International Journal of Educational Studies in Mathematics, 2022, 9(4), 233-253

The Effect of Mathematical Modeling Activities Based on STEM Approach on Mathematics Literacy of Middle School Students*

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ABSTRACT

The aim of this study is to examine the effects of mathematical modeling activities related to STEM approach on mathematical literacy levels and achievements of secondary school students. The universe of the research consists of eighth grade students studying in a public school in the district of Iskenderun in Hatay province in the 2020-2021 academic year. The study group consists of 66 students determined according to the criterion sampling method. 33 of these students were determined as the experimental group and 33 as the control group. "Mathematics Literacy Scale", "Mathematics Literacy Achievement Test" and "Semi-structured interview form about mathematical modeling activities based on STEM approach" were applied as data collection tools. In the study, while mathematical modeling activities based on STEM approach were applied to the experimental group, the control group was taught according to normal mathematics curriculum. As a result of the research, it was found that the mathematics literacy levels and achievements of the students developed positively.

ARTICLE INFO

Article History:
Received: 11.08.2022
Received in revised form: 08.11.2022
Accepted: 09.11.2022
Available online: 31.12.2022
Article Type: Research paper
Keywords: STEM education, mathematical modeling, mathematical literacy, eighth grade students, STEM-based mathematical modeling activities

1. Introduction

The goal of raising useful individuals who have 21st century skills and contribute to scientific and technological developments stands out as an indispensable basic element of educational processes in many countries (Altunel, 2018; English, 2016; Murat, 2018). In this context, the need for individuals who research, think, question and make new discoveries is constantly increasing depending on the developments in technology. In this respect, Science, Technology, Engineering, Mathematics (STEM) education, which aims to transform the knowledge gained by learners from STEM disciplines into applications, new inventions and products, is also of great importance in terms of education programs. (Mass and Engeln, 2019; Ministry of National Education (MoNE), 2016). The STEM approach is important both in terms of combining theoretical knowledge from different disciplines and in terms of skill development in these areas. In addition to interdisciplinary cooperation, it could integrate by benefiting from different disciplines.

In the STEM education approach, the combination of STEM disciplines includes planned applications for designing new products that facilitate human life and meet their wishes and needs, and the process that can produce these products. STEM education practices also enable students to build interdisciplinary relationships, learn collaboratively, express the information they have obtained in the form of real-life situations, and develop their worldview by establishing a link between engineering and science (Roehrig, Dare, Whalen and Wieselmann, 2021).

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DOI: https://doi.org/10.17278/ijesim.1160204

Some educators recommend that all school subjects be STEM-focused, while others argue that STEM is nothing more than a restructuring of the teaching process across all subjects (Arleback and Albarracín, 2019). The second group focuses on creating meanings for students in the solution process with the collaborative method of real-life problems with the necessary information. For STEM educators, how to effectively integrate disciplines but also how to ensure the integrity of each discipline is still an unanswered question. Although little is known about how this integration can be achieved, interdisciplinary integrated approaches to STEM education are nevertheless widely emphasized (English 2017; Honey Pearson and Schweingruber (2014); STEM Task Force Report 2014; Arleback and Albarracín, 2019).

Researchers use test results such as PISA and TIMMS to indicate the extent to which the need for STEM education is necessary (Wang, Guo, and Jou, 2015; Corlu, 2014). It has been determined that countries such as the UK, Japan and the USA, which integrate STEM education into their own education policies, have taken the lead in the field of economics and that there have been significant increases in the PISA and TIMMS exam results, which measure the competence of students in mathematics and science, in favor of their students (Sakarya, 2015). In this context, it can be said that STEM Education improves students' mathematical literacy positively.

In order to achieve success in mathematics education, significant changes should be made in the approach to education. When we look at this process from the point of view of students; It is aimed to be individuals with 21st century skills, who adopt the STEM education approach and who have a STEM interest. From the point of view of the teacher; It aims to increase STEM content knowledge and pedagogical field knowledge. For this process to work effectively, it is expected that STEM will be integrated into the curriculum and that students will have the necessary competencies for the process (Çepni, 2017). When the objectives of the mathematics curriculum are considered, it is aimed to educate students who can solve problems, make modeling, use the information obtained in real-life problems, establish interdisciplinary relationships and support mathematical information with materials (MEB, 2017).

The relationship between STEM education and mathematics education can be considered in this context. How STEM education will be implemented and how it will be adapted to existing education systems is an important issue. When we look at the studies in the literature aimed at solving this issue, we see that basically integration; (1) content, and (2) context, can be done in two different ways (Roehrig, Moore, Wang and Palrk, 2012).

Content integration envisages the organization of science, technology, engineering and mathematics into a single discipline and reduced to a single curriculum (Breiner, Harkness, Johnson and Koehler, (2012); Roehrig et al., 2012). This approach threatens the existence of field education spaces and identifies a STEM education field that is poised to replace them. When looking at context integration, any of the fields is centered and at least one of the others; it is used as an aid to better teach the discipline that is centered (Roehrig et al., 2012; Corlu, Capraro and Capraro, 2014). The central structure of the education system in our country, its curricula, the number of personnel working in related fields; Considering variables such as the university structure, the relevant departments in universities and especially the inadequacy of the studies in the field of STEM education, it is seen that the first option is not suitable for the education system in our country. Therefore, it can be assumed that the second option is more feasible. In this respect, in this research, STEM education and mathematics education are handled according to context integration.

With the use of mathematics as a tool in many fields and the increasing need for mathematics, it brings to the fore the mathematical modeling approach that offers the opportunity to associate mathematics with different disciplines and enables mathematics to be used more in real life. Mathematical modeling provides the ability and competence to use mathematics to understand and solve real-life problems (Gürbüz and Doğan, 2018; English, 2016; Deep, 2017; Kaiser, 2005).

STEM education also contributes to the development of 21st century life skills by providing effective and permanent learning and interdisciplinary interaction of students, developing critical thinking skills, creativity and productivity in individuals. Through this teaching, students are enabled to use research-questioning, production and scientific research methods (Yıldırım and Altun, 2015; Bakırcı and Kutlu, 2018). STEM Education and Mathematical modeling activities develop students' skills to use mathematics in their daily lives, while at the same time providing the opportunity to discover, interpret and create an original product in real life situations of the mathematical concepts they have learned.

