Id: 1431975

Participatory Educational Research (PER)
Vol.11(4), pp. 160-183, July 2024
Available online at http://www.perjournal.com
ISSN: 2148-6123
http://dx.doi.org/10.17275/per.24.54.11.4

The Effect of Computer-Supported Stem Applications on Secondary Students' Achievement and Computational Thinking Skills

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Article history
Received:
05.02.2024

Received in revised form:
12.05.2024

Accepted:
05.07.2024

Key words:
academic achievement; computational thinking skills; computer-supported materials; STEM

In this study, the effect of STEM applications integrated with computer-supported materials on mathematics achievement in the subject of ratio-proportion and percentages was examined. In addition, it was aimed to reveal the effect of these applications on computational thinking skills. Furthermore, we aimed to reach the opinions of the experimental group students about the materials they used, STEM applications, and the application process. A mixed method was used with a sample consisting of 89 students in grade 7 of a secondary school. An achievement test, a scale of levels of computational thinking, and learning diaries were used as tools for data collection. The data were analyzed using t-test and content analysis. It was found that there was a significant difference between the experimental and control groups in terms of achievement in favor of the experimental groups. In terms of computational thinking, there was a significant difference in favor of the experimental groups, except for the creativity aspect of computational thinking skills. Based on the findings obtained with the computational thinking skills scale the study had a positive impact on most aspects of computational thinking. Accessed through the learning diaries students' views on learning with STEM applications were generally positive. In particular, the opinions on computer-supported materials pointed to a very satisfactory process. The findings suggest that the inclusion of STEM activities and the use of computer technology in education contribute to students' computational thinking skills and learning.

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Introduction

In the 21st century, the importance of scientific and technological innovations is increasing as we face the benefits and harms of globalization and the knowledge-based economy. In the knowledge-based new economy and high-tech society, students must develop their skills in science, technology, engineering, and mathematics (STEM) and exceed what was considered sufficient in the past. Fifty years ago, being able to read, write, and do simple arithmetic was considered quite sufficient to hold a job and to be both a consumer and a citizen in society. Today's students may have to work with new technologies that were not invented when they were students. Thus, innovative educational approaches are crucial in reaching the universal standards of the 21st century, catching up with world-class scientific and technological developments, and producing a workforce that will contribute to the nation's economy. (Akgündüz et al., 2015, p. 1-12). One of the widely used approaches is STEM education (Çorlu et al., 2014). STEM aims to provide students with critical thinking skills, thus enabling them to enter business life as creative and problem-solving individuals (White, 2014). According to Morrison (2006), STEM education not only enables students to follow and adopt technological developments but also helps them to increase their self-confidence by enabling them to think algorithmically and logically. Olivarez (2012) states that STEM-based learning had a positive impact on eighth-grade students' reading, science, and mathematics achievement. In STEM courses, students use scientific methods, mathematical models, and engineering principles to solve real-world problems. These experiences help students develop problem-solving, research, critical, and creative thinking skills, supporting their success in academic and daily life. Teaching processes carried out with STEM integration are more hands-on and engaging and provide students with the opportunity to use their knowledge to solve real-life problems. Therefore, STEM increases students' motivation to learn and positively affects academic achievement. The results of the International Mathematics and Science Education Survey (PISA) show that in countries where STEM education is more common, students are more successful in mathematics and science. Robelen (2011) states that students will improve their mathematics learning abilities and critical thinking skills due to the use of real-life situations in STEM education and the capability of students to apply mathematical concepts to real-life situations. It is also stated that STEM education improves students' problem-solving, critical, and analytical thinking skills (Brown et al., 2011). STEM and computational thinking are related fields that support each other. STEM education focuses on teaching problem-solving skills such as mathematical modeling, data analysis, and scientific research, while computational thinking focuses on skills such as algorithmic thinking, abstraction, and coding. In this respect, the use of computational thinking skills for data analysis and modeling in scientific research, the use of computer-based modeling tools to create designs in the field of engineering, or the use of computer programs to solve complex problems in the field of mathematics show the strength of this link. Wing (2006), on the other hand, states that one of the skills expected from students today is computational thinking skills. He also states that computational thinking and mathematical thinking are interrelated.

