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Middle School Students' Views about STEM Activities Used in Teaching Ratio and Proportion

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ABSTRACT

The purpose of the study was to investigate middle school students' views about STEM activities used in teaching ratio and proportion concepts in a mathematics classroom. The research was designed as a phenomenology study. Participants were eight middle school students who were selected among 20 students based on different proportional reasoning skills. Data were collected through semi-structured interviews. In the mathematics classroom where the participants of the study were selected, the subject of ratio and proportion was taught to the students with the help of STEM activities. Students had the chance to experience how the mathematics lesson was taught with STEM activities. After all the STEM activities were completed, semi-structured interviews were held with each participant. According to the findings, the students focused on the positive aspects of STEM activities. Students mentioned that STEM activities were enjoyable, interesting, and collaborative. Moreover, students stated that the activities provided active participation, permanent learning, creative thinking, and developed hand skills. Additionally, students argued that STEM activities were interdisciplinary, technology related, and related to everyday life.

Keywords: STEM education, ratio and proportion, middle school students

Ortaokul Öğrencilerinin Oran ve Orantı Konusunun Öğretiminde Kullanılan STEM Etkinliklerine Yönelik Görüşleri

ÖZ

Bu araştırmanın amacı, ortaokul öğrencilerinin oran ve orantı kavramlarının öğretiminde kullanılan STEM etkinlikleri hakkındaki görüşlerini incelemektir. Araştırma bir fenomenoloji çalışması olarak tasarlanmıştır. Katılımcılar, farklı orantısal akıl yürütme becerilerine dayalı olarak 20 öğrenci arasından seçilen sekiz ortaokul öğrencisidir. Veriler yarı yapılandırılmış görüşmeler yoluyla toplanmıştır. Araştırmanın katılımcılarının seçildiği matematik sınıfında oran ve orantı konusu STEM etkinlikleri yardımıyla öğrencilere öğretilmiştir. Öğrenciler, STEM etkinlikleriyle bir matematik dersinin nasıl yürütüldüğünü deneyimleme şansı bulmuşlardır. Tüm STEM etkinlikleri tamamlandıktan sonra her bir katılımcı ile yarı yapılandırılmış görüşmeler yapılmıştır. Elde edilen bulgulara göre; öğrenciler STEM etkinliklerinin olumlu yönlerine odaklanmışlardır. Öğrenciler, STEM etkinliklerinin eğlenceli ve ilgi çekici olduğunu ve işbirlikçiliği desteklediğini belirtmişlerdir. Bunun yanında, öğrenciler etkinliklerin aktif katılımı, kalıcı öğrenmeyi, yaratıcı düşünmeyi ve el becerilerini geliştirmeyi sağladığını söylemişlerdir. Ayrıca öğrenciler, STEM etkinliklerinin disiplinler arası, teknoloji ve günlük yaşamla ilgili olduğunu ileri sürmüşlerdir.

Anahtar kelimeler: STEM eğitimi, oran ve orantı, ortaokul öğrencileri

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1 | INTRODUCTION

Individuals in the developing world are required to investigate, research, reason, and adapt what they produce to a variety of situations (Akgündüz et al., 2015; Çepni, 2017). For this reason, educational approaches that support 21st century skills, such as critical thinking, groupwork, collaboration, problem-solving, creativity, and logical reasoning, should be included by creating science and technology-friendly learning settings. A qualified workforce is a result of high-quality learning environments (Bowman, 2010; Rennie et al., 2012). Countries that need productive individuals have begun to invest in various educational approaches. One of these educational approaches is the Science, Technology, Engineering and Mathematics (STEM) education. STEM education facilitates learning by removing the boundaries between science, technology, mathematics, and engineering disciplines (Gallant, 2010). The four disciplines in STEM acronym could be summarized as, Science – is a branch of the world around us, Technology – all kinds of human-made products to meet people's wishes and needs, Engineering – the design processes that children use to solve problems, and Mathematics – the language of numbers, shapes, and quantities (Jolly, 2014).

STEM education, which should be provided from kindergarten to university, allows students to apply what they have learned to a variety of settings. This production-oriented education requires the effective application of technology while also enhancing creativity, critical thinking, and problem-solving skills (Ministry of National Education [MNE], 2018). These features, which are demanded by the 21st century, have become essential for countries that want to keep up with the rest of the world's education. It is foreseen that the transfer of science and mathematics, technology and engineering disciplines used in the application process, which make up STEM education, to classroom environments can offer solutions to current and future problems (Gökbayrak & Karışan, 2017; Lacey & Wright, 2009; MNE, 2019; National Research Council [NRC], 2012).