Mathematical literacy; It includes knowledge and skills such as being able to convert the information reached into a mathematical expression, using the mathematical language, producing appropriate solution stages to the problem by interpreting the problem and making sense of it mathematically, and thinking mathematically (MEB, 2013). Mathematical literacy according to Özgen and Bindak (2008); It has enabled the person to be aware of the role of mathematics, to understand it and to develop the ability to apply it to his daily life. In mathematical literacy problems, it measures how much students can use their math knowledge to overcome real-life problems. Therefore, mathematical modeling is important as an interdisciplinary transition tool to enable students to think analytically, develop problem-solving, technological knowledge and skills. Research showing that mathematical modeling can be used as a tool in the transition to STEM education (English, 2015; Kertil and Gürel, 2016; Doğan, Gürbüz, Çavuş Erdem and Şahin, 2018).

In STEM education integration, appropriate activities should be prepared and implemented to strengthen these contexts. These activities should develop skills such as analyzing, producing, designing, expressing mathematically, communicating. In this context, students also experience the process of solving mathematical modeling problems in STEM activities (MEB STEM Report, 2016; Yıldırım, Yıldırım, Yetişir and Ceylan, 2013; Breiner, Harkness, Johnson and Koehler, 2012; Doğan, Gürbüz, Çavuş Erdem and Şahin, 2018). With mathematical modeling activities in the context of STEM, students can relate mathematical concepts that are quite abstract to real life. In the Mathematics Course Curriculum, skills such as mathematical communication, discussion, problem building and solving, mathematical reasoning, modeling, reasoning and association are explained for individuals to become mathematically literate.

On the other hand, mathematical modeling, which is an important factor in the implementation of STEM (Hamilton, Lesh, Lester and Brilleslyper, 2008), one of the important research areas of mathematics education, has come to the forefront with its interdisciplinary dimension in recent years (English, 2016; Doğan, Gürbüz, Çavuş Erdem and Şahin, 2018; English, 2015). Mathematical modeling refers to the process of solving a real-life situation by turning it into a mathematical problem and dealing with its consequences in real life (Kaiser, 2007). In this context, many researchers emphasize that students' critical thinking, generalization and abstraction skills are developed through mathematical modeling activities (NCTM, 2000; Boaler, 2001). In addition, the ability to model mathematically in a real-life situation also means the ability to identify questions, assumptions or appropriate variables, analyze and compare given models (Güzel, 2016; Niss, Blum and Galbraith, 2007). From this point of view, mathematical modeling and STEM Education studies not only develop students' skills to use mathematics in their daily lives, but also provide the opportunity to discover, interpret and create an original product of the mathematical concepts they learn in real-life situations. From this point of view, there are many national and international studies in the literature that show that mathematical modeling is an important factor in the transition to STEM education. It is seen that these studies are generally focused on teacher candidates and teachers (Bergsten, Frejd, 2019; Bozan, 2018; Czocher, 2016; Du Plessis, 2018; English and Mousoulides, 2015; Geiger, 2019; Ozdemir, Cappellaro, 2019; Weber, 2015). For example; In his work with engineering students, Czocher (2016) concluded that students have difficulty in mathematical modeling processes using Fermi problems. Similarly, Bergsten and Frejd (2019) have found that pre-service teachers plan activities appropriate to STEM education and twenty-first century skills with mathematical modeling. Again, Güder and Gürbüz (2018) concluded that with STEM activities prepared according to mathematical modeling, students' interdisciplinary relationship skills developed and they developed positive attitudes towards mathematics and science.

On the other hand, English (2016) drew attention to the importance of developing students' mathematical literacy at the same time in order to give the necessary importance to mathematics in the STEM approach. For this reason, many researchers point out that more attention should be paid to studies aimed at increasing students' thinking skills, such as mathematical problem solving, modeling and reasoning (English, Gainsburg, 2016; MacDonald, Goff, Dockett and Perry, 2016).

In most studies with teachers, teachers' views on the STEM approach (Du Plessis, 2018; Geiger, 2019; Gül Biçer, Uzoğlu and Bozdoğan, 2018; Özcan, Koştur, 2018; Weber, 2015), competencies and attitudes (Ersoy, 2018; Ozturk 2018; Yildirim, Turk, 2018). On the other hand, work with students is often experimental work (Cho, Lee, 2013; English and Mousoulides, 2015; Miller, 2019) and academic achievements (Ceylan, Karahan, 2021; Bergsten, Frejd 2019; Kennedy, Odell, 2019). 2014; Murat, 2018; Yıldırım and Türk 2018). On the other hand, it is seen that there are limited number of studies in which STEM and mathematical modeling are carried out together. These studies often focus on the role of mathematics in STEM education (Albarracín, Gorgorio 2019; Czocher, 2018; Derin, Aydin, 2020; Ferrando et al. 2017; Mass, Geiger, Arisa and Goss, 2019) and STEM and mathematical modeling skills (Arleback and Albarracin). , 2019; Schukajlow et al. 2018;) (Güder and Gürbüz, 2018; English, 2016). For example; In their study, Derin and Aydın (2020) examined the STEM and mathematical modeling competencies and problem-solving skills of pre-service teachers and concluded that there were significant and positive developments in teachers' STEM and mathematical modeling and problem-solving skills.

There are serious problems about how to integrate mathematical modeling into curricula and it is insufficient to provide students with modeling skills (Gürbüz, Doğan, 2018). In this context, mathematical modeling activities have an important place in STEM education as they can improve students' problem-solving skills and increase their scientific, critical and analytical thinking, reasoning and communication skills. Models can be used for different purposes such as logical thinking at cognitive, social and behavioral levels, in the development of mathematical literacy and problem solving skills. Therefore, mathematical modeling, which aims to solve real life problems and learn in relation to other fields, is seen as an important process for educators and students (Karahan, Bozkurt, 2017; Çepni, 2017; Korkmaz, 2010). It is thought that this study is also important in terms of contributing to the integration of the STEM approach, which is a new educational approach, with mathematical modeling applications and mathematical literacy skills in line with the purposes of the curriculum.