Recently, there has been an increase in STEM-related studies. These studies release that STEM education has a positive effect on variables such as learning (Acar et al., 2018; Ashford, 2016; Becker & Park, 2011; Guzey et al., 2016; Judson, 2014; Han et al., 2015; Han et al., 2016; Olivarez, 2012; Riskowski et al., 2009; Tolliver, 2016; Wade-Shepherd, 2016; Yildirim & Selvi, 2017; Young et al., 2011) motivation, attitudes, self-efficacy, problem-solving and computational thinking skills (Aydın, Saka & Guzey, 2017; Cotabish et al., 2013; Çakır & Ozan, 2018; Elliott et al., 2001; Fortus et al., 2005; Guzey et al., 2016; Karışan & Yurdakul, 2017; Kececi et al., 2017; Kurt & Benzer, 2020; Ozyurt et al., 2018; Özcan & Koca, 2019;

Psycharis & Kotzampasaki, 2019; Weese et al., 2016).

Many research findings have found positive results of STEM activities in educational settings. Çakır and Ozan (2018) state that STEM activities increase secondary school students' mathematics achievement. Prawvichien, Siripun, & and Yuenyong (2018) state that STEM activities improve students' mathematical problem-solving skills. According to Swaid (2015), advanced technologies combined with complex data will continue to emerge. STEM educators should be encouraged to use computational thinking skills in their teaching, as it will not be possible to solve the challenging and complex problems that will arise in the future without using computational thinking skills. Weese, Feldhausen, and Bean (2016) examined the effect of STEM experiences on students' self-efficacy for computational thinking in grades 5-9. As a result of this research, an improvement in students' computational thinking skills was observed. In a study conducted with 5-6th grade students studying in Greek public schools (Psycharis & Kotzampasaki; 2019), the results showed that STEM had a positive effect on students' confidence in using computers and their computational thinking skills. The fields of science, engineering, and mathematics are of great importance for technological development. For this reason, it is believed that mathematics-centered applications that include STEM disciplines in which technology is attempted to be effectively integrated will contribute to the training of needed individuals. It is believed that this study, conducted using new technologies, is crucial in terms of literature and can answer the question of how to incorporate these technologies in educational environments. It is believed that especially the use of 3D printers for the creation of products prepared by students will provide a very effective and new learning environment. 3D printers are used in many fields and education is one of the fields affected by this technology. 3D printers draw attention as a technology that increases students' imagination, offers new learning opportunities, and allows them to transform their designs into concrete objects. Various experiences and educational learning objectives can be achieved by effectively using 3D printer technology, which is used from the primary school level to the undergraduate level, as a material in the education and training environment (Güleryüz et al., 2019). In terms of STEM integration in education, 3D printers can be a powerful tool. Because STEM education aims to develop problem-solving skills by using knowledge and skills in different disciplines. At the point of transforming these goals into practice, 3D printers appear as a technology that increases the effectiveness and efficiency of applications and enables them to be transformed into concrete products. Without doubt, in the background, it directly affects processes such as design, problem-solving, collaboration, and model development by learning mathematical skills and engineering principles. These processes offer a more meaningful learning process by affecting students' problem-solving skills, and critical, creative, and computational thinking skills. Davis (1997) states that the use of technology in mathematics teaching has many benefits in increasing students' self-confidence and success. According to Patel (2010), complex concepts in STEM disciplines are best learned through active participation. It is emphasized that today's students feel better in lessons that include applied activities and active learning with new technologies (Philips & Trainor, 2014). Subsequently, it is believed that STEM applications will contribute to students' learning of mathematics.

Due to the increasing interest in technology and the rapid development of computer systems, the need for manpower with complex skills is increasing and, in this direction, computational thinking skill is considered as an important skill. When we look at this skill as thinking processes that include problem-solving, system design, and formulation of problems and solutions using the basic concepts of computer science (Wing, 2006), 3D printers that can be used to develop products are an important technology that will support computational thinking. computational thinking skills can be developed in teaching that integrates information such as formulating the problem needed for the model to be printed and designing and creating computer output. In addition, the application side of STEM integrations can be enriched with a 3D printer. The use of problem analyses of different disciplines in computer processes by performing computations and transforming them into a common design and product with a 3D printer can create an effective cognitive load on computational thinking.

