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Research Article

Improving middle school students' proportional reasoning through STEM activities

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The aim of this study was to examine the proportional reasoning skills of seventh-grade students before and after the implementation of STEM activities involving proportional and non-proportional relationships. Case study, one of the qualitative study methods, was used in the research. The data for the study was obtained from eight students. Seven different STEM activities were implemented over a seven-week period. A Proportional Reasoning Test and semi-structured interviews were used as data collection tools before and after the implementation of STEM activities. The findings revealed that the STEM activities contributed to the development of students' proportional reasoning skills. Before the STEM activities, students mostly used a cross-multiplication strategy to solve proportional problems. Moreover, they had difficulties in solving numerical comparison and qualitative reasoning problems. Additionally, students frequently used multiplicative relations in non-proportional problems. After the STEM activities, students used multiplicative relations to solve proportional problems. Furthermore, students could solve numerical comparison and qualitative reasoning problems.

Keywords: Proportional reasoning; STEM education; Middle school students; Ratio and proportion

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1. Introduction

Individuals should develop 21st century abilities, such as critical thinking, teamwork, problem-solving, originality, logical reasoning, and collaboration, to take advantage of future job opportunities (Bowman, 2010; Rennie et al., 2012). To develop these skills, individuals are expected to exhibit characteristics that question, investigate, reason, and adapt knowledge to different environments (Akgündüz et al., 2015; Çepni, 2017). Thus, educational approaches that support 21st century skills should be included to create learning environments suitable for science and technology. With a perspective that brings together disciplines, STEM education (Science, Technology, Engineering, and Mathematics) aims to enable individuals to develop 21st century skills, thus increasing the quality of education and the workforce (Turkish Industry and Business Association, 2017).

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1.1. What is STEM Education?

STEM education, an innovative approach, facilitates learning by eliminating the boundaries between science, technology, mathematics, and engineering disciplines (Gallant, 2010). According to Lantz (2009), the mathematics, engineering, science, and technology needed to produce practical knowledge should be considered together. In other words, STEM education is teaching through interdisciplinary approaches (Bozkurt, 2014; Czerniak et al., 1999; Moore et al., 2014; Öner & Caproro, 2016). It is predicted that the integration of science and mathematics, technology and engineering can offer solutions to current and future economic problems (Gökbayrak & Karışan, 2017; Lacey & Wright, 2009; Ministry of National Education [MoNE], 2019; National Research Council [NRC], 2012). Students should be guided to solve problems they may encounter in everyday life by integrating the STEM disciplines (Çorlu, 2012). According to Bender (2017), STEM education should take place in the following ways in the classroom:

- Problems should be based on real-life situations.
- Engineering design processes should be used in teaching.
- Inquiry-provoking questions should be asked.
- A conducive environment for group work should be developed.
- The development of high-level thinking skills should be supported.
- Multiple solutions are possible and should be iteratively tests.

Bender (2017) provided practical guidance to assist teachers to implement project-based STEM learning, modify strategies to meet students' needs, focus on real-world problems using engineering design principles, and promote cooperation and collaboration around STEM subjects. The STEM activities planned in this study placed mathematics at the center, while considering suggestions about STEM education and the engineering design process (Bender, 2017; Massachusetts Department of Education [MDoE], 2016; MoNE, 2016; NRC, 2010). Engineering made up the application component of STEM. The goal of incorporating engineering is to develop engineering knowledge and abilities by utilizing current concepts rather than introducing new ones (Barnett & Hodson, 2001). To this end, in the engineering design process, students first identify a problem within its parameters, then research and develop alternative solutions, construct a prototype, test, and evaluate the solution, and finally communicate and share with one another (Bender, 2017; MDoE, 2016). The engineering design process is a cyclical and iterative process designed to increase creativity (NRC, 2012).

Studies on STEM education have been carried out with students at all levels, from kindergarten to high school. In particular, studies at the middle school level are discussed in this section. Lamb et al. (2015) examined middle school students' approaches to STEM education. According to the findings, it was seen that the cognitive and affective achievement of the students who learned through STEM applications were higher than the students in the control group. Similarly, Pekbay (2017) examined the development of middle school students' ability to solve everyday problems and their interest in STEM disciplines. They determined that STEM activities improved students' problem-solving skills and their opinions about STEM were positive. Similar results were found in a study by Aydın (2019) conducted with middle school students. The findings of this study showed that students' problem solving, creative thinking, mental risk-taking, motivation, and attitudes towards the lesson increased by means of STEM activities. Correspondingly, Macun (2019) aimed to examine seventh-grade students' mathematics achievement, attitudes, opinions, and self-efficacy by teaching the topics of ratio, proportion, and percentages with STEM activities. The findings showed that STEM activities improved students' mathematics achievement, attitudes, opinions, and self-efficacy. On the other hand, Erçetin (2021) examined seventh-grade students' mathematics achievement and attitude towards the lesson after STEM-centered mathematics teaching. While the subject of algebraic expressions was taught to the control group with traditional methods, it was taught to the experimental group with STEM. Findings from the study revealed no significant differences between the achievements and attitudes of the experimental and control group students. However, in a study by Daymaz (2019), the findings revealed that middle school students' success and motivation increased after STEM activities designed to teach the concept of circles.

Overall, the literature shows that students' views of STEM activities were generally positive and STEM education positively addressed students' 21st century skills (Daymaz, 2019; Lamb et al., 2015; Pekbay, 2017; Şahin et al., 2014). Moreover, researchers found that STEM education increases students' motivation in learning (Aydın, 2019; Daymaz, 2019), problem-solving skills (Aydın, 2019; Bal, 2018; Pekbay, 2017) and creativity (Aydın, 2019; Çiftçi, 2018). Furthermore, it is predicted that the STEM approach would greatly contribute to the labor force and economic development of the country by increasing the orientation of the students to STEM professions (Badur, 2018; Çiftçi, 2018; Daymaz, 2019; Erçetin, 2021; Gülhan & Şahin, 2018; Şahin et al., 2014). Considering the results of these studies, STEM classroom activities should be adapted to these learning outcomes (Akay, 2018). In addition, Güder and Gürbüz (2018) found that STEM activities increased interdisciplinary interaction in their study conducted with mathematics and science teachers and students. In some studies, it was revealed that STEM activities also increased academic achievement (Altan et al., 2016; Barcelona, 2014; Daymaz, 2019; Macun, 2019). However, Erçetin (2021) concluded STEM applications did not change students' mathematics achievement and attitudes. In this context, careful planning and implementation of the STEM activities appears to be of critical importance.