However, within the scope of the current literature, no study has been found examining the effect of students' mathematical modeling skills on their mathematical literacy in the context of STEM education. Based on this idea; The aim of this study is to provide mathematical modeling skills based on the STEM education approach that will contribute to the achievement of the objectives of our curriculum. In addition, in order to improve mathematical literacy, it is necessary to contribute to the integration of the problems that provide these skills into our education system and to benefit from the modeling that has found expression in our curriculum. In this context, in this study, it is aimed to examine the effect of the application of mathematical modeling activities based on the STEM education approach on the mathematical modeling skills and mathematical literacy of secondary school students in the context of STEM and their views on STEM education.

1. Does it show that there is a significant difference between the mathematical literacy levels of the students in the experimental group where mathematical modeling activities were carried out in the STEM context and the control group in which the teaching was carried out?

2. Does it show that there is a significant difference between the math literacy achievement scores of the students in the experimental group where mathematical modeling activities were carried out in the STEM context and the control group in which the teaching was carried out?

3. Is there a significant difference between the level of Mathematical Modeling Activities in STEM Context of the students in the experimental group where mathematical modeling activities are applied in the STEM context and the students in the control group where the current teaching is applied?

4. Is there a relationship between Mathematical Literacy levels and Mathematical Modeling Test in STEM Context levels?"

5. What are the opinions of the experimental group where mathematical modeling activities are applied in the context of STEM about the teaching process?

2. Method

This research is an explanatory mixed design study aimed at examining the effect of mathematical modeling activities based on STEM approach and the impact of teaching process on mathematical literacy levels and achievements of eighth grade students. Explanatory mixed design is a type of research in which the researcher reaches a conclusion by analyzing first quantitative and then qualitative data obtained according to the purpose (Creswell 2018). In this context, a semi-experimental design, which is one of the quantitative research methods, was first applied. In semi-experimental design studies, the research group is determined by selecting among ready-made groups that are similar to each other in terms of input characteristics and is estimated by pre-test. In this process, while the experimental procedures appropriate to the purpose of the research are carried out in the experimental group, the existing teaching is applied in the control group. On the other hand, semi-structured interviews were conducted with students about qualitative research design and mathematical modeling activities based on STEM approach.

2.1. Workgroup

The study group of the study consists of 66 eighth grade students who continue their education in the district center of Hatay. The study group in question consisted of 66 students who were trained in the Elective Mathematics Applications Course at the school where one of the researchers worked (Experimental Group: 33 individuals and Control group: 33). The study group consists of 32 female and 34 male students. Criterion sampling method was used in the sampling method of the study. As a criterion within the scope of this study; the conditions for students to be eighth grade, to attend school, to be open to new methods in teaching, to have a more positive attitude towards the course, to participate in the implementation process and to volunteer were taken into consideration. The researchers identified the study groups on the condition that they were randomly selected from three eighth-grade classes that met the specified criteria. When determining the working groups, the equality of these groups (gender (X^2=.96 Sd=1 P=.423) and academic achievement (($t(64)= .239$; $p>.05$)) was taken into consideration. In order to conduct the research, the condition of being eighth grade students, attending LGS preparatory studies and school, being open to new methods in teaching, having a more positive attitude towards the lesson, participating in the application process and problem solving test was taken as a basis. The qualitative data of the study group were selected by purposeful sampling method among six students with different academic achievements in mathematics. Two of these students are at a low level, two are at an intermediate and two are at a high math achievement level.

2.2. Data Collection Tools

In the study, mathematical literacy scale, mathematical literacy achievement test, semi-structured interview form about mathematical modeling activities based on STEM approach were used as data collection tools.

Mathematical Literacy Scale: This scale was developed by Kükey (2013) to determine the mathematical literacy levels of students. This scale is a five-point Likert-type (always (5)-never (1)) measurement tool consisting of 40 items to measure the mathematical literacy of middle school eighth-grade students. In order to determine the construct validity of this mathematical literacy scale, Exploratory

Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were applied to the scale. As a result of EFA, it was concluded that the scale has four factors (relationship, research and interpretation, invention/evidence, visuality). It was concluded that the compliance values obtained as a result of CFA were at an adequate level. In addition, the Cronbach Alpha internal consistency coefficient of the scale for this sample was determined as .95.

Mathematical Literacy Achievement Test: In the development of the Mathematical Literacy Achievement Test, a pool of questions was created by using the relevant literature. The questions in this pool are created in such a way that they can be solved in four operations in line with the achievements of the students before. In order to determine the content validity of the prepared questions, a pilot application was made by taking the opinions of four experts on mathematics education. Within the scope of this application, the suitability of the questions in the test to the level of the student, their understandability, the mistakes made and the application period were evaluated. In this context, the results obtained from the pilot studies were examined. Accordingly, item difficulty value (pj), discrimination index (rjx) of the questions in the test, and independent groups t-test were calculated for 27% of the upper and lower groups. Accordingly, the pj value of the questions in the test is between .42 and .72; It was concluded that the distinctiveness value was between .41 and .82. On the other hand, it was determined that there were significant differences between the scores of all students in the 27% of the lower and upper groups. According to the results obtained, the mathematical literacy achievement test consisting of 14 questions was reached.

Mathematical Modeling Problems in the Context of STEM: 'Mathematical Modeling Activities in the Context of STEM', which is used as a pre-test and post-test, consists of four mathematical modeling problems. Each of the 'Stadium', 'Water Waste', 'Biopsy' and 'Bicycle Safety' problems in the test were created by scanning the questions in the relevant literature and books, including more than one discipline, and associating real-life problems with mathematical achievements. The 'Water Waste' and 'Biopsy' questions were changed according to the level of the students. The other two questions were taken as is. “Waste of Water”, “Biopsy” and “Bicycle Safety” questions were prepared by Sergeant Erdem, Doğan and Gürbüz (2018). The “Stadium” question was prepared by Bukova Güzel (2016). The validity of the measurement tools prepared by taking the opinions of the experts in the field about the clarity, comprehensibility and suitability of the questions to the level was ensured

Semi-structured interview form about mathematical modeling activities based on STEM approach:

This form was used to get students' views on mathematical modeling activities based on the STEM approach. With the semi-structured interview method, in-depth information is provided both from fixed-choice answers and from the field related to the research topic (Büyüköztürk, 2017). In this context, while preparing the interview questions, it was prepared within the framework of the studies on STEM and Mathematical modeling and the relevant literature. Afterwards, the prepared questions were presented to expert opinions, and the validity of the questions was ensured.