There are various studies on STEM education, but these studies mostly focus on integrating mathematics-technology or science-technology disciplines. Sometimes engineering integration is also encountered as a third discipline. However, there are few multidisciplinary STEM education studies in which both mathematics and science-oriented technology and engineering disciplines are connected. This deficiency in the literature motivated this study to plan multidisciplinary STEM activities with different natures. It is believed that these activities will stimulate new ideas in researchers and contribute to the literature. In addition, STEM education research is usually introduced to student groups at certain socio-economic levels or to large student groups in countries where it is very widespread. It is a natural consequence that this educational approach is carried out in appropriate environments since it usually requires time, budget, and comprehensive teaching planning. However, this situation carries with it uncertainties about the applicability of the research findings to general education. Inclusive research involving students with different knowledge, skills, and backgrounds in different learning environments is insufficient. For this reason, in this study, it was aimed to expand the study group by conducting the process with students in schools in two different regions and the effects of the activities on students were tried to be revealed.

In this study, STEM activities supported by computer technology were carried out. These activities required students to use their knowledge of mathematical calculations and science. Within the scope of the activity, while students used computer programs to create designs, they used technological tools (digital scales, 2D and 3D printers) to transform the designs into products. In this context, some problem situations associated with real-life were planned. In line with these conditions, STEM applications were carried out to determine the effect of these applications on students' achievement in the subject of ratio-proportion and percentages units in mathematics courses and their computational thinking skills. Secondly, it was aimed to determine students' views on STEM applications and the application process through learning diaries. The following research questions guide the present study:

(1) When the pre-test is taken under control, is there a significant effect of computer-supported STEM applications on the academic achievement of the experimental group students?
(2) Do computer- supported STEM applications have a significant effect on the computational thinking skill levels of the experimental group students?
(3) How are the opinions of the experimental group students about learning with computer-supported STEM applications?

Method

Research Design

A mixed method research approach was used, utilizing quasi-experimental and case study designs. A mixed method approach that combines qualitative and quantitative findings, utilizing the strengths and perspectives of each method (Johnson & Onquegbuzie, 2004). In this study, a triangulation research design was used in line with Creswell's (2017) classification.

The purpose of this design is to combine the results of quantitative and qualitative data analyses. Since the two types of data provide different perspectives, it enables us to define the problem both quantitatively and qualitatively and to look at the problem from different perspectives (Creswell, 2017, p.36-37).

Sample

This study was conducted with experimental and control groups in schools with different physical facilities. Since it was thought that STEM applications carried out in learning environments with different backgrounds and different teaching conditions would provide more valid and reliable research findings, the study group tried to expand. One school is a normal secondary school and the other school is an Imam Hatip secondary school (which includes disciplines such as mathematics, science, and religious education). Both schools had an experimental and a control group. Experimental and control groups in these schools were randomly selected.

The sample of the study consists of 89 students, 40 boys and 49 girls, at the 7th-grade level, studying in two separate secondary schools in the 2018-2019 academic year. Information about the sample is presented in Table 1.

Table 1. Demographic Information of Sample

Groups	**Female**	**Male**	**Total**
Experimental 1	13	10	23
Control 1	14	10	24
Experimental 2	22	0	22
Control 2	0	20	20
Total	49	40	89

A convenience sampling method was used in this study. In this sampling method, the researcher determines the working group he needs by considering the accessible people, and the situations that will provide maximum savings and easy management (Cohen & Manion, 1989; Fraenkel, Wallen & Hyun 2011).