The application of STEM education in schools and how it would be adapted to the education system were discussed. Considering the studies on this subject, content and context were emphasized (Roehrig et al., 2012). The content focused on developing a new curriculum by bringing together the STEM disciplines (Science, Technology, Engineering, and Mathematics) under one roof (Breiner et al., 2012). In the context, it was emphasized that one of the disciplines was centered and the other disciplines were used as a tool to facilitate teaching (Moore et al., 2014; Yamak et al., 2014). In a similar way, the STEM activities in the current study put mathematics at the center. In Turkey, it was observed that studies examining STEM activities for teaching mathematics concepts were fewer than studies on teaching science concepts. However, in recent years, it was seen that there was an increase in STEM studies with mathematics concepts (Aydın, 2019; Çiftçi, 2018; Daymaz, 2019; Delen & Uzun, 2018; Erçetin, 2021; Macun, 2019). Correspondingly the current study investigated middle school students' views about STEM activities used in teaching ratio and proportion concepts in a mathematics classroom. The STEM activities planned in this study considering suggestions about STEM education and the engineering design process (Bender, 2017; Massachusetts Department of Education [DoE], 2016; MNE, 2016; NRC, 2010). Students first identify a problem within its parameters, then study and develop various solutions, build a prototype, test, and assess the answer, and ultimately discuss and share with one another in the engineering design process (Bender, 2017; Massachusetts DoE, 2016). Engineering design is a cyclical and iterative process that aims at enhancing creativity (NRC, 2012).

According to STEM education research, students' attitudes toward STEM activities were generally positive, and STEM education addressed students' 21st century skills (Daymaz, 2019; Goonatilake & Bachnak, 2012; Lamb et al., 2015; Nugent et al., 2010; Pekbay, 2017; Şahin et al., 2014). Furthermore, STEM education was shown to improve students' willingness to learn (Aydın, 2019; Daymaz, 2019; Elam et al., 2012; Master et al., 2017), problem-solving capabilities (Aydın, 2019; Bal, 2018; Pekbay, 2017), mathematical thinking (Singh et al., 2018), and originality (Aydın, 2019; Çiftçi, 2018). Based on the findings of the studies, STEM classroom activities should be adjusted to the curriculum's learning outcomes (Akay, 2018). Furthermore, in a study involving mathematics and science teachers and students, Güder and Gürbüz (2018) discovered that STEM activities promoted multidisciplinary interaction. In contrast to these findings, Erçetin (2021) indicated that STEM applications had no effect on students' attitudes toward the lesson. In this setting, it appears that careful planning and implementation of STEM activities is crucial.

Considering the mathematics curriculum in Turkey, students are expected to be able to use mathematical literacy skills effectively, adapt mathematical concepts to daily life, realize their proportional thinking and reasoning while solving problems, see and discuss the deficiencies in their mathematical reasoning in group work, use terminology while expressing themselves mathematically, and associate mathematics with objects and events (MNE, 2018). Beyond calculation of numeric values, mathematics education aims to transform students' abilities such as thinking skills, seeing relationships between situations, problem solving, and comparison, and turning them into life skills (Umay, 2003). One of the real-world abilities is proportional reasoning (Al-Wattban, 2001; Dooley, 2006; MNE, 2018). According to Lamon (2007) proportional reasoning is "detecting, expressing, analyzing, explaining, and providing evidence in support of assertions about proportional relationships" (p. 647). One of the most important steps of proportional reasoning is to be able to express proportional situations in problems mathematically by noticing them (Cramer & Post, 1993). The ability to understand and apply proportionality rules is the most general definition of proportional reasoning (Flowers, 1998). Proportional reasoning skills are seen as one of the basic building blocks of primary and secondary school mathematics curricula (Lesh et al., 1988). Rather than focusing on what proportional reasoning was, studies focused on how it worked. When we examined the areas where it was employed, we could see that it spread to a wide range of topics, including ratio and proportion, speed, moment, power, pressure, density, systems, and genetics (Lamon, 2007; Mitchell & Lawson, 1988). In particular, individuals use proportional reasoning when solving daily life problems. Proportional reasoning is a bridge that connects disciplines by bringing them together (Akkuş-Çıkla & Duatepe, 2002). Research studies argued that students' problem solving and reflective thinking skills could not be separated from proportional reasoning (Aladağ & Dinç-Artut, 2012; Çelik, 2010; Öztürk, 2020). As in the teaching of every mathematical concept, the idea of 'mathematics is a mass of formulas' should be removed in the teaching of ratio and proportion, and students should be enabled to learn by making use of their reasoning and experiences (Küçük & Demir, 2009). Students should be encouraged to solve problems by combining STEM disciplines so that they learn that mathematics is not hard to grasp and is more than just a collection of operations (Çorlu, 2012). Thus, it is important to investigate the seventh-grade middle school students' views about STEM activities used in teaching ratio and proportion concepts in a mathematics classroom. The research question of the study was: "What is the seventh-grade middle school students' views about STEM activities used in teaching ratio and proportion concepts?"