1.2. Proportional Reasoning

Proportional reasoning is a type of mathematical thinking (Shield & Dole, 2008). Lamon (2007) defined proportional reasoning as "detecting, expressing, analyzing, explaining, and providing evidence in support of assertions about proportional relationships" (p. 647). A proportional reasoner should be capable of solving a variety of proportional problems and discriminating between proportional and nonproportional situations (Cramer et al., 1993; Hoffer, 1988; Lamon, 2007). Furthermore, most of the researchers have focused on the relationship between proportional reasoning and daily life (Al-Wattban, 2001; Ayan & Işıksal-Bostan, 2019; Dooley, 2006; Flowers, 1998). It was observed that people implement proportional reasoning were more successful in making accurate decisions in their daily lives (Erdem & Gürbüz, 2015). According to Cramer et al. (1993), people unconsciously used proportional reasoning in daily life. Flowers (1998) also defined proportional reasoning as understanding the relations of proportion and using these relations effectively in daily life. Correspondingly, Al-Wattban (2001) stated that proportional reasoning was important in solving daily life problems beyond formal education.

Proportional reasoning skills could be examined by using problem types containing proportional and non-proportional relations (Cramer et al., 1993). According to Lamon (2007), solving different types of problems requires having proportional reasoning skills. Problem types with proportional relationships include missing value problems, numerical comparison problems, and qualitative reasoning problems (Cramer & Post, 1993). A missing value problem is one in which three of the four values in a proportion are given, with the purpose of finding the missing value (Lamon, 2007). While solving missing value problems, which is one of the most preferred proportional problem types in mathematics lessons, it is seen that the students use the cross-multiplication algorithm without noticing the multiplicative relations between the quantities (Ben-Chaim et al., 2012; Cramer & Post, 1993; Duatepe et al., 2005; Lamon, 2007). In numerical comparison problems, all four quantities that make up two ratios are given, and the goal is to determine if they are equal or if one ratio is higher or smaller than the other (Ben-Chaim et al., 2012). In this problem type, students were more likely to use the unit rate technique (Duatepe et al., 2005; Pakmak, 2014). The main purpose of this technique is to find multiplicative relations between quantities by division (Cramer et al., 1993). Additionally, in qualitative reasoning problems, there are not numerical values, and the purpose is to make comparisons between ratios regardless of numerical values (Cramer et al., 1993). Since proportional reasoning encompasses both qualitative and quantitative processes, qualitative reasoning problems play an essential role

(Lesh et al., 1988). In qualitative reasoning problems, which were not commonly encountered in mathematics classes, it was observed that students used numerical values or drawings to make sense of verbal expressions (Duatepe et al., 2005; Pakmak, 2014; Umay & Kaf, 2005). Moreover, while solving these problems, rote-based solutions, such as cross-multiplication algorithm, do not work.

Another problem type to investigate proportional reasoning is non-proportional problems, which involve non-proportional relationships between variables but appear to require proportional strategies (Van Dooren et al., 2005). Research has revealed that students over-generalize and solve questions that need additive relations by employing multiplicative relations (Ayan & Işıksal-Bostan, 2019; Lamon, 2007; Toluk-Uçar & Bozkuş, 2018; Van Dooren et al., 2005; Van Dooren et al., 2010). In non-proportional problems, students' difficulty in distinguishing between proportional and non-proportional situations indicated that they had proportional reasoning difficulties (Cramer et al., 1993; Lamon, 2007; Van de Walle et al., 2010). According to Lamon (2007), proportional reasoning enabled the use of models suitable for proportional situations and distinguishing non-proportional situations. Recognizing and solving additive relationships in non-proportional problems could be accomplished by going beyond rote-based methods. Therefore, in ratio and proportion teaching, additive relations between variables in non-proportional problems should be included, as well as multiplicative relations between proportional variables (Ben-Chaim et al., 2012; Karplus et al., 1983).

In the studies carried out to evaluate and develop proportional reasoning of middle school students, different solution methods used by students in ratio and proportion problems were examined, and it was also emphasized that students were able to distinguish non-proportional situations from proportional situations (Avcu & Doğan, 2014; Ayan-Civak, 2020; Ayan & Işıksal-Bostan, 2019; Mersin, 2018). To illustrate, Avcu and Doğan (2014) determined the strategies used by seventh grade students in solving proportional problems. The findings revealed that the most frequently used solution strategy was the cross-product algorithm. Similarly, Ayan and Işıksal-Bostan (2019) examined middle school students' proportional reasoning, solution strategies and difficulties in real life contexts in the domain of geometry and measurement. The findings showed that the solution strategies used by the students in proportional and non-proportional problems were limited. In addition, students had difficulties in using additive relations in non-proportional situations. In a study about middle school students' proportional reasoning, Mersin (2018) found that students had misconceptions concerning multiplicative and additive related variables. It was observed that the students had difficulties in determining what and when to use the relation between the variables, such as using multiplicative relations where additive relations should be used. Correspondingly, Ayan-Civak (2020) aimed to examine the development of proportional reasoning of the seventh-grade students with formal and informal tools in line with a Realistic Mathematics Education perspective. As a result, it was determined that the activities gradually improved students' proportional reasoning skills. Furthermore, it was observed that students first made sense of the problems with informal tools and then used formal tools.

Rapid changes in science and technology mean it is necessary to teach students to produce, use their knowledge, solve problems, reason, and think critically (MoNE, 2018). Research studies have shown that students' problem solving and reflective thinking could not be separated from proportional reasoning (Aladağ & Dinç-Artut, 2012; Çelik, 2010; Öztürk, 2020). In the teaching of every mathematical concept, the idea of "mathematics is a mass of formulas" should be eliminated in the teaching of ratio and proportion, and students should be provided with information because of their reasoning and experiences (Küçük & Demir, 2009). Students should be guided to solve the problems they encountered by integrating the STEM disciplines to discover that mathematics was not difficult to understand and that it was not just a set of operations (Çorlu, 2012). The multiplicative nature of proportional relationships is difficult to create spontaneously and can be enhanced with education (Van Dooren et al., 2010). Studies indicate that proportional reasoning skills can be developed by going beyond traditional methods, such as practice-based mathematics education (Hillen, 2005; Sowder et al., 1998), realistic mathematics education (Altaylı, 2012), and creative drama-based teaching (Debreli, 2011). Moreover, traditional approaches are lacking in adapting skills such as proportional reasoning to real-life situations. Approaches using technology are required to develop individuals who have 21st century skills, are creative, can reason, produce, and adapt what they produce to different environments (Orhan et al., 2014). Proportional reasoning can be developed by extending instructional time and gaining experience. Finding solutions to real-life problems and active engagement in the classroom are required to attain the development of proportional reasoning (Dooley, 2006). Correspondingly, the National Council of Teachers of Mathematics (2000) stated that students can develop their proportional reasoning skills by solving different problem types sufficiently at middle school level. Accordingly, the STEM approach creates environments that are favorable to achieving proportional reasoning. By connecting real-life situations with different disciplines, STEM education allows students to find effective solutions to problems (Bender, 2017). Therefore, it is important to investigate how STEM education contributes to the development of proportional reasoning. In this sense, the main purpose of this research was to examine the development of proportional reasoning skills of students before and after STEM activities. In order to investigate this development, the solution strategies used by the students in problem types with proportional (missing value, numerical comparison, and qualitative reasoning problems) and non-proportional relationships were examined in detail. The study was guided by the following research question: "How are the proportional reasoning skills of the seventh-grade students developed with STEM activities?"