Computer-Supported Materials Development Process

The computer-supported materials used in the study were designed and developed by the researcher. These materials are interactive materials that are used as a design interface in the process of STEM applications, appropriate to the level of the student, and provide feedback according to the procedures performed. These materials were developed using the Wolfram Mathematica program. The developed materials are saved with the ".cdf" extension, which allows the creation of interactive Mathematica documents. The materials were used by viewing them on student computers using the Wolfram CDF Player. This has reduced the workload by making objects easier to use and installing only a file player on student computers instead of software. Three applications were carried out by integrating them into the mathematics classroom. These applications are:

(1) Designing a Turkish Flag by the Turkish Flag regulations
(2) Specific calorie calculations, and preparing a fruit salad according to vitamin contents in class,
(3) Designing a house by making mathematical calculations by some determined dimensions and realizing the thermal insulation of the house created by transforming the designed house into a concrete product using a 3D printer.

Screenshots and contents of computer-supported materials used in STEM applications are presented in Figure 1.

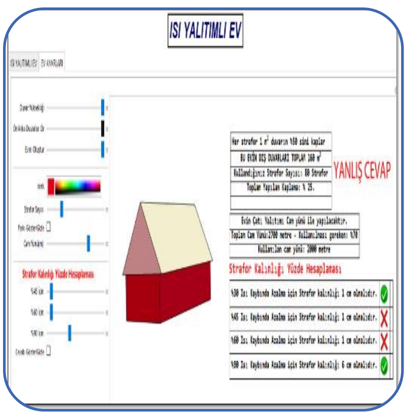
Turkish Flag

- This object consists of two pages. On the first page accessed with the 1st tab, the Turkish Flag standard rates and letters representing the rates are introduced. On the other page, which can be reached with the 2nd tab, there is the application page where the targeted flag can be created.
- In the middle of the application page, the Turkish Flag element is formed, which is sized according to the entered measurement values.
- The rate (width, height, tip, moon, star) values of the flag are located on the left side of the page in a way that can be adjusted by the students.
- Below the Turkish flag on the page, the results of the ratio values determined by the students are displayed, and feedback is provided with a green tick or a red cross on whether these results are appropriate ratios.
- With the Export["ev.jpg", designed flag object] code of the designed flag, two-dimensional output can be taken from the software and printed on a color printer.

Fruit Salad

- This object consists of three pages. The first page accessed through the 1st tab contains information on a balanced diet and the daily calorie needs of a girl and a boy.
- On the second page accessed by the 2nd tab, a girl's; On the third page, which is accessed through the 3rd tab, a boy's calorie calculations are made.
- In this object, there is a slider at the top of the page where the calorie value of that day concluded be adjusted by the student.
- On the lower side, there are areas where gram and calorie values of certain fruits and drinks like milk-ayran can be determined.
- In line with the calorie adjustments, the total calorie value reached is formed at the bottom of the page.
- If the total calorie value exceeds the daily limit, the child in the image gets fat, and feedback is provided in this way.

Heat Insulated House



- This object consists of two pages. On the first page accessed with the 1st tab, there is a guideline for energy saving and sample application. On the second tab, there is the application page.
- On the application page, there are areas where adjustments of the house, its height, styrofoam amount, and thickness can be made. The 3D house element is created in the middle of the page according to these adjustments.
- On the right side of the page, there are percentage calculation fields for the number and thickness of Styrofoam required for house insulation, which will enable to prepare for the main application.
- "CORRECT ANSWER" if the calculations are correct; If it is wrong, feedback is provided as "WRONG ANSWER".
- With the export["home.stl", designed house object] code, the three-dimensional output of the item can be taken from the software and printed on a 3D printer.