2 | METHOD

RESEARCH DESIGN

This study designed based on qualitative research techniques which provided an in-depth explanation and rich description of the phenomenon. Creswell (2007) defined the phenomenology in qualitative research as an approach which "describes the meaning for several individuals of their lived experiences of a concept or a phenomenon" (p.57). Considering this definition and the phenomenon of this study as views about STEM activities used in teaching ratio and proportion concepts, a phenomenological design was employed for the study. The views of the students about STEM activities were investigated through their perspectives and lived experiences.

PARTICIPANTS

Participants of the study were eight seventh-grade students enrolled in the Mathematics Applications course in a public middle school. The course was an elective course with the goal of integrating mathematics into everyday life issues through the creation of mathematical models and the development of unique problem-solving strategies (MNE, 2018). Since generalization in statistical concern was not the goal of qualitative research, purposeful sampling was the method of choice (Patton, 2002). Patton (2002) stated that the power of purposive sampling lies in selecting information-rich cases to get in depth information. In this research study, it was important for the authors to investigate students' views about the STEM activities in teaching mathematics. Thus, to get deep insight about the students' views about STEM education, the authors decided to concentrate on the students who experienced learning ratio and proportion concepts with STEM activities in the Mathematics Applications course conducted by the second author. Since maximum variation sampling aims at capturing and describing the central themes that cut across a great deal of participant variation, maximum variation sampling was used (Patton, 2002). Participants were selected among 20 students who took the course according to their different proportional reasoning skills. Before the STEM activities a "Proportional Reasoning Test" was administered to the students who were enrolled in the course. The test aimed to measure students' proportional reasoning skills by analyzing the solution strategies used by students for different types of problems and their ability to distinguish non-proportional relationships from proportional ones. There were eight missing value problems, two numerical comparison problems, four qualitative reasoning problems and three non-proportional problems. The researchers chose and/or adapted some of the problems in the test from the literature (Akkuş-Çıkla & Duatepe-Paksu, 2006; Cramer et al., 1993; Hillen, 2005; Noelting, 1980) and wrote some of them. The test was conducted only to identify the students who participated in the semi-structured interviews. The genders of the participants and the scores they obtained from the "Proportional Reasoning Test" are given in Table 1.

Table 1. Gender and Test Scores of the Participants

Participants	**Gender**	**Test Scores**
S1	Male	34
S2	Female	47
S3	Female	60
S4	Female	57
S5	Male	16
S6	Female	34
S7	Male	20
S8	Female	11

As seen in the Table 1, S1, S3, and S4 were chosen from the highest test scores, S8, S5, and S7 were chosen from the lowest test scores, and S2 and S6 were chosen from the medium test scores.

DATA COLLECTION

Data were collected through semi-structured interviews. In the mathematics classroom where the participants of the study were selected, the subject of ratio and proportion was taught to the students with the help of STEM activities. By this way, students had the chance to experience how the mathematics lesson was taught with STEM activities. After all the STEM activities were completed, semi-structured interviews were held with each participant. For each interview, first, the aim of the interview was explained. Then, the students were asked to answer the questions that were prepared previously. After their explanation, general inquiries were made, such as, "explain", "clarify", or "give details". In other words, although there was an interview protocol, there was also flexibility in the interviews. The questions in the interview protocol were: "What do you think about the STEM activities we use in the lessons?", "What makes STEM activities different for you? Can you explain?", "What do you think these activities contributed to you? Can you explain?" and "Do you want application of STEM activities in teaching other mathematics concepts? What is the reason for this?". Each interview was conducted in a quite area of the school to enable students to express themselves comfortably. To make the data collected from interviews more reliable, short notes were taken and interviews were recorded. The interviews lasted between 20 and 25 minutes.

Following the formation of the interview protocol, it was provided to two field experts for their feedback. Simultaneously, the form was forwarded to a language expert, who verified that the questions contained clear and understandable expressions. With the interview protocol prepared by planning in line with the expert opinions received, first a pilot interview was made with a student who was enrolled in the Mathematics Applications course. The interview protocol was completed in accordance with the feedback from the pilot interview, and the research data collection started. During each application of the STEM activities, the researcher, who applied the activities, took brief field notes. To get a detailed and precise description of the students' views, the interview data were supported by the field notes.

