the importance of designing instructional strategies and activities that align with students' current knowledge and skill levels. Educators can achieve more effective learning outcomes by ensuring students are gradually exposed to progressively more challenging questions in mathematical modeling activities. For mathematical modeling activities to effectively develop students' skills, the difficulty of the questions should be carefully considered. Questions that are clear and appropriately challenging can help students express

themselves better and improve their modeling abilities. Cheng (2001) defined mathematical modeling as the process of translating real-world problems into mathematical terms in order to better understand them and find solutions. In the study by Baran and Türker (2022), some 8th-grade students struggled with mathematical modeling, while others could only create simple models. These findings suggest that students' modeling skills are generally at an intermediate level. Similarly, a study by Çoksöyler and Bozkurt (2021) observed that 6th-grade students faced challenges in the modeling process, often resorting to operational expressions without fully understanding the problems or considering the modeling stages. In Gündüzalp (2019) study, it was found that despite high achievement levels, 11th-grade students' mathematical modeling skills were insufficient, with many struggling to interpret modeling situations. The reason for this may be a lack of prior exposure to such problems. In their study, Krawitz and Schukajlow (2018) examined how students' use of prior mathematical knowledge affected the modeling process, with results indicating that prior knowledge plays a significant role in successful modeling.

Addressing the third research question, the data suggests that mathematics performance on exams like the LGS is not the sole determinant of students' higher-order cognitive skills, such as mathematical modeling. This finding highlights the need for different teaching strategies and more comprehensive educational approaches to foster these cognitive skills. Specifically, it points to the importance of developing skills like mathematical modeling independently of standardized test performance. The lack of a clear relationship between LGS performance and modeling skills suggests two possibilities. First, students may not have had sufficient exposure to mathematical modeling in their education. While they may have succeeded on exams, this may have hindered their ability to apply modeling skills effectively. Second, students may have struggled to learn and apply mathematical modeling skills in real-life contexts, indicating difficulty in acquiring and using these skills. Therefore, educational programs should focus not only on test performance but also on developing higher-order cognitive skills, particularly modeling. Prioritizing these skills and providing more opportunities for their development could have a positive impact on both test success and overall cognitive growth.

Concerning the fourth research question, the results indicate a significant relationship between students' achievement in problem-posing activities and their success in mathematical modeling tasks within the number and algebra learning area. As students' scores in problem-posing activities increased, their scores on mathematical modeling tasks also tended to rise. This finding suggests that problem-posing skills may contribute to students' success in mathematical modeling tasks. In other words, students with higher problem-posing skills tend to perform better in modeling tasks. This result provides valuable insights for educators and curriculum developers, indicating that problem-posing and mathematical modeling skills should be developed concurrently and supported throughout the learning process. Kaplan (2022) found that mathematical modeling skills can be enhanced through problem-posing activities, emphasizing the importance of teaching problem-posing before introducing mathematical modeling, particularly in earlier grades. Gade and Blomqvist (2015) highlighted that the processes of formulating and reflecting on problems in groups help develop mutual challenges, self-regulation, and independent thinking, all of which are crucial for mathematical modeling.

Finally, the results of the study reveal a significant prediction: students' success in problem-posing activities in the number and algebra learning area significantly predicts their mathematical modeling performance. This indicates that problem-posing skills positively impact modeling success. Students who excel in problem-posing tend to perform better in mathematical modeling tasks. These findings reinforce the idea that problem-posing skills are foundational to the development of mathematical modeling abilities. Hartman et al. (2021) concluded that problem-posing supports mathematical modeling, suggesting that problem-posing should be prioritized in teaching the modeling process.