2. Method

Case study is one of the qualitative studies that is most appropriate for investigating the details that make up a phenomenon, as well as developing and evaluating interpretations regarding the phenomenon (Gall et al., 1996). Moreover, case studies use multiple data collection strategies to investigate interrelated systems (Creswell, 2007; McMillan, 2000). In the same way, the current study aimed to examine the development of proportional reasoning of the seventh-grade students before and after the implementation of STEM activities used on to teach ratio and proportion concepts.

2.1. Participants

The selection of the participants was carried out in two stages. In the first stage, convenience sampling method was used. At this stage, a class of 20 seventh-grade students was selected. This class took the mathematics applications course conducted by one of the researchers. This sampling method brings speed and practicality to the researcher (Yıldırım & Şimşek, 2018). In the second stage, maximum variation sampling was used, which is one of the methods that allows for in-depth analysis to reach rich data (Patton, 2002; Suri, 2011). Eight students were selected based on their pre-test Proportional Reasoning Test [PRT] scores to investigate their improvement. According to PRT scores, S1, S3 and S4 were chosen from the highest scores, S8, S5 and S7 from the lowest scores, and S2 and S6 from the middle scores. Five of the students were girls and three were boys.

2.2. Data Collection Tools

2.2.1. Proportional Reasoning Test

The Proportional Reasoning Test aimed to examine students' proportional reasoning skills, the solution strategies they use for different problem types, and their ability to distinguish situations with non-proportional relationships from proportional situations. The same test was used as a pre-test before STEM activities were applied, and as a post-test after the activities were applied. PRT had eight missing value problems, two numerical comparison problems, four qualitative reasoning problems and three non-proportional problems (See Appendix 1). The researchers chose and/or adapted some of the problems in the instrument from the literature (Akkuş & Duatepe-Paksu, 2006; Cramer et al., 1993; Hillen, 2005; Noelting, 1980) and wrote some of them. To ensure the instrument's validity, two mathematics teachers and a mathematics education instructor were asked to assess whether the instrument's items corresponded to the study's research questions and objectives. The items were then updated until all agreed. Afterwards, the instrument was pilot tested with a class of 40 students to check that the problem statements were clear and that the problems were relevant, as well as to determine how long it required completing the instrument. There was no change in the items in the PRT, but it was seen that the time (40 minutes) given to the students was insufficient. Therefore, the time of the test was changed to 60 minutes.

2.2.2. *Interviews*

Semi-structured interviews were conducted to gather detailed information about students' solutions from the PRT and to reveal the students' ability to distinguish non-proportional from proportional situations. The interviews were applied as a pre-interview following the pre-test before the STEM activities, and again as a post-interview after the post-test. The interviews were audio recorded and then transcribed. During the interview, the students were asked to explain their solutions from the PRT in more detail. The students were provided with their own solutions during the interview and the questions about their solutions were asked for each problem such as "What did you think when solving this problem? Can you explain your solution? Why did you solve it with this strategy?" and "How did you decide whether the quantities in this problem are proportional or not? Can you explain one by one? Why do you think so?". In addition to these questions, in the post-test, the students were asked why they solved the problem this way and if they solved it differently in the pre-test. The interviews took place in the school library and lasted approximately 30-40 minutes.

2.3. STEM Activities

The STEM activities were prepared using an engineering design process that consisted of seven stages (Massachusetts DoE, 2016). These stages were: (1) identify a need or a problem, (2) research (develop potential solution strategies), (3) design (selecting the possible solution that best address the problem), (4) construct a prototype, (5) test and evaluate the solution, (6) provide feedback (constructive criticism to improve design), (7) communicate, explain, and share. STEM activities were implemented in the math applications course sessions with a class of 20 students divided into four groups. This course was an elective course, and the aim of the course was to integrate mathematics into daily life situations by establishing mathematical models and developing original strategies for solving problems (MNE, 2018). STEM activities were implemented for two hours a day for seven weeks in the course. At the same time, the students continued their regular math classes. During the intervention, in the regular math classes, geometry subjects (i.e., angles and polygons) were taught. Detailed information about STEM activities is given in Table 1. Each of the seven different STEM activities focused on the concepts of ratio and proportion. The activities were finalized with the guidance of a mathematics teacher, a science teacher, and a technology design teacher who were trained in STEM education. When planning the activities, special attention was paid to bringing the disciplines together.

2.4. Data Analysis

Content analysis was used to analyze the data obtained from both the pre- and post-tests and interview. Content analysis is carried out to bring together themes gathered around a certain concept and to interpret them systematically (Patton, 2002). The data were analyzed according to the types of problems in the proportional literature by examining the solution strategies used in the PRT and the explanations in the interviews. The data were analyzed under two main themes.

Table 1

STEM Activities and the Related Objectives

Activity and Content	*Objectives*
Let's Prepare Mixtures Students prepared some mixtures such as Oobleck dough mix, lemonade, and mud. They investigated the ratio of materials in the mixtures and how the properties of the mixtures changed as this ratio changed.	*Mathematics* • Determines the ratio of two quantities of the same or different units to each other. • Examines real-life situations and decide whether two multiplicities are proportional. *Science* • Prepares solutions using the solvents and solutes they encounter in daily life. *Technology* • Performs basic research using search engines.
Step with SCRATCH Students organized running Olympics using the SCRATCH programming language. By integrating designs such as objects, people, and animals moving at varying speeds or with different step lengths into the program, students will be able to see how proportional and disproportionate situations could occur in situations with the same or different speeds.	*Mathematics* • Examines real-life situations and decide whether two multiplicities are proportional. • Expresses the relationship between two directly proportional and inversely proportional quantities. • Solves the problem of direct and inverse proportion. *Science* • Shows the relationship between distance, time, and speed on a graph. *Technology* • Creates programs containing linear logic structure.
Wheels in Our Lives Students examined the working principle of the clock and the wheels used in it and made their own unique designs using the wheels. The goal is for students to understand the proportional relationships between wheels with varying teeth numbers.	*Mathematics* • Examines real-life situations and decide whether two multiplicities are proportional. • Expresses the relationship between two inversely proportional quantities. *Science* • Design a mechanism that will make work easier in everyday life by utilizing simple machines. *Technology* • Develops an algorithm for solving a problem.