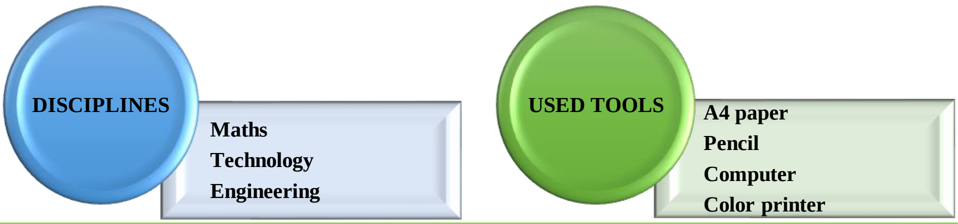
Figure 1. Computer-supported materials

Implementation Process

The knowledge and skills of the discipline of mathematics, which is at the center of the study, were explained by the same course teachers in both the experimental and control groups theoretically. In addition, prior to the STEM application, students were asked to look for information about the science course outcomes that they might need. Thus, they were prepared to come to class by filling out the first part of the learning diaries used as a data collection tool. In this way, it is aimed that students use the knowledge they have acquired while solving the problem situations presented in STEM applications correctly and creatively. In addition, it was ensured that awareness of the application was created and that they remembered the scientific achievements they had previously learned. Afterward, STEM applications were carried out at two-week intervals through the developed materials. After each application was completed, the students were asked to fill in the second part of the learning diaries of the application. In this way, students' thoughts on materials, learning with STEM applications, technological tools used in the applications, and the application process were determined.

Before the main application, a pilot application was carried out to make preliminary observations on both the materials and the student's characteristics. Necessary measures have been taken for the detected situations and problems. The main application was carried out in the same way in both experimental groups. Applications based on mathematical calculations, which produced concrete products by using technological tools, were carried out for six weeks, two weeks for each application, with the students who realized the theoretical learning about the course. These applications were carried out in the following order, respectively.

Turkish Flag Application



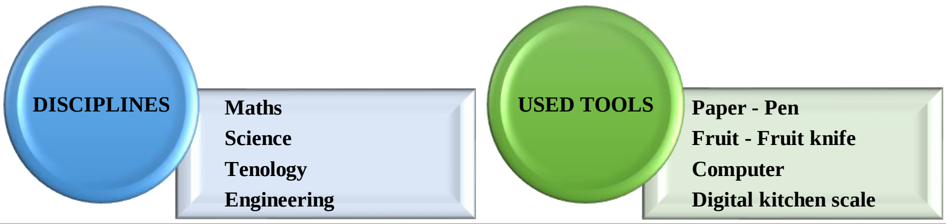
1. First of all, a few different measures were presented to get used to the material and to prepare for the main application, and the students were provided with sample applications.
2. This application was carried out in groups. Groups consist of two students each.
3. After the practice, the main application was started and the students were asked to design the Turkish Flag, which is known to be 20 cm wide, using the relevant learning object (The reason for this size is that it can be printed on A4 paper in the classroom environment).
4. The extension of the designed flags on the computer interface was carried out in the company of the researcher. This process was done by using the code "Export["flag.jpg", designed flag] in Mathematica software.
5. The obtained flag printouts were saved on the desktop of the student computers..
6. The flag of each group was printed using a color printer.
7. The groups whose flags were printed in the appropriate size were approved, and the flags of the groups that did not fit on the A4 paper or were smaller on the A4 paper were evaluated together with the students.

The STEM disciplines tried to be integrated in this application and the targeted outcomes are as in Table 2.

Table 2. Learning Objectives and Disciplines of Turkish Flag Application

Mathematics	**Technology**	**Engineering**
Makes the calculations of the measurements of the ratios given.	Organizes his/her working group and environment to support the learning process.	Design products using standard ratios in all calculations and measurements.
Discover that mathematical calculations are used in the production of objects.	Manages the design process consciously to create products or solve real-life problems.	Apply design processes as a team member, and take on different roles within the team.
Recognizes the importance of mathematics in daily life.	Thinks about the effects of the use of technology on the past, present, and future. Recognises and uses technological tools.	Prepares the prototype of the product.
Task to be Performed in Application		
Design the flag, which is known to be 20 cm wide, following the Turkish Flag standards, and create a two-dimensional extension to print it on a color printer.		