In light of the findings, it is essential to critically assess how they align with existing literature on problem-posing and mathematical modeling skills. The positive correlation between problem-posing and mathematical modeling skills observed in this study supports previous research (Kaplan, 2022; Gade & Blomqvist, 2015), which underscores the importance of problem-posing as a foundational skill for mathematical modeling. However, the finding that standardized test performance, such as LGS scores, does not significantly impact modeling skills contrasts with some expectations in the literature, where academic achievement is often viewed as a predictor of higher-order cognitive abilities (Krawitz & Schukajlow, 2018). While the literature generally suggests a strong connection between problem-posing and modeling, the results of this study reveal that this relationship may be more complex than previously thought. The findings highlight the need for more focused teaching strategies that prioritize the development of skills over standardized test scores. Future research should explore the factors influencing the divergence between test performance and modeling skills, considering how students' prior experiences, curriculum design, and teaching methodologies shape both problem-posing and mathematical modeling skills.

Conclusions and Implications

Based on the results of this study, the development of problem-posing, modeling, and mathematical modeling skills can strengthen students' analytical thinking abilities and enhance their capacity to address real-world problems. Teaching these skills as an integrated part of STEM education enables students to develop deeper insights. It is crucial that these skills be taught in a mutually reinforcing manner throughout the curriculum. This highlights the need for curricula to be enriched with strategies that focus not only on test success but also on the development of students' higher-order cognitive skills. Teachers must encourage students to engage with more complex problems and ensure that they actively participate in these processes.

When developing problem-posing and mathematical modeling skills, it is essential for teachers to receive the necessary training and pedagogical support to use these skills effectively in the classroom. Additionally, providing continuous feedback to students during problem-posing and modeling activities plays a crucial role in the development of these skills. The use of digital tools in STEM education should be increased, and software like GeoGebra can enrich students' learning experiences. Finally, long-term research into how these skills develop across different education levels is vital. Such research will provide valuable data for continuous improvement and innovation in education. Several important recommendations can be made for future research. It would be beneficial to examine how problem-posing and mathematical modeling skills vary across all levels of upper-secondary education and among different demographic groups. Additionally, comparing the problem-posing and mathematical modeling skill levels of lower and upper-secondary students could be a significant step in understanding the changes and implications for the development of these skills. Given that problem-solving skills support mathematical modeling, qualitative and quantitative studies exploring whether these skills negatively influence each other could contribute to a better understanding of the relationship between them. It is also essential to examine whether problem-posing and mathematical modeling skills differ significantly based on gender variables. In this context, teaching problem-posing skills first and then mathematical modeling skills in the mathematics classroom may lead to more effective learning of these skills.

Limitations

The study's limitations include the sample being limited to a specific geographical region or school group, which may affect the generalizability of the results. Additionally, the research

was conducted within a limited time frame and resources and did not thoroughly explore demographic factors such as gender, age, and socioeconomic status. The focus on a specific mathematical subject also limits the analysis of broader factors influencing problem-posing and mathematical modeling skills. Addressing these limitations will help in interpreting the findings more accurately and guiding future research.

Acknowledgements

Gratitude is extended to all the people and institutions that contributed to the realization of this study.

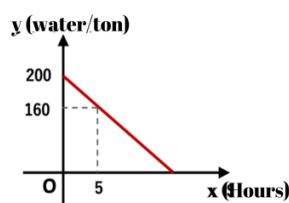
Appendix-A. Semi-Structured Problem-posing Questions

P1. Given " $5x + 3 = 18$ " equation and solve a problem using this equation?

P2. Set up and solve a problem involving operations in algebraic expressions by completing the problem given below?

"An internet operator charges a fixed monthly fee of 15 TL and an additional fee of 1.25 TL for each hour of connection. Accordingly..."

P3.



Set up and solve a problem using the graph given above?

P4. Set up and solve a problem involving an equation using the expressions given below?

" $x + y, x - y, 24, 6$ "

P5. " $4x + 3(25 - x) = 88$ "

Set up and solve a problem using the equation given above?

P6. Set up and solve a problem using the algebraic inequality given below?