Table 1 continued

Activity and Content	*Objectives*
Do All Wheels Go the Same? Based on the relationship between thick and thin rolling pins, students make designs using the advantages and disadvantages of vehicles having different wheels. Students are expected to answer the following questions: "What happens when a big-wheeled truck completes one lap compared to a small-wheeled car? What's the relationship between them?"	*Mathematics* • Examines real-life situations and decide whether two multiplicities are proportional. • Expresses the relationship between two directly proportional quantities. *Science* • Shows the relationship between distance, time, and speed on a graph. • Design a mechanism that will make work easier in everyday life by utilizing simple machines. *Technology* • Develops an algorithm for solving a problem.
Solving Traffic Problems with mBlock In a situation where traffic converges and everyone had to catch up someplace, the students attempted to predict the interval at which the traffic lights would switch on. The students were given the responsibility of setting up mBlock structures, determining the interval at which the red, yellow, and green lights would switch on using the Arduino set, and correcting the traffic flow.	*Mathematics* • Examines real-life situations and decide whether two multiplicities are proportional. • Expresses the relationship between two directly proportional quantities. *Science* • Shows the relationship between distance, time, and speed on a graph. *Technology* • Develops an algorithm for solving a problem. • Creates programs containing linear logic structure.
My Model House Students designed models of their dream house, which were reduced to 1/20 ratio. The only rule of design was that they made their dream house in accordance with real dimensions. In this way, the students realized that they could enlarge or reduce the quantities proportionally.	*Mathematics* • Examines real-life situations and decide whether two multiplicities are proportional. • Expresses the relationship between two directly proportional quantities. *Science* • Compares balanced and unbalanced forces by observing the movements of objects. *Technology* • Develops an algorithm for solving a problem.
Power of Waves To help the stranded fisherman, the students created designs that measured how long it would take the fisherman to get to the beach. The students measured the distance between the points by placing wooden sticks at the opposite ends of a basin. While one was throwing a stone from the starting point, the other recorded the time. Students investigated the relationship between time and distance of the waves formed by the stone.	*Mathematics* • Examines real-life situations and decide whether two multiplicities are proportional. • Expresses the relationship between two directly proportional quantities. *Science* • Shows the relationship between distance, time, and speed on a graph. • Analyzes the reflections of linear and circular water waves. *Technology* • Develops an algorithm for solving a problem.

The first theme was determined as "Students' Proportional Reasoning in Proportional Problems" and the second was "Students' Proportional Reasoning in Non-Proportional Problems". Different problem types under the first theme were divided into categories: Missing Value, Numerical Comparison, and Qualitative Reasoning. The codes under the Missing Value and Numerical Comparison categories were the proportional strategies students used to solve the problems. For Missing Value problems, there were five different solution strategies: cross-multiplication, factor of change, building-up, unit rate and the additive strategy. Additionally, for numerical comparison problems, there were three different solution strategies: factor of change, unit rate, and additive strategy. Moreover, some of the students left some problems blank, so they were classified as blank in both categories. Under the Qualitative Reasoning category, there were two main codes: students could make multiplicative comparisons and students could not make multiplicative comparisons. In the first case, students solved the qualitative reasoning problems correctly, whereas in the second case, the students used additive relations and solved the problems incorrectly. Students were also classified according to their use of visual, verbal, and numerical expressions under both codes. The nonproportional problems used in PRT were analyzed under the second theme. The codes under this theme were the two strategies students used to solve the non-proportional problems: additive and wrong multiplicative strategies.

Solution strategies of students in PRT and interviews before and after the STEM activities were determined separately for eight students and comparison tables were constructed. Numerical data were used to make comparisons (Yıldırım & Şimşek, 2018). In comparisons, the increase in correct solutions, students' explanations, and the ability to notice proportional relations were examined. Moreover, the variation in solution strategies was analyzed based on students' PRT scores (i.e., low, medium, high) and looking at the differences between pre- and post-findings. The data were analyzed independently by two researchers. The reliability of the data analysis was calculated by using Miles and Huberman's (1994) percentage of agreement formula "Percent of agreement = [Agreement / (Agreement + Disagreement)] x 100". Reliability over 70% in qualitative studies is considered reliable for research (Miles & Huberman, 1994). In the study, the percentage of agreement between the two evaluators was found to be 94% and it was considered reliable for the study.

3. Results

3.1. Findings Related to Students' Proportional Reasoning in Proportional Problems

In this section, the solution strategies of the students from the pre- and post-test for the proportional problems and their explanations about these solutions in the pre- and post-interview are compared.

3.1.1. Missing value problems

The PRT had eight missing value problems. In Table 2, the frequency and percentages of the strategies used by the students for missing value problems in the pre-test and post-test are provided.

The findings obtained from the PRT and interviews were revealed five different solution strategies: cross-multiplication, factor of change, building-up, unit rate and the additive strategy in which the students used additive relationships instead of multiplicative ones. In addition, some of the students left some problems blank. Except for one student (S5), the students reached the correct answers by using the multiplication strategies (i.e., cross-multiplication, factor of change, building-up, unit rate). In the pre-test, S5 solved problem 3 incorrectly because he made a calculation mistake while doing the cross-multiplication algorithm. In the missing value problems, it was observed that while the students mostly (51.6%) used the cross-multiplication algorithm before the STEM activities, the frequency decreased (15.6%) after the STEM activities. In the pre-test, the

Table 2
Solution Strategies in Missing Value Problems

		Problems																	
		1		2a		2b		3		4		5		6		7		Total	
Strategies		f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
Cross-multiplication	Pre-test	6	75	0	0	4	50	4	50	5	67.5	5	67.5	4	50	5	67.5	33	51.6
	Post-test	0	0	0	0	2	25	2	25	2	25	1	12.5	1	12.5	2	25	10	15.6
Factor of change	Pre-test	2	25	5	67.5	2	25	2	25	0	0	1	12.5	2	25	1	12.5	15	23.4
	Post-test	7	87.5	4	50	6	75	1	12.5	5	67.5	6	75	1	12.5	5	67.5	35	54.7
Building-up	Pre-test	0	0	0	0	0	0	0	0	0	0	0	0	1	12.5	0	0	1	1.6
	Post-test	1	12.5	3	37.5	0	0	0	0	0	0	1	12.5	1	12.5	0	0	6	9.4
Unit rate	Pre-test	0	0	0	0	0	0	1	12.5	0	0	1	12.5	0	0	0	0	2	3.1
	Post-test	0	0	0	0	0	0	5	67.5	0	0	0	0	5	67.5	0	0	10	15.6
Additive	Pre-test	0	0	2	25	1	12.5	1	12.5	2	25	0	0	1	12.5	1	12.5	8	12.5
	Post-test	0	0	1	12.5	0	0	0	0	0	0	0	0	0	0	0	0	1	1.6
Blank	Pre-test	0	0	1	12.5	1	12.5	0	0	1	12.5	1	12.5	0	0	1	12.5	5	7.8
	Post-test	0	0	0	0	0	0	0	0	1	12.5	0	0	0	0	1	12.5	2	3.1

students used factor of change (23.4%), unit rate (3.1%) and building-up (1.6%) strategies, respectively, after the cross-multiplication algorithm. After the STEM activities, students mostly (54.7%) used the factor of change strategy. In the post-test, unit rate (15.6%) and building-up (9.4%) were used, respectively after the factor of change strategy.