STEM-related activities were planned by considering The Engineering Design Process (Bender, 2017; Massachusetts DoE, 2016). The Engineering Design Process helps to compare scientific and mathematical data in a variety of ways. The engineering design process also involves the stages of defining the problem and solving the problem (NRC, 2010). The first stage in solving the problem is to generate possibilities and choose the most appropriate one. Instead of following the steps presented to them sequentially, engineers must cyclically return to some stages and revise what they have done while solving their difficulties (NRC, 2012). The 5E model was chosen for the lesson plans because it is compatible with the Engineering Design Process phases. The following is the relationship between the MTS process and the 5E Model: problem definition, introduction, development of possible solutions, discovery, determination of the most appropriate solution, explanation, prototype creation, deepening, testing the solution, evaluating, and sharing the evaluation part. When weaknesses in the solution are discovered, the method is changed, and a reversible system is built into the loop. Seven separate STEM activities about ratio and proportion concepts were conducted in a two-hour Mathematics Applications course with a class of 20 students. The activities were finalized with the collaboration of three STEM-trained teachers: a mathematics teacher, a science teacher, and a technology design teacher. Special attention was devoted to bringing the disciplines together when designing the activities. The first activity was about preparing mixtures. First, students used search engines to research how the mixtures we wanted them to prepare were made. Then, they prepared mixtures: Oobleck dough mix, lemonade, and mud. They examined how the ratio of ingredients in the mixtures affected the attributes of the mixtures as the ratio changed. The second activity was about organizing running Olympics using the SCRATCH program. Students were able to see how proportional and disproportionate circumstances might emerge in settings with the same or different speeds by incorporating designs such as items, people, and animals moving at varying speeds or with different step lengths into the software. The third activity was about the clock's mechanism and the wheels that are utilized in it. The students used the wheels to create their own unique designs to learn the proportional relationships between wheels with different tooth counts. In the fourth activity, students created designs employing the advantages and disadvantages of vehicles with varied wheels based on the interaction between thick and thin rolling pins. The fifth activity involved creating mBlock structures, utilizing the Arduino set to determine the interval at which the red, yellow, and green lights should turn on, and adjusting the traffic flow. In the sixth activity, students designed models of their ideal home that were scaled down to a 1/20 ratio. The students understood that they would proportionally increase or decrease the quantities in this way. In the last activity, to assist a stranded fisherman, the students created designs that calculated the time it would take him to reach the beach. The students used wooden sticks at the opposite ends of a basin to measure the distance between the points. One recorded the time while the other threw a stone from the starting location. Students looked at the relationship between the time and distance of the stone's waves. A sample activity lesson plan is presented in Appendix 1 to clarify how STEM activities were organized in the lesson.

DATA ANALYSIS

For the analysis of data, the interviews were transcribed. In data analysis, content analysis method was used to organize and interpret data into meaningful themes or categories (Patton, 2002). Content analysis is a method that needs in-depth data analysis and allows previously unidentified themes and dimensions to be revealed (Yıldırım & Şimşek, 2018). Initially, interview audio recordings were transcribed into written documents. The information gathered from field notes and semi-structured interviews were then read and categorized several times, and themes and codes were obtained. The themes of the study were affective domain, cognitive domain, psychomotor domain, and making relationships. First, the codes under the affective domain theme were enjoyable, interesting, and collaborative. STEM activities, according to students, were enjoyable, fun, fantastic, entertaining, delightful, and enabled students to have a good time in the class. All these statements were coded under the enjoyable code. Moreover, some students stated that the activities were interesting, different, and attractive when they compared with regular mathematics lessons. These statements were coded under the interesting code. An example quotation of this code was "I suppose in the regular lesson I don't want to tackle math problems, but for example, the activity with traffic lights was challenging, but I was curious how to solve it, so I tried to do it." Furthermore, according to some students, in STEM activities there were cooperation, collaboration and interaction. These statements were coded under collaborative code. These statements were grouped together under the theme of the affective domain since they were related to the students' affective gains and emotions. Second, the codes under the cognitive domain theme were active participation, permanent learning, and creative thinking. Some of the students stated that STEM activities allowed to learn by exploring, doing, and experiencing. Additionally, the activities provided active participation, active engagement, permanent learning, better understanding, and creative thinking. Since these statements were related to the cognitive gains of the students, they were gathered under the theme of the cognitive domain. Third, the code under the psychomotor domain theme was hand skills. Some of the students expressed that their hand skills and manual dexterity were used and developed in STEM activities. These statements were grouped under the theme of the psychomotor domain because they were related to the students' psychomotor gains. Finally, the codes under the making relationships theme were interdisciplinary, technology related, and related to everyday life. According to some students, STEM activities were related to other disciplines technology, and everyday life. Therefore, the statements about the relationships of the activities were classified under the theme of making relationships.

Researchers critically questioned themselves and the research process and checked whether the findings and results they obtained reflect the truth (Yıldırım & Şimşek, 2018). It was aimed to compare, check, and confirm the findings obtained using multiple data collection tools (field notes and semi-structured interviews). In addition, some of the data obtained from the research were analyzed by a mathematics teacher as the second coder. The reliability of the data analysis was calculated using Miles and Huberman's (1994) percentage formula "Percent Consensus = [Agreement / (Agreement + Disagreement)] x 100". In the study, the percentage of agreement between the two coders was found to be 93% and it was considered reliable for the study (Miles & Huberman, 1994). Rich and detailed definitions made to increase the level of transferability of research findings to different situations (Merriam, 2015). In addition, the research group and data collection process were explained in detail. In addition, the research findings were expressed in a clear and detailed way, supported by direct statements.