" $x + (4x - 4) \leq 3x + 20$ "

P7. A mixture is prepared by taking x gram, y gram, z gram of substances A, B, C, respectively.

Set up and solve a problem involving equations using the expressions given below?

" $5x, 3y, 4y, 3z, 440$ gram mixture"

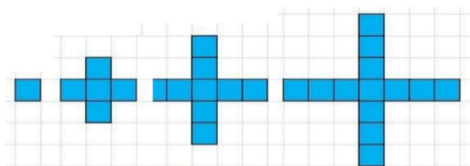
P8. Set up and solve a problem involving an equation using the expressions given below?

" $\frac{x}{6}, \frac{x}{10}, 15$ cm, fabric"

P9. " N : notebook, B : book, $3N, 15B, 6N, 3B$ "

Set up and solve a problem using the data above?

P10.



Construct a problem for the pattern given above?

P11. Set up and solve a problem involving the sum of algebraic expressions using the expressions given below?

" $2x, 13, 7x, 8$ "

P12. Using the information given below, set up and solve a problem involving patterns in algebraic expressions?

" $3, 8, 13, 18, 23 \dots$ "

P13.

%25	%37	%45
A	B	C
56 lt	84 lt	28 lt

The percentages of salt in a mixture are given above. Set up and solve a problem using this information?

P14. Given the selling price (S) and the buying price (B) of a good, construct and solve an algebraic inequality problem using the following information.

" $3B + 8000, 7B - 200, S$ "

P15. Table. Distances of a vehicle to fueling stations (A, B, C and D) at the end of the first three hours

	B	C	D
HOUR 1	15		120
2ND HOUR	25		
3RD HOUR		45	

Set up and solve a problem using the information given above?

Appendix-B. Mathematical Modeling Questions

https://ogmmateryal.eba.gov.tr/panel/upload/etkilesimli/kitap/beceri_temelli/9/matematik-modelleme/index.html#p=2

M1. How Should I Spend My Energy (Page 9)

M2. Green Cities (Page 12)

M3. Coronavirus (Page 20)

M4. Healthy Weight Loss (Page 40)

References

- Altun, M. (2002). *İlköğretimde problem çözme öğretimi* [Teaching problem solving in primary education]. Uludağ Üniversitesi Yayınları.
- Arikan, E. E., & Unal, H. (2015). An investigation of eighth grade students' problem-posing skills (Turkey sample). *International Journal of Research in Education and Science (IJRES)*, 1(1), 23-30. <https://files.eric.ed.gov/fulltext/EJ1105100.pdf>
- Aykurtlu, G. (2019). *9. sınıf öğrencilerinin kesir ve yüzde problemleri konusunda problem çözme başarılarının ve problem kurma becerilerinin incelenmesi* [Investigation of 9th grade students' problem-solving success and problem posing skills on fraction and percent problems]. [Yüksek Lisans Tezi, Balıkesir Üniversitesi]. Balıkesir Üniversitesi Fen Bilimleri Enstitüsü.
- Bakker, A., & Gravemeijer, K. (2021). Designing problem-solving tasks for mathematical modeling. *Journal of Mathematical Behavior*, 62, 100-112. <https://doi.org/10.1016/j.jmathb.2021.100112>