Mathematical Modeling Activities Based on the STEM Approach to the Application Process: The questions in the literature and related books of the four activities such as 'Heat Insulation', 'Lemonade Sales', 'Electricity Production', 'Height Footprint' from the mathematical modeling activity in the context of STEM developed by the researcher to be used in the teaching process (Bozkurt Altan, Karahan, 2019; Dost, 2019; Yüksel, Kaya, Urhan and Şefik, 2019; Dede, Bukova, 2018; Çavuş Erdem et al., 2018) were scanned and were created in line with the gains that students had foreseen. As explained in the theoretical framework, the activities were finalized in line with the opinion of an expert, taking into account the characteristics that model building activities should have, and two mathematical modeling activities were prepared as mathematical modeling activities in the context of STEM.

The research was carried out in a total of 12 weeks, with an 8-week teaching process and a two-week application period of the pre-test and post-tests. Only pre-test and post-tests were administered to the control group students. In addition, in the control group, the teacher followed the current curriculum.

In this process, the subjects and activities in the textbook were covered. The tests and activities applied to the students in this process are given in the table below, respectively:

Table 1. Application process of the study

Week	Application Name
1st and 2nd week	STEM Interest Scale Mathematical Literacy Self-Efficacy Scale, Mathematical Literacy test, Mathematical Modeling Activities in the Context of STEM Pre-Test
3rd week	Information About STEM Education and Mathematical Modeling
4th and 5th week	Mathematical Modeling Activity—Lemonade Sales
6th and 7th week	Mathematical Modeling Activity —Height Footprint
7th and 8th week	Mathematical Modeling Activity in the Context of STEM —Electricity Generation
9th and 10th week	Mathematical Modeling Activity in the Context of STEM—Heat Insulation
11th and 12th week	STEM Interest Scale Mathematical Literacy Self-Efficacy Scale, Mathematical Literacy test, Mathematical Modeling Activities in the Context of STEM Post-Test

Information about the STEM education approach and mathematical modeling used in the application process, the definition of STEM education approach, its importance, the definition of mathematical modeling and the solution process of the problems are given. Two Mathematical Modeling in STEM Contexts and two Mathematical Modeling activities were implemented over an eight-week period. Each activity was applied by the researcher himself in the 'Elective Mathematics Applications' course, which is two hours per week.

In addition, the opinions of four experts in the field of mathematics education were used for the content validity of these activities. One of the activities prepared is as follows:

Efficiency of Thermal Insulation: Mr. Adam is considering building a one-story building on a plot of 120 square meters with four sides open and covering the exterior of this building. Adam, who met with an insulation company for the sheathing business, informed the company representative about two different brands. Students are required to provide maximum energy efficiency by making the best thermal insulation, to evaluate them with the life of the materials and the total cost of the design. It is desirable that the house to be built and its thermal insulation be both economical and cost-effective. This design task has been explained and the guidelines are as follows: (Bozkurt Altan and Karahan, 2019; İnceyol and Doğan, 2018).

-Students plan the knowledge and skills necessary to perform the main design task.

In line with the planning, it is expected that possible solutions will be investigated and the most appropriate solution will be selected. The necessary criteria are determined for the success of the solution process. These criteria are to determine the dimensions of the house for the construction of the house, determine the type of material and the appropriate brand for thermal insulation.

-Mathematical calculations are made according to the determined criteria and students organize the studies they design in the computer program in cooperation with their friends.

These activities were evaluated with the mathematical modeling evaluation title developed by Kertil (2008). The rubric in question is the definition, mathematical explanation and solution of the problem; It consists of the stages of expressing and solving problems with mathematical formulas and equations. In the evaluation process of these stages, the correct answer was determined as 2 points, the missing answer as 1 point, and the wrong answer as 0 points. Rubric assessment was used to evaluate practice activities and mathematical modeling activities in the STEM context.

2.3. Analysis of Data

Since the data obtained as a result of the research showed a normal distribution, independent groups t-test was applied since there were two groups in the study. The results of the analysis conducted to examine the normality distribution of the data are given in Table 2.

Table 2. Mathematics Literacy Scale Analysis Results and Achievement Tests Applied to Students

	Group	Skew	Sunken
Math Literacy Scale Pretest	Experimental Group	-.726	.888
	Control Group	.236	-.383
Mathematical Literacy Scale Final Test	Experimental Group	-1.460	1.668
	Control Group	-.284	-.537
Mathematics Literacy Achievement Preliminary Exam	Experimental Group	1.301	1.846
	Control Group	1.018	-.068
After Math Literacy Achievement Test	Experimental Group	-.554	-.777
	Control Group	1.058	.618

Since the curtosis and skewness values of the data obtained according to Table 1 are between -1.96 and +1.96, it can be said that the data provide the normal distribution status (Büyüköztürk, 2017; Tabachnick and Fidell, 2019).

While analyzing the data of the research, quantitative analysis methods were used. In this context, parametric tests were used to provide assumptions in the study group. For this reason, descriptive statistics (frequency, percentage, arithmetic mean and standard deviation), independent groups T-test, ANCOVA, correlation analysis were used in the analysis of the relevant data. Accordingly, whether there is a significant difference between the pre-test and post-test averages of the students in the study group, which constitutes the study group, was examined using the independent groups t-test (Can, 2014). ANCOVA is a useful and powerful statistic if its assumptions are met (Büyüköztürk, 2017).

In the analysis of the Mathematical Literacy Self-Efficacy Scale data, the ranges according to the mean data were 1-1.80, "Never"; 1.81-2.60, "Sometimes"; 2.61-3.40, "Sometimes"; 3.41-4.20, "Most of the Time"; 4.21-5.00, "Always" and the Mathematical Literacy Self-Efficacy Scale according to the results of the students as 1.00-1.80, "I see myself completely inadequate", 1.81-2.60, "I see myself as inadequate", 2.61-3.40, "I am undecided. ", 3.41-4.20, "I consider myself sufficient", 4.21-5.00, "I consider myself completely sufficient" were evaluated.