RESEARCH ETHICS

Participants were informed about the purpose of the research and their rights in the research. Afterwards, parental consent forms were obtained from the parents of the students that they participated in the research voluntarily. They were informed that they could freely withdraw from the research without any risk or bias. In order to protect the anonymity and privacy of the participants, middle school students were coded as S1, S2. In addition, during the writing process of the study, ethical and citation rules were followed by the researchers and the collected data were analyzed without making any changes. In addition, within the scope of legislative ethics, approval was obtained for this study from the Human Research Ethics Committee (29/03/2019-547) of the university to which the authors belong.

3 | FINDINGS

According to the analysis of data, views of the middle school students regarding the STEM activities applied in the teaching ratio and proportion concepts were classified under themes and codes. The themes, codes and frequencies are summarized in the Table 2.

Table 2. Student Views Related to STEM Activities

Themes	Codes	Frequency	Students
Affective Domain	Enjoyable	8	S1, S2, S3, S4, S5, S6, S7, S8
	Interesting	4	S1, S4, S5, S8
	Collaborative	3	S1, S7, S8
Cognitive Domain	Active participation	8	S1, S2, S3, S4, S5, S6, S7, S8
	Permanent learning	7	S1, S2, S3, S4, S5, S6, S7
	Creative thinking	4	S4, S5, S7, S8
Psychomotor Domain	Hand skills	3	S1, S6, S7
Making Relationships	Interdisciplinary	5	S1, S2, S3, S4, S6
	Technology related	5	S2, S4, S5, S6, S7
	Related to everyday life	4	S4, S5, S6, S7

As seen in Table 2, students focused on the positive aspects of STEM activities. In a similar way, field notes revealed that the students had positive opinions about STEM activities. The themes obtained from data analysis were students’ views about the affective, cognitive, and psychomotor domains and making relationships in STEM education.

The first theme was students’ views about the affective domain. In the affective domain, students stated that STEM activities were enjoyable, interesting, and collaborative. All the students stated that STEM activities were enjoyable. S1, for example, said, “We put it into practice, and it was more enjoyable.” S2: “It was fantastic because we performed it live, and we had a lot of fun.” S3: “I think everyone participated because it was entertaining, and I think we understood better.” S4: “We learned by seeing, and it was more enjoyable.” S5: “I reinforced the subject; it was a lot of fun.” S6: “It was very entertaining and memorable for me.” S7: “First and foremost, it was delightful and enjoyable.” S8: “Mathematics lesson was fun, but then it became even more enjoyable; everyone had a good time.” Similarly, in class, the students stated that STEM activities were fun because of their own participation and production. While applying STEM activities, it was seen that the structures created using the engineering discipline were especially liked by the students. Moreover, the students appeared to be having a good time as they worked together to tackle the difficulties using their own experiences and concrete models. Some of the students expressed that STEM activities were interesting and attracted their attention. To illustrate S1 said: “I will never forget the activity we prepared Oobleck dough mix because it was so different and interesting to me. We've never done anything like this before.” Correspondingly, S4 stated that STEM activities were interesting, and she explained such as: “I suppose in the regular lesson I don't want to tackle math problems, but for example, the activity with traffic lights was challenging, but I was curious how to solve it, so I tried to do it.” As can be seen in the above quotes students thought that STEM activities were different, interesting, and attractive when they compared with regular mathematics lessons. Some of the students underlined the importance of collaboration in STEM activities. For example, S8 said: “We completed the STEM activities as a group by assisting each other, but we also thought of ourselves individually. I asked my friends for help by asking their ideas.” The student mentioned that there was cooperation and interaction in the group. Students' cooperation and teamwork enhanced because of being in groups during STEM activities. All students in the group were required to come up with their own solutions to problems and share and develop them with the rest of the group. It was observed that the students were in cooperation at every stage, from the point of entrance to the evaluation, while the STEM activities were being carried out.