- Baran, D., & Türker, M. (2022). Ortaokul öğrencilerinin üslû ifadeler konusunda modelleme yeterliklerinin incelenmesi: Sarmal kitaplık problemi [Investigation of middle school students' modeling competencies on exponential expressions: Spiral bookshelf problem]. *Recep Tayyip Erdoğan Üniversitesi Eğitim Fakültesi Dergisi (REFAD)*, 2(2), 39-56.
- Basmadjian, D. (2003). *Mathematical modeling of physical systems: An introduction*. Oxford University Press.
- Blum, W. (2011). Can modelling be taught and learnt? Some answers from empirical research. In G. Kaiser, W. Blum, R. B. Ferri, & G. Stillman (Eds.), *Trends in teaching and learning of mathematical modelling: ICMTA 14* (pp. 15-30). Springer. https://doi.org/10.1007/978-94-007-0910-2_3
- Blum, W., & Niss, M. (1991). Applied mathematical problem-solving, modelling, applications, and links to other subjects – State, trends and issues in mathematics instruction. *Educational Studies in Mathematics*, 22, 37-68
- Brown, S. I., & Walter, M. I. (1990). *The art of problem posing*. Lawrence Erlbaum Associates.
- Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association Press.
- Cai, J. (1998). An investigation of U.S. and Chinese students' mathematical problem-posing and problem-solving. *Mathematics Education Research Journal*, 10, 37-50. <https://doi.org/10.1007/BF03217121>
- Cai, J., & Hwang, S. (2002). Generalized and generative thinking in U.S. and Chinese students' mathematical problem-solving and problem-posing. *The Journal of Mathematical Behavior*, 21(4), 401-421.
- Canköy, O., & Darbaz, S. (2010). Effect of a problem-posing based problem-solving instruction on understanding problem. *Hacettepe University Journal of Education*, 38, 11-24.
- Chamberlin, S. A., & Moon, S. M. (2005). Model-eliciting activities as a tool to develop and identify creatively gifted mathematicians. *Journal of Secondary Gifted Education*, 16(1), 24-32. <https://doi.org/10.4219/jsge-2005-282>
- Chang, K.-E., Wu, L.-J. J., Weng, S.-E. E., & Sung, Y.-T. T. (2012). Embedding game-based problem-solving phase into problem-posing system for mathematics learning. *Computers and Education*, 58, 775-786. <https://doi.org/10.1016/j.compedu.2011.10.002>
- Chen, L., Van Dooren, W., & Verschaffel, L. (2013). The relationship between students' problem-posing and problem-solving abilities and beliefs: A small-scale study with Chinese elementary school children. *Frontiers of Education in China*, 8, 147-161. <https://doi.org/10.3868/110-002-013-0010-5>
- Cheng, K. C. (2001). Teaching mathematical modelling in Singapore schools. *The Mathematics Educator*, 6(1), 63-75. <https://repository.nie.edu.sg/server/api/core/bitstreams/4fa446a4-f90c-4ec5-8497-40261e7e54dc/content>
- Christou, C., Mousoulides, N., Pittalis, M., Pitta-Pantazi, D., & Sriraman, B. (2005). An empirical taxonomy of problem-posing processes. *ZDM*, 37(3), 149-158. <https://doi.org/10.1007/s11858-005-0004-6>
- Çetinkaya, A., & Soybaş, D. (2018). An investigation of problem posing skills of elementary school 8th grade students. *Journal of Theoretical Educational Science*, 11(1), 169-200.
- Çoksöyler, A., & Bozkurt, G. (2021). Bilişsel perspektif bağlamında matematiksel modelleme süreci: Altıncı sınıf öğrencilerinin deneyimleri. *Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Dergisi*, (52), 480-502.
- Diefes-Dux, H. A., Hjalmarson, M. A., Miller, T. K., & Lesh, R. (2008). Modeleliciting activities for engineering education. In J. S. Zawojewski, H. A. Diefes-Dux, & K. J. Bowman (Eds.), *Models and modeling in engineering education: Designing experiences for all students* (pp. 17-35). Sense Publishers. https://doi.org/10.1163/9789087904043_003
- Downton, A. (2013). Problem posing: a possible pathway to mathematical modelling. In G. A. Stillman, G. Kaiser, W. Blum, & J. P. Brown (Eds.), *Teaching Mathematical Modelling: Connecting to Research and Practice* (1st ed., pp. 527-536). (International Perspectives on the Teaching and Learning of Mathematical Modelling). Springer. https://doi.org/10.1007/978-94-007-6540-5_45
- English, L. D. (1997). The development of fifth-grade children's problem-posing abilities. *Educational Studies in Mathematics*, 34, 183-217.
- English, L. D. (2013). STEM education: Perspectives on integration. In L. D. English & J. T. Watters (Eds.), *Mathematics education in the early years* (pp. 3-18). Springer. https://doi.org/10.1007/978-94-007-4978-8_1