While analyzing the students' mathematical modeling problems activity papers in the context of STEM, each student's performance score was calculated by using the mathematical modeling stages evaluation rubric. However, two encoders were used to calculate the performance score, and a comparison was made between encoders. The first coder is the researcher himself, and the second coder is a field expert in mathematics education. Afterwards, the Cronbach Alpha reliability coefficient was found to be .91 as a result of the evaluation of the activities considering the total score. By using the evaluation rubric, the scores that the students got from each step of the activities were collected, the 'T-Test for Unrelated Samples' was used to analyze the relationship between the pre-test and post-test overall scores, and the 'Pearson Correlation Coefficient' was calculated using the simple correlation technique to find out whether there was a significant relationship. has been used.

PISA mathematical literacy questions are scored according to their difficulty level. The obtained mathematics overall performance score is used to indicate both a student's performance and the difficulty of a question. A student with a certain score is expected to be able to solve questions with difficulty level at that point level or lower (MEB, 2005). In this study, in order to determine the mathematical literacy levels of the students, the number of proficiency levels was determined by dividing the total score (30) from the test's own scoring system and the '0' difference in the lowest score to be obtained at the 1st level. These levels are indicated in Table 3.

Table 3. Mathematical Literacy Sufficiency Levels Scores

Mathematical Literacy Sufficiency Levels	PISA scores	Determined in the Study points
1. Level	357.77-420.07	0-4
2. Level	420.07-482.38	5-10
3. Level	482.38-544.68	11-15
4. Level	544.68-606.99	16-20
5. Level	606.99-669.30	21-25
6. Level	669.30 ve üzeri	26-30

According to Table 14, 0-4 points range is 1st level, 5-10 points range is 2nd level, 11-15 points range is 3rd level, 16-20 points range is 4th level, 21-25 points range is 5th level. and the range of 26-30 points was determined as the 6th level.

The evaluation of the PISA questions in the Mathematical Literacy Achievement Test was scored according to the criteria specified in the PISA Explained Questions Mathematics Scoring Guide published by the Ministry of National Education. The correct answer is; full score (2), partial response; missing points (1), incorrect answer is considered as zero points.

In the analysis of qualitative data, content analysis was applied. Content analysis enables the uncovering of previously unknown themes and dimensions that require in-depth analysis of the collected data. In this context, the data obtained from the students were first coded separately by the researchers and the agreement between the two coders was determined as 87%. In the next step; The data obtained were presented to the opinions of two experts on mathematics and qualitative research, and codes and themes were created in accordance with the purpose of the research. In addition, when the interviewed students were ranked according to their math achievements, two of these students were found to have low (T1, T2), two were found to be at medium (T3, T4) and two were at high (T5, T6) achievement levels.

In this context, the data obtained from the students were first coded separately by the researchers and the agreement between the two coders was determined as 87%. In the next step; The data obtained were presented to the opinions of two experts on mathematics and qualitative research, and codes and themes were created in accordance with the purpose of the research.

3. Findings

3.1.Findings for the first sub-goal

According to the first sub-objective of the study, the mathematical literacy status of the students in the study group was examined. For this reason, the math literacy test scores of the students in the study group are given in Table 4 and Table 5, respectively.

Table 4. Analysis Results of the Preliminary Test Scores of the Mathematics Literacy Scale of the Students in the Study Group

Group	N	X	Courage	Sd	t	p
Experimental Group	33	4,90	6,40	64	.239	.812
Control Group	33	5,24	4,81			

As can be seen in Table 2, the arithmetic mean of the pretest scores of the students in the experimental group was 4.90 and the arithmetic mean of the students in the control group was found to be 5.24. In this context, it is seen that there is no statistically significant difference between the experimental group and the control group in terms of the preliminary test scores of the mathematical literacy scale ($t(64)= .239$; $p>.05$). The final test scores of the mathematics literacy scale of the students in the study group are given in Table 5.

Table 5. Analysis Results of the Mathematics Literacy Scale Post-Test Scores of the Students in the Working Group

Group	N	X	Courage	Sd	t	p
Experimental Group	33	18,09	10,45	64	6.051	.000
Control Group	33	6,03	4,68			

When Table 5 is examined, the arithmetic average of the final test scores of the students in the mathematical literacy scale experimental group is 18.09 and the arithmetic average of the students in the control group is 6.03. In this context, it is seen that there is a statistically significant difference between the experimental group and the control group in favor of the experimental group in terms of the final scores of the mathematical literacy scale (t(64)= 6.051; p=.001).

3.2.Findings for the second sub-goal

According to the second sub-objective of the study, the mathematical literacy achievement scores of the students in the experimental group and control group were examined. For this, the pretest and post-test scores of the students in the study group are given in Table 6 and Table 7.

Table 6. Results of the Analysis on the Mathematics Literacy Achievement Pretest Scores of the Students in the Working Group

Group	N	X	Courage	Sd	t	p
Experimental Group	33	10,88	6,17	64	,272	,786
Control Group	33	11,39	8,95			

As can be clearly seen in Table 6, the arithmetic mean of the students in the experimental group was 10.88, while the arithmetic mean of the students in the control group was found to be 11.39. In this context, it is seen that there is no statistically significant difference between the experimental group and the control group in terms of the preliminary test scores of the mathematical literacy scale (t(64)=.272; p>.05). The math literacy achievement post-test scores of the students in the study group are given in Table 7.

Table 7. Mathematics Literacy Achievement Results of the Students in the Study Group Analysis Results of the Post-Test Scores

Group	N	X	Courage	Sd	t	p
Experimental Group	33	18,12	7,84	64	,272	,786
Control Group	33	14,18	8,03			

When Table 7 is examined, the arithmetic mean of the mathematical literacy achievement post-test scores of the students in the experimental group is 18.12 and the arithmetic average of the students in the control group is 14.18. As a result of the analysis applied in this context, it was revealed that there was a statistically significant difference between the experimental group and the control group in favor of the experimental group in terms of mathematical literacy achievement final test scores (t(64)= 2.015; p>.05).