Fruit Salad Application



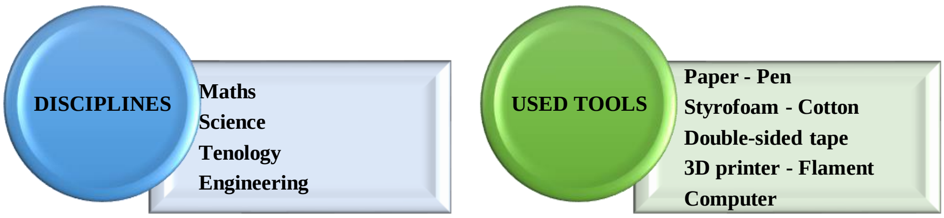
1. First of all, students were asked to make sample applications by presenting several different calorie values on some fruits.
2. In this application, groups consist of three students each.
3. After the exercises, the main application was started and fruits (apple, orange, kiwi, banana) were distributed to each group. Each group was asked to prepare a fruit salad that would not exceed the daily calorie limit according to the instructions presented to them by using the fruits in their hands in the appropriate amount.
4. The students determined the grams of fruits using a digital kitchen scale.
5. In this application, students were allowed to use the fruit knife with their teacher or researcher.
6. It was requested to use more fruits containing vitamin C in the fruit salad to be prepared.
7. The students were asked to note the steps they followed while preparing the fruit salad, which fruit they used, how much and why.

The STEM disciplines tried to be integrated in this application and the targeted outcomes are as in Table 3.

Table 3. Discipline and Learning Objectives for Fruit Salad Application

Mathematics	**Science**	**Technology**	**Engineering**
Establishes ratio-proportion using the given information.	Explains his/her thoughts on nutrition and research results.	Recognizes technological tools and shows the ability to use them.	Uses appropriate ratios and units in all calculations and measurements.
Makes percentage calculations.	Explains the properties of vitamins.	Develops ideas on these problems by exploring real-life problems.	Evaluates the benefits and risks of a design.
			Recognizes and makes calculations related to nutrient analysis and calorie values.
Task to be Performed in Application			
You know that you have taken in 900 calories today. Imagine that you want to eat a fruit salad as your last meal in the evening. Keep in mind that the season is winter and you need to take vitamin C. Using a kitchen scale, determine the grams of fruit you have. Prepare a fruit salad using appropriate amounts of fruit so as not to exceed your daily calorie needs.			

Home Insulation Application



1. Students were provided with different styrofoam numbers and thickness information independent of the main application, and they were provided to make sample applications in the material interface.
2. In this application, groups consist of three students each.
3. In the main application, they were asked to design a house where thermal insulation could be made with 12 pieces of styrofoam.
4. The students designed a house where they could make the targeted insulation in the computer interface, and the 3D extensions of the houses designed with the researcher were taken.
5. The resulting extensions were turned into concrete objects using a 3D printer.
6. Since the process of printing products from 3D printers is a very time-consuming process, a small sample was used in the classroom. The outputs of the houses created by the students were printed by the researcher in the following days, independently of the classroom.
7. Objects belonging to each group were distributed to the groups in the last week.
8. The styrofoam to be used was presented to the students by the researcher in equal sizes and ready to use.
9. The students actualized their house insulation by sticking double-sided tape to the styrofoam.
10. The necessary amount of cotton was given to the students to make the roof insulation of the houses.
11. The groups that could not provide proper insulation with the styrofoam offered in certain standards and numbers came to the conclusion that they made the wrong ratio and percentage calculations of the house they formed, and the applications of all groups were evaluated in the presence of the researcher and the course teacher.

The STEM disciplines tried to be integrated in this application and the targeted outcomes are as in Table 4.

Table 4. Discipline and Learning Objectives for Thermal Insulation Application

Mathematics	Science	Technology	Engineering
Establishes ratio, and proportion using the information presented.	Explain their thoughts and research results.	Demonstrates the ability to solve problem situations using new technologies.	Creates a representative structure using objects and models.
Makes percentage calculations.	Explores their learning about thermal insulation by experimenting.	Understands some concepts in technological processes.	Explains the basic processes needed for a project.
		Apply design steps related to physical system problems.	Uses various technologies to design and create products.
			Uses appropriate ratios and units in all calculations and measurements.
Task to be Performed in Application			
Each of the styrofoam in your hand covers 50% of the 10 cm2 wall. You are presented with 12 styrofoam. Using all of these styrofoams, design a house where you can make thermal insulation and create your house with a three-dimensional printer with your teacher by taking the three-dimensional extension.			