- Gade, S., & Blomqvist, C. (2015). From problem-posing to posing problems via explicit mediation in grades 4 and 5. In Singer, F., F. Ellerton, N., & Cai, J. (Eds), *Mathematical problem posing. Research in mathematics education* (pp. 195-213). Springer. https://doi.org/10.1007/978-1-4614-6258-3_9
- Gravemeijer, K. (2007). Emergent modelling as a precursor to mathematical modelling. In W. Blum, P. L. Galbraith, H. W. Henn, & M. Niss (Ed.), *Modelling and applications in mathematics education: The 14th ICMI study* (pp. 137-144). Springer. https://doi.org/10.1007/978-0-387-29822-1_12
- Groshong, K. A. (2018). *Defining mathematical modeling for K-12 education* [Doctoral dissertation, The Ohio State University]. Graduate School of The Ohio State University.
- Gündüzalp, M. (2019). 11. sınıf öğrencilerinin modelleme becerilerinin incelenmesi [Investigation of 11th grade students' modeling skills]. [Master's thesis, Marmara University]. Marmara University Institute of Educational Sciences.
- Gürbüz, R., Erdem, Z. Ç., Şahin, S., Temurtaş, A., Doğan, C., Doğan, M. F., Çalık, M., & Çelik, D. (2018). Bir disiplinler arası matematiksel modelleme etkinliğinden yansımalar [Reflections from an interdisciplinary mathematical modeling activity]. *Adıyaman Üniversitesi Eğitim Bilimleri Dergisi*, 8(2), 137-156. <https://doi.org/10.17984/adyuebd.452269>
- Hansen, R., & Hana, G. M. (2015). Problem-posing from a modelling perspective. In Singer, F., F. Ellerton, N., & Cai, J. (Eds), *Teaching mathematical modelling: Connecting to research and practice* (pp. 527-536). Springer. https://doi.org/10.1007/978-1-4614-6258-3_2
- Hartmann, L. M., Krawitz, J., & Schukajlow, S. (2021). Create your own problem! When given descriptions of real-world situations, do students pose and solve modelling problems? *ZDM—Mathematics Education*, 53, 919-935. <https://doi.org/10.1007/s11858-021-01224-7>
- Hu, X., Li, W., Geng, X., & Zhao, L. (2023). Exploring the effects of different interventions of the problem-oriented teaching model on students' creativity in STEM education. *Science & Technological Education*. <https://doi.org/10.1080/02635143.2023.2219622>
- Kaplan, S. (2022). Lise öğrencilerinin matematiksel modelleme sürecinin problem kurma bağlamında incelenmesi [Investigation of upper-secondary students' mathematical modeling process in the context of problem posing]. [Master's thesis, Marmara University]. Marmara University Institute of Educational Sciences.
- Kojima, K., Miwa, K., & Matsui, T. (2015). Experimental study of learning support through examples in mathematical problem posing. *Research and Practice in Technology Enhanced Learning*, 10(1), 1. <https://doi.org/10.1007/s41039-015-0001-5>
- Kopparla, M., Bicer, A., Vela, K., Lee, Y., Bevan, D., Kwon, H., Caldwell, C., Capraro, M. M., & Capraro, R. M. (2019). The effects of problem-posing intervention types on elementary students' problem-solving. *Educational Studies*, 45(6), 708-725. <https://doi.org/10.1080/03055698.2018.1509785>
- Krawitz, J., & Schukajlow, S. (2018). Activation and monitoring of prior mathematical knowledge in modelling processes. In E. Bergqvist, M. Österholm, C. Granberg, & L. Sumpter (Eds.), *Proceedings of the 42nd conference of the international group for the psychology of mathematics education* (Vol. 3, pp. 243–250). Umeå, Sweden:PME.
- Milli Eğitim Bakanlığı Ortaöğretim Genel Müdürlüğü. (n.d.). *9. sınıf modelleme etkinlik kitabı* [9th grade modeling activity book]. T.C. Milli Eğitim Bakanlığı.
- Mousoulides, N., & Leikin, R. (2022). Mathematical problem-posing and solving in secondary education. *Mathematics Education Research Journal*, 34(2), 231-249. <https://doi.org/10.1007/s13394-021-00434-9>
- National Governors Association Center for Best Practices (NGA) & Council of Chief State School Officers (CCSSO). (2010). *Common core state standards for mathematics*. Authors.
- O'Neill, S., & Robson, M. (2023). Advancing problem-solving skills through innovative teaching approaches. *Educational Studies in Mathematics*, 113(1), 85-102. <https://doi.org/10.1007/s10649-022-10154-w>
- Priest, D. J. (2009). *A problem-posing intervention in the development of problem-solving competence of underachieving, middle-year students* [Doctoral dissertation, Queensland University of Technology].
- Rasmussen, C., & Marrongelle, K. (2022). Developing problem-posing skills in mathematics education: Insights from recent research. *Journal of Mathematics Teacher Education*, 25(4), 345-364. <https://doi.org/10.1007/s10857-021-09584-w>