Table 8. Math Literacy Self-Efficacy Scale ANCOVA Results for Comparison of Final Test Scores Adjusted for Pretest Scores

Groups	Sum of squares	Sd	Squares average	F	p	Partial n²
Math Literacy Scale Pre-Test	17396,3	1	17396,3	79,7	,000	,601
Experiment-Control	1081,5	1	1081,5	4,9	,030	,086
Mistake	11560,7	53	218,1			
Sum	1206700	56				

When Table 8 was examined, it was found that there was a significant difference between the final test scores adjusted according to the preliminary test scores of the Mathematics Literacy Self-Efficacy Scale according to the ANCOVA results, F(1.58)=4.9, p<.05). Partial n2 = .086. After mathematical modeling activities based on the applied STEM approach, it was seen that 8% of the students' mathematics literacy scale scores were in favor of the experimental group and the effect size was found to be at a medium level (Büyüköztürk, 2017). In other words, there is a significant difference between the Mathematics Literacy Self-Efficacy Scale final test totals of eighth grade students before and after application to the experimental and control group. Following the application activities applied in the experimental group, the final test scores of the Math Literacy Achievement Test of the experimental group and the control group were analyzed by independent group t-test. The findings are shown in Table 9.

Table 9. Independent Group t-Test Results for Comparison of Math Literacy Achievement Test Final Test Scores

Groups	N	X	Ss	Sd	t	p
Experimental Group	33	17,12	8,81	32	3,43	,001
Control Group	33	10,73	6,06	32		

p>.05

When Table 9 was examined, it was seen that there was a significant difference between the last test totals of the Mathematical Literacy Achievement Test performed before and after the application to the experimental and control group of eighth grade students since p<.05 (t(32)= 3.43; p=.001).

3.3. Findings for the third sub-goal

The final test scores of the experimental group and the control group's Mathematical Modeling Test in STEM Context were analyzed by independent group t-test. The findings are shown in Table 8.

Table 10. Control Group Mathematical Modeling Test in STEM Context Pretest and Posttest Dependent Group t-Test Results

Groups	N	X	Ss	Sd	t	p
Experimental Group	33	36,66	8,81	32	5,369	,000
Control Group	33	15,06	6,06	32		

p>.05

When Table 10 was examined, it was seen that there was a significant difference between the final test totals of the Mathematical Modeling Test in STEM Context performed before and after the application of the eighth grade students to the experimental and control group since p<.05 (t(32)= 5.369; p=.000).

3.4. Findings for the fourth sub-goal

Pearson Correlation Coefficient was applied to determine whether there was a relationship between the participants' final test scores and the findings obtained as a result of the analysis were presented in Table 11.

Table 11. Pearson Correlation Results for the Relationship Between Mathematical Literacy Self-Efficacy Levels and Mathematical Modeling Test Levels in STEM Context Final Test Scores

		Math Literacy Achievement Level	Mathematics Literacy Self-Efficacy
Mathematical Modeling Skills Final Test in STEM Context	Pearson Correlation	,797**	,797
	Sig. (2-tailed)	,000	,000
	N	66	66

As a result of the Pearson Correlation analysis conducted to determine the relationship between Table 11 a Mathematical Modeling Test Final Test scores in STEM Context and Mathematical Literacy Self-Efficacy Levels and Mathematical Literacy Achievement levels, a statistically significant positive and high relationship was found between Mathematical Literacy Self-Efficacy level and Mathematical Modeling Skills in STEM Context. A statistically significant relationship was found between the level of Mathematical Literacy Achievement Test and the level of Mathematical Modeling Test in STEM Context. The relationship between the level of the Mathematical Literacy Achievement Test and the level of the Mathematical Modeling Test in the STEM Context was found to be high with the Pearson Correlation coefficient of .797. Accordingly, since it is found to be statistically positive, it can be interpreted that the level of Mathematical Modeling Test in STEM Context tends to increase, while the level of Mathematical Literacy Achievement Test tends to increase in a positive direction.

3.5. Findings for the fifth sub-goal

As the last sub-objective of the research, the opinions of the experimental group where mathematical modeling activities were applied in the context of STEM regarding the teaching process were taken. Accordingly, the opinions of the students are given in Table 12.

Table 12. Analysis of semi-structured interview data

Theme	Category	f
Cognitive dimension	Gaining a Different Perspective	4
	Thinking More Accurately	3
	Better Learning	2
	Reasoning	1
Emotional dimension	Having fun	3
	Be interesting	1
	Enjoy group work and collaboration	3
Features of activities	Being involved in everyday life	6
	Too long	4
	Being complicated	3
	Be useful	2

As can be seen in Table 10, the opinions of the students are grouped under three themes: "cognitive dimension", "emotional dimension" and "characteristics of activities". Accordingly, on the cognitive level, all students stated that they gained different perspectives with in-class activities. The student coded S1 on this: "It was very difficult for me because the questions were about real life. I read the problems many times, I had difficulty understanding. After some thought, we decided how to solve it with our group mates. I struggled a lot, especially since the problems were long, and I was finally able to solve them." On the other hand, the student with the S5 code said: "We had a hard time solving problems at first, but when we argued with our friends, when everyone said something different, we understood how to solve the problem. I understand the logic of such problems and always want to solve them. It allowed me to think better, make the right decision and gain a different perspective."

As for the second theme, on the emotional level, the students stated that they enjoyed group work and cooperation and that the process was fun. In this context, for example, the opinion of the student with the code S4 is as follows: When I first started the activities, I never understood. But then when it was explained and tried to be solved, I saw many examples of questions. I heard and learned different ideas. I think I will understand more easily when solving problems from now on. In the future, I plan to work on STEM. I want to improve myself especially in the field of engineering and technology. These topics sound very interesting and fun to me. We also shared tasks collaboratively while our group mates did the activities and it was a lot of fun.

As a final theme, regarding the characteristics of the activities, the students noted that the activities are related to everyday life, they are very long, complex and useful. The opinion of the student with code S6 is as follows: The activities were mostly related to daily life, I had a hard time when I first started, the activities seemed too long and complicated. I thought about what to do. Then I started to figure out how to figure out how to solve activities with our group mates and I started to feel easy. The modeling work carried out by the teacher, in particular, made it easier for us to understand how to think and how to solve a question when solving it.