It was seen that students' usage of informal strategies in solving missing value problems increased after the STEM activities. However, there were still a few students (15.6%) who used the cross-multiplication strategy to solve some of the problems. Indeed, after the intervention, students with high and medium PRT scores (S1, S2, S3, S4, S6) preferred to use informal strategies, while students with low scores (S5, S7, S8) continued to use the cross-multiplication strategy. For example, in the pre-test, problem 1 was one of the problems in which students utilized the cross-multiplication method the most (75%). The problem 1 was "If 8 kg of detergent costs 32 TL, how much is 1 kg of detergent?" However, in the post-test, students frequently solved the problem by using the factor of change (87.5%) strategy because they easily found the integer ratio between the quantities rather than unconsciously applying the cross-multiplication algorithm. In general, after the STEM activities, students preferred to use mostly informal strategies such as factor of change, building-up and unit rate. Based on this finding, it is thought that students could solve the proportional problems by noticing the multiplicative relationships between the quantities.

During the pre-interviews, the students stated that they used the cross-multiplication strategy because they thought it was easier, memorable, the first or the only way to solve the proportional problems. S1, S5, S6, S7, who utilized the cross-multiplication algorithm frequently, stated that it was the first method that comes to their minds. Moreover, S2 and S4 said that proportional problems could not be solved in any other way than the cross-product algorithm. For example, the explanation of S2 for Problem 2b was as follows:

> Researcher: What did you think when solving the Problem 2b, which was "If Murat can finish a storybook in two days, how many days will it take him to finish 120 storybooks?" Can you explain your solution?
>
> Student 2: If he finishes a storybook in two days, I multiply it by 2 since he finishes each of the 120 storybooks in 2 days, so 120x2=240.
>
> Researcher: But you solved it by using cross-multiplication in the pre-test, why did you solve it like that?
>
> Student 2: I wanted to show that it is also solved by proportion.

As seen in the quote above, S2 used the factor of change strategy to explain her solution. She could easily see the multiplicative relationship between the variables, but she did not think that she solved it by proportion. After the STEM activities, S2 mostly used informal strategies and it was seen that she gave up on the idea that the cross-multiplication algorithm was the only way to solve proportional problems. Similarly, S4, who thought that there was no other way to solve the proportional problems by using cross-multiplication algorithm, always used this algorithm in the pretest. However, in the post-test and post-interview, she noticed proportional relationships and used informal strategies.

After the STEM activities, in the missing value problems, the solution strategies of the students, who first tended to use cross-multiplication, diversified and there was an increase in their use of informal strategies. However, even in the pre-test, most of the students (67.5%) preferred the factor of change strategy rather than cross-multiplication to solve the Problem 2a. Considering the other missing value problems in the pre-test, the frequency of using the factor of change strategy for this problem draws attention. The problem gave the number of books in a library as 120 storybooks, 240 novels, 160 scientific books, 80 political books, and 200 science fiction books. The problem was "How many more novels are needed for the ratio of the number of science fiction books to the number of novels to be 1/4?" The Problem 2 was not a routine missing value problem in which three of the four values in a proportion were given and the missing value was asked. Correspondingly, when the answers given by the students in the pre-interview about problem 2a were examined, it was seen that students did not see the problem as a missing value problem.

Therefore, none of the students solved this problem with cross-multiplication. For example, while S7 solved most of the missing value problems by utilizing cross-multiplication algorithm, he solved this problem with factor of change. In the pre-interview he said: "I solved it like this because it is a simple problem, it is not a proportional problem." S4, on the other hand, said: "At first I tried with the cross-multiplication algorithm, but because it did not work, I used multiples". S3, S5, and S6 explained it in the same way.

As seen in the Table 2, in the pre-test, some of the students (12.5%) solved the problems by using additive relations instead of multiplicative relations. However, in the post-test, students' usage of additive relations (1.6%) decreased. For example, in the pre-test, S2 and S6, used additive strategy to solve Problem 4. The problem was "When the lengths of Masha and the Bear were measured with a pencil, it was found that the Bear's length was 14 pencils and Masha was 8 pencils long. If Masha is 12 erasers tall when measured with an eraser, how many eraser lengths is the Bear?" The students focused on the additive relation between the lengths by subtracting 14 pencils from 8 pencils, and they incorrectly found the answer as 18 erasers. However, after the STEM activities, they correctly solved the problems by using the multiplicative relations between the quantities.

3.1.2. Numerical Comparison Problems

The PRT had two numerical comparison problems. In Table 3, the frequency and percentages of the strategies used by the students for these numerical comparison problems in the pre-test and post-test are given.

Table 3

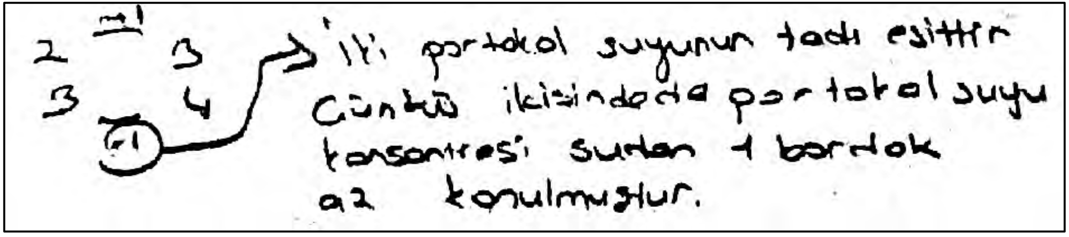
Solution Strategies in Numerical Comparison Problems

		Problems					
		9		10		Total	
Strategies		f	%	f	%	f	%
Factor of change	Pre-test	1	12.5	1	12.5	2	12.5
	Post-test	0	0	1	12.5	1	6.2
Unit rate	Pre-test	2	25	2	25	4	25
	Post-test	6	75	5	62.5	11	68.8
Additive	Pre-test	4	50	4	50	8	50
	Post-test	1	12.5	1	12.5	2	12.5
Blank	Pre-test	1	12.5	1	12.5	2	12.5
	Post-test	1	1.2,5	1	12.5	2	12.5

The findings in Table 3 revealed three different solution strategies: factor of change, unit rate, and the additive strategy in which the students used additive relationships instead of multiplicative ones. Additionally, some of the students left some problems blank. In the numerical comparison problems, it was seen that half of the students (S2, S5, S6, S7) used the wrong additive strategy before the STEM activities. For instance, problem 10 was "Jugs A and B are used to make orange juice. 2 glasses of orange juice concentrate and 3 glasses of water were placed in jug A, and 3 glasses of orange juice concentrate and 4 glasses of water in jug B. Which orange juice container is the sweeter?" In this problem, it was determined that the students mostly used additive relations both in pre-test and in their explanations in the pre-interview. For example, S7's solution for problem 10 was as follows.