The second theme was students’ views about the cognitive domain. In the cognitive domain, students stated that STEM activities provided active participation, permanent learning, and creative thinking. Because of their nature, STEM activities allow children to learn by exploring, doing, and experiencing. Since the student is at the center of the STEM activities, active engagement of the student is required. In a similar way, according to all the students, STEM activities aided their active participation in the class. To illustrate, S4 said: “For example, I was solving the ratio and proportion questions in the test book, but now I learned it better with our participation in the activities, and I figured it out”. Students highlighted in-class student participation while applying STEM activities, as can be seen from the quote, and stressed that they grasped the subject better by this way. Similarly, S1 used the following expressions: “I have always had trouble with the wheel questions, but now I realize what we accomplished in the wheel activity, and I do not forget it since I discovered it myself.” The necessity of active engagement in the design process was stressed by the students. Throughout the STEM activities, it was noticed that all students, even those who had difficulties in mathematics, actively participated in all activities, indicating that they learned through comprehension. Most of the students thought that STEM activities provide permanent learning. For instance, S7 expressed as follows: “In the activity concerning waves, for example, we found the relationship between time and distance, it was not given as a rule. While solving problems, the memories we have come to my mind, so I remember more.” Similarly, S1 and S4 used the following expressions, respectively: “I didn't forget the Oobleck activity, when I changed the proportions in the mixture, the softness of the dough changed, we did it and saw it ourselves, I understood it and it was memorable.”, “We used proportion in calculating the waves with the distance, but I could never think of it, I will not forget it anymore.” Students claimed that they learned more permanently because STEM activities were student-centered and required reasoning rather than rote rules and procedures. Despite the fact that not all of the students spoke directly, the students mentioned that the STEM activities helped them learn better and more permanently because they were able to create models by themselves and learn by doing, seeing, and touching rather than memorizing rules. According to half of the students, STEM activities helped them to be more creative. S7, for example, said, "I suppose STEM means that we solve problems without following rules by creating structures using our imagination." Furthermore, S8 remarked: "Designing my own house according to my dreams was my favorite activity, it improved my creativity." As understood from the statements of these students, they stated that STEM activities developed their imagination and creativity. Creative thinking, one of the 21st century skills, is a way of thinking that is expected to be developed in students with STEM activities. In STEM activities, problems with multidisciplinary relationships are expected to be handled through creative thinking. Moreover, the creative thinking students were able to come up with innovative solutions by approaching the problem from various perspectives. It was observed that the students also emphasized this aspect of STEM activities. Similarly, S5 said:

> *"In the traffic light activity, for example, there was not an obvious solution, you had to develop solutions for the problem yourself. It was the same way at the STRACH activity; there was no single solution; everyone came up with their own; it was difficult in this regard, but it was good because it made me think.*"

The third theme was students' views about the psychomotor domain. Some of the students thought that their hand skills were used and developed while performing the applications in STEM activities. To illustrate S6 expressed: "Apart from mathematics, STEM is accomplishing engineering tasks that demand more hand-eye coordination; in fact, mathematical operations are used later. I like to deal with such handicrafts." As can be understood from the statements of the student, she emphasized the importance of hand skills in the designs she produced. Correspondingly S1 said: "I think STEM activities also improve manual dexterity. There were experiments, for example, there were things that we created designs such as engineers, these also require manual dexterity."

The fourth theme was students' views about making relationships in STEM education. In this theme, students argued that STEM activities were interdisciplinary, technology related, and related to everyday life. More than half of the students stated that STEM activities were interdisciplinary. In other words, the students emphasized that STEM education was formed by the relationship of different disciplines. For example, S2 used the following statements:

> *"Actually, we did a lot of activities that were like a combination of three or four lessons, so it was not just about mathematics. For example, in the activities about wheels and waves we used science. Additionally, we brought our computer to school, we tried to produce using materials like in technology design class.*

Similarly, S1 and S4 used the following statements respectively: "We were not simply solving mathematics; it felt like we were performing science as well.", "While doing these activities, it was as if we had studied other lessons, as far as I know, wheels are a science subject, but thanks to these activities, I understood the working principle of wheels." The students underlined the multidisciplinary integration feature of STEM activities. To illustrate S3 said: "The activity in which we designed the house was very good. I realized how hard architects and engineers work. A wrong calculation might affect everything." and S6 stated: "In the mixture activity, we did experiment as in the chemistry class." In fact, students focused on the relationship of STEM activities with science and engineering disciplines. During the STEM activities, most of the students frequently stated that it was not just about mathematics and that they used other courses as well. Although the students did not fully comprehend the STEM approach, it was discovered that they were aware that STEM activities combined several disciplines. More than half of the students mentioned that STEM activities were related to technology. In other words, students emphasized technology, which is one of the STEM disciplines. For example, S5 stated:

> *"We designed games using SCRATCH and mBlock in STEM activities, I knew a little bit about designing games, but I never anticipated that I would use them in mathematics as well. For example, I constructed models of football and basketball games; one was going 3 and the other was going 9. The basketball was able to get into the basket faster."*

Correspondingly, S3 used the following statements: "I did not believe we would be able to solve a math problem using coding, but it was quite understandable to solve the problem about traffic lights by flashing the traffic lights." For some activities, students brought their own computers (e.g., wheels activity, SCRATCH activity) and there was always a computer for use in the classroom. Most of the students stated that they use the computer in the classroom at every opportunity. The coding programs used during the implementation of STEM in-class activities attracted the attention of the students, and they related computer use with STEM education during the interviews. It was seen that half of the students associated STEM activities with everyday life. To illustrate, S6 said: "At the traffic lights activity, I imagined my mother and I were waiting in the traffic, which was blended." Similarly, S8 and S2 used the following statements respectively: "While performing the Wheels activity, I was thinking about the pedals on my bicycle." and "I would like to design my own house as we did in the activity, everything would be as I wanted. I actually thought of designing my own house while performing the activity." According to the students' own words, STEM activities were related with events and objects they encountered in their daily lives. During the STEM activities, it was seen that the students who could make connections with everyday life could perform tasks more easily. As a result, it was considered that relating STEM activities with everyday life might help students learn mathematics more effectively.