Discussion, Conclusion and Suggestions

This research was conducted to examine the effect of mathematical modeling activities based on STEM approach and the teaching process on mathematical literacy levels and achievements of eighth grade students. Accordingly, it was concluded that the students in the experimental group were more successful than the students in the control group within the scope of mathematical modeling activities. This result is similar to the relevant literature (Erol, 2015; Köysüren, Üzel, 2018; Mujib, Mardiyah and Suherman, 2020). In this context, for example; In their study, Mujib et al. (2020) concluded that students' mathematical literacy skills are further improved with STEM education. Similarly, Erol (2015) concluded in his study that the mathematical literacy skills of secondary school students improved with applied mathematical modeling activities. Again, Köysüren and Üzel (2018) concluded that the mathematics literacy levels of sixth grade students increased with STEM-based activities applied in mathematics teaching. Similarly, Mujib et al. (2020) concluded in their study that students' mathematical literacy skills are further developed using STEM education methods.

When the mathematical literacy success scores of the students in the study group were compared according to the second purpose of the research, it was revealed as a result of the research that the students in the experimental group were more successful. In this context, it can be said that mathematical modeling activities based on the STEM approach increase the mathematical literacy gains and performance of the students in the experimental group. In this context, when the relevant literature is examined (Arleback, Albaraccin, 2019; Baran, 2019; Erol, 2015; Blacksmith, 2018; English, 2016; STEM Task Force Report, 2014), mathematical modeling activities based on the STEM approach, 21st century skills, modeling skills are also examined. There are studies that support that it increases the success of mathematics. In this context, for example; Arleback and Albaraccin (2019) emphasize that mathematical modeling is central to integrating different STEM disciplines and is an important factor in the development of twenty-first-century skills, enabling students to deal with complex situations and context across all disciplines. Baran (2019) also concluded that the teaching practices designed based on the mathematical modeling approach positively contribute to the development of students' mathematical communication skills and mathematical literacy performance. Again, Erol (2015) concluded that the applied mathematical modeling activities improved the mathematical literacy skills of the students in the experimental group. Finally, Demirci (2018) revealed that the mathematical modeling training given to tenth grade students positively improves the literacy skills of tenth grade students for mathematics.

The students' mathematical literacy levels were examined on the basis of the PISA mathematics literacy assessment score guide and framework, and students went through a series of stages when using mathematics and mathematical tools to solve problems that are within the scope of the three mental processes of formulating, executing and interpreting-evaluating. In the real-life problems solution process based on mathematical modeling within the scope of STEM, it has been observed that many students in the experimental group use some stages or many of them in the solution process, such as formulating the mathematical model, making mathematical calculations, mathematizing the data and interpreting and evaluating the result obtained. In this case, it can be said that mathematical modeling activities based on the STEM approach increase students' mathematical literacy achievements and performances. It has been observed that several students show these stages before the teaching practice. However, it was observed that the students focused only on numerical information, and it was seen that there were deficiencies in formulating, interpreting and evaluating, and using verbal information.

When the studies were examined, it was not found that mathematical modeling activities based on the STEM approach increased the mathematical literacy performance of the students, but the mathematical modeling activities based on the STEM approach were found in the 21st century. There have been studies supporting century skills, modeling skills and increasing mathematical achievements (Arleback and Albaraccin, 2019; Baran, 2019; Erol, 2015; Blacksmith, 2018). In this case 21. Due to the fact that there is a mathematical literacy skill among the century skills; In addition, it can be said that mathematical modeling activities in the context of STEM increase modeling skills and mathematical modeling activities positively affect mathematical literacy performance and success and mathematical modeling activities based on STEM approach positively affect mathematical literacy achievements. In addition, according to the positive results obtained from the scale and achievement test, it can be said that most of the students can use mathematics and mathematics tools, mathematize the real-life problem and interpret the result reached, which improves the student's mathematics literacy.

Arleback and Albaraccin (2019) argue that mathematical modeling is at the heart of integrating different STEM disciplines and is an important facilitator that enables students to deal with complex situations and content in all disciplines, and that mathematical modeling supports the development of twenty-first-century skills in STEM disciplines. Baran (2019) has shown that the teaching practices designed based on the mathematical modeling approach of the students support the development of mathematical communication skills and mathematical literacy performances. Erol (2015) has been shown to have positively improved the mathematical literacy skills applied to the experimental group students as pre-test and post-test as a result of the mathematical modeling activities applied. Demirci (2018) said that mathematical modeling education given to tenth grade students positively improved students' mathematical literacy levels.

It has been determined that the theoretical education and activities given significantly increase the students' Mathematical Modeling skills in the STEM Context. When the relevant literature was examined, similar studies were found to support this study (Arleback, Albaraccin, 2019; Ceylan, Karahan, 2021; Maass, Geiger, Ariza and Goos, 2019; Mass, Engeln, 2019; Wiedemann, 2020; English, 2016; İncikabı, 2020).

Arleback and Albaraccin (2019) argue that mathematical modeling is at the core of STEM and that mathematical modeling supports the development of twenty-first century skills in STEM disciplines. It has been determined that mathematical modeling activities can be used as an interdisciplinary tool in STEM education (English, 2016) and that interdisciplinary mathematical modeling activities improve students' interdisciplinary association skills, change their attitudes positively, and that these activities should be included in the school curriculum. Ceylan and Karahan (2021) stated that after STEM-oriented mathematics practice education, students' knowledge and attitudes about mathematics and STEM fields improved. Maass, Geiger, Ariza, and Goos (2019) stated that the role of mathematics in STEM education can be improved through three interdisciplinary approaches such as twenty-first century skills, mathematical modeling and responsible citizenship education. From a broader perspective, Maass and Engeln (2019) see business connections as a specific context for mathematical modelling. Wiedemann (2020) brought real-world mathematical modeling experiences with mathematical modeling activities, which are a common component of computer courses, and students were able to make sense of real-world problems more easily by learning to apply the mathematical modeling process. After the mathematical modeling training process, İncikabı (2020) observed that pre-service teachers' mathematical modeling competencies improved significantly and positively.