Figure 1

The additive strategy that S7 used in solving problem 10 (English translation: The two orange juices taste the same because they each contain one glass less orange juice concentrate than water.)



İki portokol suyunun tadı eşittir
Çünkü ikisindeda portokal suyu
konsontresi sudan 1 bardok
az konulmuştur.

As can be seen in Figure 1, S7 focused on the additive relationship between the quantities and could not notice the multiplicative relationship. S7 found the difference between 2 glasses of oranges and 3 glasses of water and between 3 glasses of oranges and 4 glasses of water to be 1 glass. The student thought that the tastes of the orange juices were the same because the difference between the glasses was the same. Similarly, S2 said in the pre-interview: "I think they taste the same because we add a glass to both."

In the pre-test, it was observed that the students (S1, S3, S4) who answered the numerical comparison problems correctly used the unit rate strategy (25%) and the factor of change strategy (12.5%) in their solutions. For example, the explanation of S4 for Problem 10 was as follows:

> Researcher: You said that the orange juice in jug B tastes better, how did you know that?
>
> Student 4: In jug A, 3 is 1.5 times 2. And in jug B, 1.5 times 3 becomes 4.5. However, B is sweeter now that four glasses were added. Because B has a lot of oranges but not much water as A.

As can be understood from the quote above, S4 considered the ratio of orange juice concentrate and water of the jugs separately for each jug and noticed the multiplicative relationship between the quantities.

After the STEM activities, the students (S1, S2, S3, S4, S6, S7) who utilized multiplicative strategies (i.e., factor of change, unit rate) could correctly solved both numerical comparison problems. Additionally, the students mostly used the unit rate strategy to solve the problems (68.8%). In the post-test and post-interview, the students (S2, S6, S7) were able to solve the problems with proportional strategies by leaving the additive strategies as before. In the post-interview, S6 stated: "I understand that each mixture should be analysed separately." and S7 said: "I solved it by finding the ratios for each jug." Moreover, S2 indicated that because she applied multiplicative relationships, she was able to answer the problem with a greater understanding. As it can be understood from their explanations, the students realized that it was not logical to make comparisons with additive operations, and they made the comparison using multiplicative relations.

3.1.3. *Qualitative Reasoning Problems*

The PRT had four qualitative reasoning problems. In Table 4, the frequency and percentages of the strategies used by the students for qualitative reasoning problems in the pre-test and post-test are given.

The findings in Table 4 showed two main codes: students could make multiplicative comparisons and students could not make multiplicative comparisons. Students were classified according to their use of visual, verbal, and numerical expressions under both codes. In the qualitative reasoning problems, it was seen that while the students mostly (62.4%) could not make multiplicative comparisons before the STEM activities, most of them (84.4%) could do so after the STEM activities. In the pre-test, the students, who could not make multiplicative comparisons, used verbal expressions (50%), visual expressions (6.2%), and numerical expressions (6.2%).

Table 4

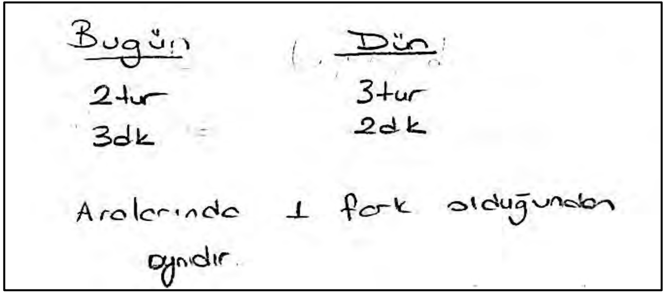
Solution Strategies in Qualitative Reasoning Problems

			Problems									
			11		12		13		14		Total	
	Strategies		f	%	f	%	f	%	f	%	f	%
Making multiplicative comparisons	Visual expressions	Pre-test	0	0	2	25	1	12.5	0	0	3	9.5
		Post-test	0	0	0	0	4	50	2	25	6	18.7
	Verbal expressions	Pre-test	3	37.5	1	12.5	0	0	3	37.5	7	21.9
		Post-test	5	67.5	5	67.5	2	25	3	37.5	15	47
	Numerical expressions	Pre-test	0	0	0	0	2	25	0	0	2	6.2
		Post-test	2	25	2	25	0	0	2	25	6	18.7
Not making multiplicative comparisons	Visual expressions	Pre-test	0	0	0	0	1	12.5	1	12.5	2	6.2
		Post-test	0	0	0	0	0	0	0	0	0	0
	Verbal expressions	Pre-test	4	50	4	50	4	50	4	50	16	50
		Post-test	1	12.5	1	12.5	1	12.5	1	12.5	4	12.5
	Numerical expressions	Pre-test	1	12.5	1	12.5	0	0	0	0	2	6.2
		Post-test	0	0	0	0	1	12.5	0	0	1	3.1

For example, S6 solved the problem 11 by giving numerical values. The problem 11 was "Deniz has run fewer laps in more time today than he ran yesterday. Accordingly, compare Deniz's running speed today with that of yesterday." In the pre-test, the solution of S6 solution for problem 11 was as follows:

Figure 2

The numerical expression that S6 used in solving problem 11(English translation: It is the same because there is a difference between them.)



Bugün Dün

2tur 3tur

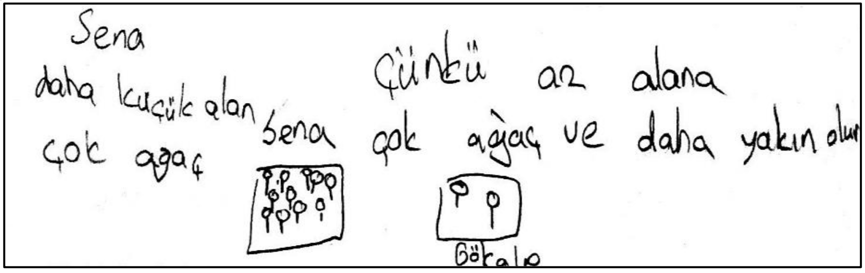
3dk 2dk

Aralarında 1 fark olduğundan aynıdır.