As a result, when the students' views about the application of STEM activities were analyzed, it was found that they totally focused on the positive aspects. Similarly, field notes revealed that the students had positive opinions about STEM activities. In addition, all the students stated that they preferred STEM activities to be used in the teaching of other mathematics concepts. Furthermore, it could be said that engineering design processes attracted a lot of attention since product creation was always the basis of codes such as hand skills, active participation, relationship with everyday life, and permanent learning.

4 | Discussion & Conclusion

The purpose of the study was to investigate middle school students' views about STEM activities used in teaching ratio and proportion concepts in a mathematics classroom. According to the findings, the students focused on the positive contributions of the STEM activities on affective, cognitive and psychomotor domains. Students mentioned that STEM activities were enjoyable, interesting, and collaborative. Moreover, they stated that the activities provided active participation, permanent learning, creative thinking, and developed hand skills. This situation might be since STEM activities were aimed at improving students' 21st century skills such as critical thinking, groupwork, collaboration, problem-solving, creativity, and logical reasoning, by using interdisciplinary relations and technology. Furthermore, the fact that STEM activities were different from traditional ways enabled all of the participants to express positive views of STEM activities, as seen by the similar findings gained in the research conducted (Gökbayrak & Karışan, 2017; Gülhan & Şahin, 2018; Özçakır-Sümen & Çalışıcı, 2016; Pekbay, 2017; Keçeci et al., 2017; Yamak et al., 2014).

Students in this study stated that they had a lot of fun conducting STEM activities and that they were very interested in them. As a result, it was noticed that STEM activities contributed to students' interest and motivation. Many studies found that STEM activities enhanced interest and motivation in students, making courses more enjoyable (Ardıç & İşleyen, 2017; Daymaz, 2019; Pekbay, 2017; Şahin et al., 2014; Şahin & Kabasakal, 2018). On the other hand, Bolat (2020) concluded that some students do not find STEM applications enjoyable. Similar results were gathered, and the importance of student readiness was emphasized (Biçer, 2018). In the interview, students claimed that STEM activities encouraged their creativity. They indicated that originality and imagination were the most critical aspects in solving problems during the application. Similarly, studies found that STEM activities required students to create products by integrating their creativity and dreams (Çiftçi, 2018).

When the students' views on STEM activities were examined, it was discovered that they, although indirectly, discussed STEM disciplines. They mostly focused on the Engineering discipline out of all the disciplines. It can be said that engineering design processes attracted a lot of attention, since product creation was always the basis of codes such as hand skills, active participation, relationship with everyday life, and permanent learning. Much research found parallel findings about this issue (Marulcu & Sungur, 2012; Özçakır-Sümen & Çalışıcı, 2016; Pekbay, 2017; Sungur-Gül & Marulcu, 2014; Şahin & Kabasakal, 2018; Yıldırım & Altun 2015). On the contrary, there were studies indicating that there was little interest in the engineering discipline (Karakaya, 2017). In this study, another STEM discipline that the students focused on was determined as technology. The students emphasized the relationship between coding and mathematics by frequently mentioning the use of computers in the lesson. Similarly, there were studies that emphasized the use of technology in STEM education (Karakaya, 2017). However, Delen and Uzun (2018) stated that teachers and prospective teachers had difficulties in using technology in STEM activities.

According to the findings obtained from the study, STEM activities supported students' active participation and cooperation with each other. Due to the nature of STEM activities, student practices and group work were included in the process. The students also expressed that they were satisfied with this situation while expressing their thoughts. Similarly, there were studies emphasizing the importance of cooperation and active participation in STEM activities (Yasak, 2017). Some studies stated that although cooperation and active participation were important, STEM activities were not used efficiently due to problems such as not being able to provide team spirit (Asghar et al., 2012), not communicating well and wanting to emphasize individuality (Bulut, 2019).

In conclusion, the results of the study showed that the students focused on the positive aspects of STEM activities. Therefore, mathematics teachers could be recommended to use STEM activities in their lessons. Even though the STEM approach has recently received a lot of attention, research concentrating on mathematics are few. For this reason, it may be suggested to researchers to conduct studies investigating how STEM activities will affect different variables in mathematics education. Furthermore, by designing STEM activities at various grade levels and in teaching various subjects, researchers might be recommended to perform new investigations.