According to another sub-problem of the study,when the process of solving the problems of the students is examined according to the mathematical modeling stages, it is seen that there are many deficiencies especially in the stages of formulating the problem and mathematical expressions and using verbal expressions (A3, B2 and C). In order to produce a solution to a problem, these stages have not been applied much in the theoretical solution process, which means dividing the problem into sub-problems or approaching the problem with different perspectives, expressing verbally mentioned mathematical expressions algebraically and performing algebraic calculations. The reason for this is that they are accustomed to multiple-choice tests and are not accustomed to open-ended long questions and daily life problems (Korkmaz, 2010). As another reason, students do not see the need to write in the solution process and only make numerical solutions because they focus on numerical values and perform the terms that they can express or formulate verbally. In addition, when students first encountered the problem, it was seen that they had a very difficult time understanding the problem in the theoretical solution, deciding what to do and where to start. On the other hand, it has been seen that they accept that mathematical modeling problems are completely in life in the context of STEM, which is an answer to questions such as 'Why do we learn mathematics?', 'What will mathematics do for us in real life?'. Looking at the studies, Arleback and Albaraccin (2019) argue that mathematical modeling is at the center of STEM and that mathematical modeling supports the development of twenty-first century skills in STEM disciplines. Derin (2017) concluded that teacher candidates showed progress in mathematical modeling skills after activities in the STEM context and that mathematical modeling could be used as a tool to adapt STEM education to our education system. Güder and Gürbüz (2018) stated that mathematical modeling activities can be used as an interdisciplinary tool in STEM education (English, 2016) and that interdisciplinary mathematical modeling activities improve students' interdisciplinary association skills, change their attitudes in a positive way and that these activities should be included in the school curriculum. Ceylan and Karahan (2021) stated that after STEM-oriented mathematics application education, there was an improvement in students' knowledge and attitudes about mathematics and STEM fields. Derin and Aydın (2020) made significant progress in both mathematical modeling competencies and problem-solving skills of teacher candidates by making use of mathematical modeling in mathematics education of STEM education. Maass, Geiger, Ariza and Goos (2019) noted that the role of mathematics in STEM education can be enhanced through three interdisciplinary approaches, including twenty-first-century skills, mathematical modeling, and responsible citizenship education. From a broader perspective, Maass and Engeln (2019) see connections to the world of work as a specific context for mathematical modeling.

According to the other sub-objective, the main reason why there is a significant relationship between mathematical modeling skills in the STEM context and mathematical literacy scale and achievement scores is that the STEM education approach is 21. It is acceptable that it provides century skills and that mathematical modeling is an important part of the concept of mathematical literacy. Therefore, mathematical literacy is also 21. Considering that it is among the skills of the century, the competencies gained by STEM activities and mathematical modeling problems are also the competencies expected from students with high mathematical literacy success. For this reason, the development of mathematical modeling competencies in the context of STEM also improves mathematical literacy. When the relevant literature was examined, research and report supporting this study were found (English, 2016; STEM Task Force Report, 2014). English (2016) has reached a general conclusion by examining the effects of problem-solving and modeling in the context of STEM and the skills it imparts, arguing that the roles and positions of mathematics are in danger of being overlooked or downsized in the context of increasing STEM. Problem-solving and modeling in the STEM context provides equal opportunities for students to develop mathematical literacy for their successful participation in their current and future worlds. Regarding the STEM approach and Mathematical modeling problems, it has been seen to support problem-solving competencies in contextual situations in teaching and learning mathematics (Albarracín and Gorgorio 2019; Czocher, 2018; Ferrando et al. 2017). Therefore, since real life problems are not limited, it can be said that a well-chosen and designed mathematical modeling problem in the content of different disciplines provides mathematical literacy skills when used as a tool in the integration of the STEM approach.

According to the last sub-objective of the study, it was revealed that the students who participated in mathematical modeling activities in the context of STEM generally had difficulty in understanding the activities, gained a different perspective, had fun in the process and these activities were related to daily life. Accordingly, it can be said that students have difficulties in the first stage because they have not encountered mathematical modeling problems in the STEM context before and do not know how to solve the problem and where to start solving the problem. In addition, it was revealed that students were able to make progress in problem solving thanks to communication and collaboration with their group mates. This result is similar to the relevant literature (Derin, Aydın, 2020; Doruk, 2010; Guder ,Gurbüz, 2018; Deaf, 2010; Ozer, A. O. and Bukova Guzel, E. (2020); Zawojewski, Lesh and English, 2003). For example, Deaf (2010) concluded that mathematical modeling problems contribute to students' ability to see and use, think and interpret mathematics in their daily lives. Özer, A. Ö., Bukova Guzel, E. (2020), In this study, the difficulties such as the inability of students to determine the variables necessary for the solution of the problem and their inability to comment on the simplification step of the process of modelization in classroom applications and the tendency to solve the problem without creating a model were also revealed in this study. Similarly, Zawojewski, Lesh, and English (2003) have studied modeling in small groups as a result of students asking critical questions in class, expressing their differing opinions, and trying to prove it; Discussing the results, they concluded that their ability to come up with new ideas had improved. Again, Sandalcı (2013) revealed that students' modeling activities contribute to the level of realization of mathematics in daily life. Finally, Doruk (2010) has reached the conclusion that the success levels of the students have increased as a result of the study examining the ability of the students to transfer mathematics to daily life.

In summary, it was determined that mathematical modeling activities based on the STEM approach and the teaching process positively affected the mathematical literacy levels and achievements of eighth grade students. This study was conducted with eighth grade students. Future studies may include longer-term paint studies with larger sample groups. On the other hand, within the scope of this study, mathematical literacy scale and success test variables were discussed. In addition to these variables, different studies can be done in which different variables such as the interest scale and the attitude scale towards STEM are discussed. In addition, this study was examined within the framework of the STEM approach, which is considered only in the context of mathematics lessons. In prospective studies, studies can be carried out with branch teachers from other disciplines and mathematical modeling activities lesson plans can be designed in the context of STEM appropriate to each course.

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