As can be seen in Figure 2, the student (S6) gave numerical values (2 laps in 3 minutes for today, 3 laps in 2 minutes for yesterday) to solve the problem. However, she focused on the additive relationship between the values and could not notice the multiplicative relationship. Because the difference between the values was the same, she made the wrong decision and said, "Yesterday's run is the same as today's run." In the pre-test, the students making multiplicative comparisons used verbal expressions (21.9%), visual expressions (9.5%), and numerical expressions (6.2%). After the STEM activities, the students mostly utilized verbal expressions (47%), then they utilized visual expressions (18.7%), and numerical expressions (18.7%) to make multiplicative comparisons. In general, findings before the STEM activities showed that there were few correct solutions, and the students frequently used verbal expressions (21.9%). For example, the problem 14 was "Sena and Gökalp regularly plant trees on different lands. Sena plants more trees on a smaller land than Gökalp. As a result, whose land has the trees that are closer to each other?" In this problem, most of the students, who could make correct multiplicative comparisons, used verbal expressions (37.5%). To illustrate, S1 stated "The answer is Sena because more trees are planted on a smaller land, so the trees are closer to each other". After the STEM activities, more students were able to make multiplicative comparisons in this problem and used different strategies (See Table 4). For example, S5's solution for problem 14 was as follows.

Figure 3

The visual expression that S5 used in solving problem 14 (English translation: Sena, because she plants more trees in a smaller area, and it will be closer.)



As can be seen in Figure 3, while the student (S5) drew more trees on Sena's land, he drew Gökalp's land smaller and drew fewer trees. Similarly, in the post-interview, S5 said: "The area gets narrower, the trees inside it increase, they automatically become closer. I drew it so that it can be understood better." Another strategy students used for making multiplicative comparisons after the STEM activities was using numerical expressions (18.7%). For instance, S3 solved the problem 13 by giving numerical values. The problem 13 was "On a running track, Esra ran more laps in less time than Gonca. Which is the faster runner?" The explanation of S3 for Problem 13 was as follows:

> Researcher: You decided that Esra is faster, how did you know that?
>
> Student 3: I found the speeds. I gave numbers according to the information in the question. I said that Esra should be 12 km for the long road and 8 km for the short road to Gonca. I said Esra 3 minutes, Gonca 4 minutes. Then I find the ratios and so Esra was faster.

The student gave numerical values to Esra's and Gonca's distance and time to solve the problem. Then, she found the correct answer by calculating the speeds (the ratio of distance to time) with these numerical values.

3.2. Findings Related to Students' Proportional Reasoning in Non-Proportional Problems

In this section, the solution strategies of the students in the pre- and post-test for the non-proportional problems and their explanations about these solutions in the pre- and post-interview were compared. The PRT had three non-proportional problems. In Table 5, the frequency and percentages of the strategies used by the students for non-proportional problems in the pre-test and post-test are given.

Table 5

Solution Strategies in Non-Proportional Problems

		Problems							
		2c		8		15		Total	
Strategies		f	%	f	%	f	%	f	%
Additive	Pre-test	3	37.5	4	50	3	37.5	10	41.7
	Post-test	4	50	7	87.5	4	50	15	62.5
Multiplicative	Pre-test	5	62.5	4	50	5	62.5	14	58.3
	Post-test	4	50	1	12.5	4	50	9	37.5

The findings in Table 5 show there were two different solution strategies: additive and wrong multiplicative strategies. In the non-proportional problems, while 41.7% of the students used additive relationships before the STEM activities, it was observed that this frequency increased to 62.5% after the STEM activities. Furthermore, students using the additive relationships solved the non-proportional problems correctly according to the pre and post findings. Before the STEM activities, the students mostly solved the problems using a multiplicative strategy that was cross-multiplication algorithm (58.3%). However, after the STEM activities, the frequency decreased to

37.5%. In the pre-test, the students (S3, S5, S8), who found correct answers, solved the problems by using additive relations. However, in the pre-interview, it was seen that students with low PRT scores were not aware that the quantities in the problems were non-proportional. For example, S5 and S8 stated that the problems that they solved correctly using additive relations were proportional. Some students (S1, S2, S4, S6, and S7) could not found the correct answers of the problems in the pre-test since they used multiplicative relationship (i.e., cross-multiplication algorithm).

As a result, before the STEM activities, the students were not able to distinguish non-proportional from proportional situations. After the STEM activities, S1, S2, S3, S4, S5 and S7 were able to solve some of the problems by establishing additive relations. However, S1, S4 and S7 only solved one non-proportional problem (problem 8) correctly. Problem 8 was "The mother is 40, the daughter is 10 years old. How old is the daughter when the mother is 60 years old?" Most of the students (87.5%) could realize the constant difference between mother′ age and daughter′ age after the STEM activities. On the other hand, even after the STEM activities, half of the students could not realize additive relationships in the other problems (See Table 5).

4. Discussion and Conclusion

In general, the results of the study revealed that the STEM activities used to teach ratio and proportion concepts contributed to the development of students′ proportional reasoning skills. First, it was determined that the solution strategies used by the students in solving proportional and non-proportional problems changed according to the problem types. This situation was parallel to many studies in the literature (Cramer & Post, 1993; Duatepe et al., 2005; Kayhan, 2005; Lamon, 1993; Pakmak, 2014). In this study, it was aimed to develop the proportional reasoning of the students by preparing STEM activities to address each problem type.

Before the STEM activities, it was observed that the seventh-grade students mostly solved the missing-value problems with the cross-multiplication algorithm, which is a rote-based solution method. It was an expected result because missing value problems are frequently encountered in the subject of "Ratio and Proportion" and these types of problems are generally taught with the cross-multiplication algorithm in mathematics classrooms (Duatepe et al., 2005). Similarly, studies showed that the majority of teachers, prospective teachers, and students prefer the cross-multiplication algorithm for solving missing value problems (Arıcan, 2020; Avcu & Doğan, 2014; Ayan & Işıksal-Bostan, 2019; Bal-İncebacak & Ersoy, 2016; Ben-Chaim et al., 2012; Boyacı, 2019; Cramer & Post, 1993; Duatepe vd., 2005; Kahraman vd., 2019; Toluk-Uçar & Bozkuş, 2018). After the STEM activities, it was observed that the use of the cross-multiplication algorithm in missing value problems decreased, while the use of the informal strategies such as factor of change increased. Therefore, it is thought that STEM activities improved students' proportional reasoning for missing value problems (see week 4 activities in Table 1). Correspondingly, studies have shown that proportional reasoning skills could be improved by moving away from traditional methods (Altaylı, 2012; Dinç-Artut & Pelen, 2015; Debreli, 2011; Hillen, 2005; Hilton et al., 2016; Öztürk, 2017; Sowder et al., 1998).