Data Collection Tools

In the study, achievement tests, a computational thinking skills level scale, and learning diaries were used. The data collection tools used in the study within the framework of the research questions are presented in Table 5.

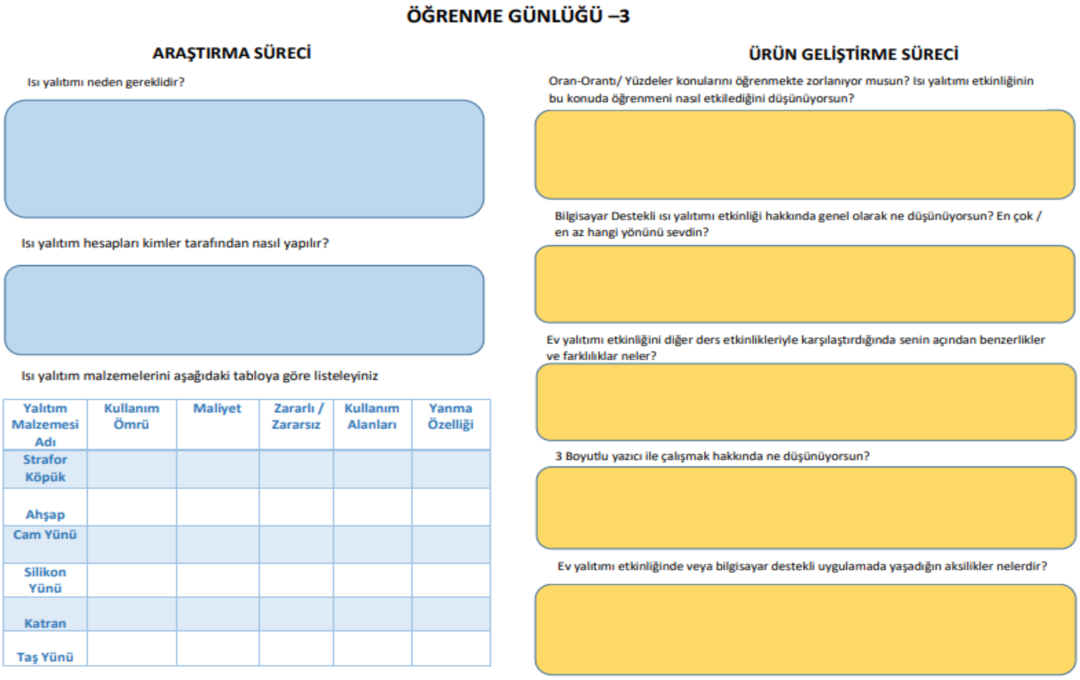
Table 5. Data Collection Tools Used According to Research Questions

Research Questions	Data Collection Tools	Test/Scale/Form	Source
1	Academic Achievement Test	Multiple Choice Test	Created by researcher
2	Computational Thinking Skill Levels Scale	5-point Likert Type Scale	Developed by Korkmaz, Çakır and Özden (2015)
3	Learning Diaries	Written Opinion Form	Developed by researcher

An achievement test consisting of 15 questions on topics of ratio proportion and percentages was created. The achievement test was used as a pre-test and post-test in the study. The questions in the achievement test were selected from the questions prepared by the mathematics teachers. With the help of a field expert, important learning objectives in the subject of ratio-proportion and percentages were determined and questions were included to measure these learning objectives. In terms of the reliability of the test, the Cronbach Alpha value was calculated to determine the internal consistency. Cronbach Alpha value was calculated as .81 for this study. Item difficulty and discrimination indices of the items in the achievement test were calculated and it was determined that the items were at the level of 'typical good item' and 'difficult but discriminating item'. To ensure the language and face validity of the test, the opinion of a Turkish field expert was consulted.