- Retnowati, E., Fathoni, Y., & Chen, O. (2018). Mathematics problem-solving skill acquisition: Learning by problem-posing or by problem-solving? *Jurnal Cakrawala Pendidikan*, 37(1), 1-10. <https://doi.org/10.21831/cp.v37i1.18787>
- Silver, E. A. (1994). On mathematical problem posing. *For the Learning of Mathematics*, 14, 19-28.
- Stoyanova, E., & Ellerton, N. F. (1996). A framework for researching students' problem-posing in school mathematics. In P. Clarkson (Ed.), *Technology in mathematics education* (pp. 518-525). Mathematics Education Research Group of Australasia.
- Sullivan, P., & Lilburn, P. (2021). Problem-posing and problem-solving in the mathematics classroom: A review of recent advances. *Research in Mathematics Education*, 23(3), 279-297. <https://doi.org/10.1080/14794802.2021.1942823>
- Walkington, C., & Hayata, C. A. (2017). Designing learning personalized to students' interests: Balancing rich experiences with mathematical goals. *ZDM: The International Journal on Mathematics Education*, 49, 519-530. <https://doi.org/10.1007/s11858-017-0842-z>
- Williams, J., & Goos, M. (2013). Modelling with mathematics and technologies. In M. A. Clements, A. J. Bishop, C. Keitel, J. Kilpatrick, & K. S. Leung (Eds.), *Third international handbook of mathematics education* (pp. 549-570). Springer.
- Xie, J., & Masingila, J. O. (2017). Examining interactions between problem posing and problem solving with prospective primary teachers: A case of using fractions. *Educational Studies in Mathematics*, 96, 101-118. <https://doi.org/10.1007/s10649-017-9760-9>

Received: December 02, 2024 Revised: January 31, 2025 Accepted: February 20, 2025

Cite as: Karabiyik, Ü. (2025). Upper-secondary students' problem-posing and mathematical modeling skills in the context of STEM education and 21st century skills. *Problems of Education in the 21st Century*, 83(1), 81–100. <https://doi.org/10.33225/pec/25.83.81>

Ümit Karabiyik

PhD, Assistant Professor, Faculty of Science, Mathematics and Computer Science,
Necmettin Erbakan University, Konya, Türkiye.
E-mail: ukarabiyik@erbakan.edu.tr
ORCID: <https://orcid.org/0000-0001-7989-7321>