Prior to the STEM activities, only students with the high PRT scores were able to complete the numerical comparison problems correctly using multiplicative relations. Students with the medium and low scores, on the other hand, did not successfully solve the tasks. As a result, the students mostly solved the numerical comparison problems incorrectly by using additive relationships. Similarly, Kayhan (2005) found that middle school students frequently incorrectly solved numerical comparison problems using additive relations. Following participation in the STEM activities, all of the students, except for two with low PRT scores, stopped using the wrong additive relations and instead employed the unit ratio strategy in numerical comparison problems. This follows from other studies that emphasize the importance of using unit rate in this problem type (Ben Chaim et al., 1998; Cramer & Post, 1993; Duatepe et al., 2005; Kahraman et al., 2019; Kayhan, 2005; Küpçü, 2008; Lamon, 2007; Pakmak, 2014). The use of the unit rate strategy enabled quantitative comparisons that required multiplicative thinking and was an indicator of the development of proportional reasoning skills (Çelik, 2010; Van de Walle et al., 2010). Research argued that the multiplicative structure of the proportional relationship was difficult to form spontaneously and could be developed with different methods (Aladağ & Dinç-Artut, 2012; Hilton et al., 2016; Sowder et al., 1998). In this study, activities to support quantitative comparisons in STEM activities were also found to be productive (for example, week 1 activities in Table 1).

The pre-test results revealed that most of the students incorrectly solved the qualitative reasoning problems, which were not frequently encountered in mathematics lessons. Rote-based solutions, such as the cross-multiplication algorithm, cannot be used when solving these types of problems. Since proportional reasoning encompasses both qualitative and quantitative processes, qualitative reasoning problems play an essential role in the development of proportional reasoning (Lesh et al., 1988). After the STEM activities, it was observed that the students could make multiplicative comparisons to solve the qualitative problems and used visual, verbal, and numerical expressions. Similarly, other researchers have shown that students used numerical values or drawings to make sense of verbal expressions (Duatepe et al., 2005; Pakmak, 2014; Umay & Kaf, 2005). In the current study, students' ability to make qualitative comparisons was supported by asking students to express the relationships verbally and visually in the activities. Proportional reasoning, and especially qualitative reasoning problems, require understanding the relationship between inversely proportional quantities. Thus, STEM activities (Step with SCRATCH and Wheels in Our Lives) with inversely proportional were purposefully developed and included.

Proportional reasoning also requires being able to distinguish non-proportional from proportional situations (Cramer et al. 1993). For this reason, in the PRT, non-proportional problems were included, in addition to proportional problems. Before the STEM activities, it was observed that the students mostly solved the non-proportional problems using the cross-multiplication algorithm. Prior research showed that this method was used by rote operations even in non-proportional problems without questioning whether the relationship between quantities were multiplicative (Arıcan, 2020; Brown et al., 2020; Cramer & Post, 1993; Duatepe et al., 2005; Kahraman et al., 2019; Van Dooren et al., 2005). After the STEM activities, it was observed that there was an increase in the number of students who correctly solved the non-proportional problems. It could be concluded that STEM activities contributed to students' awareness of non-proportional situations. In the STEM activities, students were made aware of the non-proportional relationships by including problems containing additive relationships, as well as proportional problems.

The results of the current study indicate that STEM activities contribute to the development of proportional reasoning skills of students. Proportional reasoning can be developed with innovative approaches such as STEM. Although the STEM approach has been studied extensively recently, studies focusing on the discipline of mathematics are rare. Therefore, we urge researchers to extend this work by developing and researching STEM activities connected to proportional reasoning at other grade levels.

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Appendix 1

The Proportional Reasoning Test

Problems	*Problem Types*
1. If 8 kg of detergent costs 32 TL, how much is 1 kg of detergent?	MVP
2. Books in the school library: 120 storybooks, 240 novels, 160 scientific books, 80 political books, and 200 science fiction books.	
a. How many more novels are needed for the ratio of the number of science fiction books to the number of novels to be 1/4?	MVP
b. If Murat can finish a storybook in two days, how many days will it take him to finish all the storybooks?	MVP
c. Emre and Gökhan read at the same pace. Emre started reading before Gökhan. If Gökhan reads 4 when Emre reads 6 books, how many books will Emre read when Gökhan reads 24?	NPR
3. Rıdvan and Sadık are driving at the same speed. If Rıdvan travels 12 km in 4 minutes, in how many minutes will Sadık travel 36 km?	MVP
4. When the lengths of Masha and the Bear were measured with a pencil, it was found that the Bear's length was 14 pencils and Masha was 8 pencils long. If Masha is 12 erasers tall when measured with an eraser, how many eraser lengths is the Bear?	MVP
5. A minibus passes through three towns, named A, B, C, with distances of 10, 15 and 25 km, respectively. The cost of this minibus is determined in direct proportion to the distances of the towns. If going to town C pays 10 TL; how much do those who go to towns A and B pay?	MVP
6. A car traveling 300 km in 4 hours, in how many hours will it travel 750 km at the same speed?	MVP
7. Mert and Uras work at the same speed and paint a wall in 15 days. In how many days will the same wall be painted when 3 more people working at the same speed join them?	MVP
8. The mother is 40, the daughter is 10 years old. How old is the daughter when the mother is 60 years old?	NPR
9. Car A travels 180 km in 3 hours. If car B travels 400 km in 7 hours, which car is faster?	NCP
10. Jugs A and B are used to make orange juice. 2 glasses of orange juice concentrate and 3 glasses of water were placed in jug A, and 3 glasses of orange juice concentrate and 4 glasses of water in jug B. Which orange juice container is the sweeter?	NCP
11. Deniz has run fewer laps in more time today than he ran yesterday. Accordingly, compare Deniz's running speed today with that of yesterday.	QRP
12. Tufan drank her tea at breakfast this morning in a larger glass, with less sugar than yesterday. How does today's tea taste compare to yesterday's tea?	QRP
13. On a running track, Esra ran more laps in less time than Gonca. Which is the faster runner?	QRP
14. Sena and Gökalp regularly plant trees on different lands. Sena plants more trees on a smaller land than Gökalp. As a result, whose land has the trees that are closer to each other?	QRP
15. Aslı and Nehir are running at the same speed on the jogging track. Aslı started running before Nehir. When Aslı completes 9 laps, Nehir completes 3 laps. How many laps will Aslı complete when Nehir completes 15 laps?	NPR

Note. MVP: Missing value problem; NPR: Non-Proportional Problem; NCP: Numerical Comparison Problem; QRP: Qualitative Reasoning Problem.