STATEMENTS OF PUBLICATION ETHICS

The principles of publication ethics were obeyed in the study. Ethical permission of the research was approved by Zonguldak Bülent Ecevit University Human Research Ethics Committee (29/03/2019-547).

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RESEARCHERS' CONTRIBUTION RATE

Researchers' Contribution Rate

Authors	Literature review	Method	Data Collection	Data Analysis	Results	Conclusion	(Ot her)
Author 1	☒	☒	☐	☒	☒	☒	☐
Author 2	☒	☐	☒	☒	☒	☒	☐

CONFLICT OF INTEREST

There is no conflict of interest in the study.

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APPENDIX

Appendix 1. A sample STEM activity lesson plan (Wheels in Our Lives)

The activity was about the clock's mechanism and the wheels that are utilized in it. The students used the wheels to create their own unique designs to learn the proportional relationships between wheels with different tooth counts.

Objectives

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 uses simple machines to make work easier in everyday life.

Technology

- Develops an algorithm for solving a problem.

21st century skills: critical thinking, collaboration, problem-solving, creativity, and logical reasoning

Duration: 40 minutes + 40 minutes

Materials Needed: Gears, toy figures, styrofoam, color cardboard, glue, scissors

Engage

At this phase, the teacher should remind the students of their prior knowledge, draw their attention, and inform them about the aim of the lesson. In this lesson, the teacher tries to attract the attention of the students with the example of a clock. The teacher brings a clock to the class where the students can see the mechanism. The members of the group examine the gear wheels that allow the hour and minute hands to rotate. The teacher tells the students that a boy named Mert is very curious about the workings of time and opens the mechanism by lowering the clock on the wall. The teacher states that Mert noticed that the minute hand is turning faster while the hour hand is turning slower. In addition, Mert saw that when one of these interconnected wheels stops, the other also stops. Then the teacher asks the students the following question: "Then why does one go more laps than the other?"

Explore

During the lesson, the teacher requested the students to investigate the structure of the wheels, where they are used, and what the gears do (all groups have computers). In this process, she also asked them to research what other materials could be made of what the gears did. Moreover, answers to the following questions are sought: "What are the advantages of designs with wheels?", "What are the advantages or disadvantages of rotating gears with a big number of gears and gears with a limited number of gears?", "Can you give some instances of gear-related items?"

Explain

First and foremost, the teacher tells the students to present the information gathered from their investigation. Students share their findings with their friends.

Elaboration

The teacher brings up the topic of proportion at this phase. Following that, engineering integration is provided. As a result of the research, the students obtained information such as: "The gears work in inverse proportion, the number of teeth and the number of rotations is inversely proportional. One revolution with 20 teeth rotates and two turns with 10. Simple machines made with impellers make people less tired..." The teacher asks the students to create designs that will make work easier at this phase utilizing the knowledge they have gathered. Through student examples, draws attention to designs with wheels, such as correction fluid.

Problem statement: You want to design a dancing present box for your friend, and you don't want your friend to get tired spinning this dancer. You'll make the gift with your own hands to make it more personal, and you don't want your friend to get tired spinning this dancer. How do you make a design utilizing the wheel's working system?

Group work: Students develop solutions together with their groupmates regarding the problem situation they have identified. And they write their proposed solutions on worksheets.

Research: Students combine the wheels and choose the gear on which the figure they want to spin will be placed. The important question is: "How to create the ideal gift with a figure that turns more with less work?" Brainstorm with your team to come up with a plan for what needs to be done to solve the problem given above. Then fill in your design and plan in the space given to you. What steps did you follow to find a solution to the problem statement given to you? Explain these. Write down your questions and curiosities about the problem statement. Draw the gift design you want to make.

Construct a prototype

The purpose of this phase is for students to create designs that are suitable for the working principle of the wheels. What students need to know: Gear wheels are basic cylindrical machines that rotate around an axis and have regularly spaced teeth. The teeth make it possible for the wheels to engage with one another. With the help of teeth, the force imparted to one of the gears is communicated to the other. The concept of operation of the gears is like that of a spinning wheel. The concentric gears revolve in the same direction and have the same number of revolutions because they are riveted together. They rotate in opposite directions and the number of rotations is inversely proportional to the radii for gears in contact with each other, each gear related to the previous one. Write on the "Wheels in Our Lives Activity Report Paper", explaining how you did your design step by step with reasons.

Evaluation

Sharing the Solution

The students present how the inverse ratio helps them work more efficiently with the designs they have created. The teacher assesses the students using the rubric that has been prepared. Students can also provide each other feedback.

Finalizing the Design

Students revise and finalize their designs, taking into account the teacher's and other friends' ideas.