To measure the computational thinking skills of the students, the Computational Thinking Skill Levels scale developed by Korkmaz, Çakır, and Özden (2015) was used. The five-point Likert-type scale consists of 22 items and consists of creativity, algorithmic thinking, collaboration, critical thinking, and problem-solving dimensions. Before the data were collected with the scale, a pilot application was carried out in a secondary school that was not included in the sample. At the end of this application, it was observed that some students did not understand the meaning of the word ‘systematic’ in an item in the critical thinking dimension of the scale. Accordingly, the word ‘planned’ was used instead of ‘systematic’ in line with the opinions of Turkish language field experts. To determine the applicability of the scale in the groups in this study, Cronbach's Alpha reliability coefficient was calculated. The Cronbach's Alpha coefficient was calculated as .71 for the whole scale, .80 for the creativity dimension, .81 for the algorithmic thinking dimension, .73 for the collaboration dimension, .79 for the critical thinking dimension, and .71 for the problem-solving dimension.

To determine the students' thoughts on the application process, computer-supported materials, and used technological tools, individual written opinion documents called "Learning Diary" were created by the researcher. These documents can be defined as documents conveying students' studies, experiences, and beliefs (Biklen & Boğdan, 2007, p.133). Learning diaries created by the researcher in cooperation with Turkish, science, and mathematics field experts are forms consisting of two parts, which include both preparation stages for applications and areas where opinions can be expressed about the application process, materials used, and technological tools. These forms were prepared separately for each application as three pieces. The forms were distributed to the students 1 week before each application and collected 1 week after the application was made. They were asked to fill in the first part of the learning diary in the first week (before the application) and the second part in the second week (after the application). An example of one of these diary pages is shown in figure 3. The page was developed with a two-step design. The blue-coloured parts are the parts filled in before the application to reflect the process based on the theoretical knowledge to be filled in the first week of each application. For example, this section in the thermal insulation application was created with a science expert and the students were followed by this expert during the usage process. In the yellow-coloured sections, students were asked to express their opinions on the subject of ratio-proportion and percentages. In the other text boxes, there are areas where students can express their opinions about the computer-supported materials used, the planned STEM applications and the implementation process.


ÖĞRENME GÜNLÜĞÜ –3

ARAŞTIRMA SÜRECİ

Isı yalıtımı neden gereklidir?

Isı yalıtım hesapları kimler tarafından nasıl yapılır?

Isı yalıtım malzemelerini aşağıdaki tabloya göre listeleyiniz

Yalıtım Malzemesi Adı	Kullanım Ömrü	Maliyet	Zararlı / Zararsız	Kullanım Alanları	Yanma Özelliği
Strafor Köpük					
Ahşap					
Cam Yünü					
Silikon Yünü					
Katran					
Taş Yünü					

ÜRÜN GELİŞTİRME SÜRECİ

Oran-Orantı/ Yüzdeler konularını öğrenmekte zorlanıyor musun? Isı yalıtımı etkinliğinin bu konuda öğrenmeni nasıl etkilediğini düşünüyorsun?

Bilgisayar Destekli ısı yalıtımı etkinliği hakkında genel olarak ne düşünüyorsun? En çok / en az hangi yönünü sevdin?

Ev yalıtımı etkinliğini diğer ders etkinlikleriyle karşılaştırdığında senin açından benzerlikler ve farklılıklar neler?

3 Boyutlu yazıcı ile çalışmak hakkında ne düşünüyorsun?

Ev yalıtımı etkinliğinde veya bilgisayar destekli uygulamada yaşadığın aksilikler nelerdir?

Figure 2. Learning diary sample page

Data Analysis

The data collected within the scope of the study were analyzed using quantitative and qualitative analysis methods. The data analysis methods used in line with the research questions are presented in Figure 2.

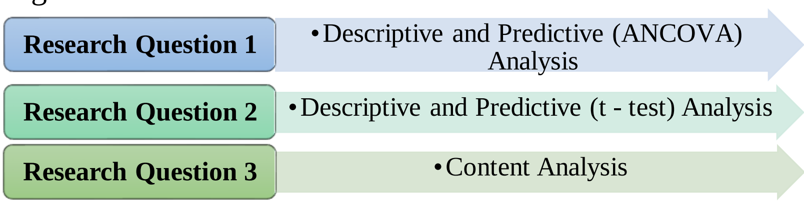


Figure 3. Data analysis methods in line with research questions

The quantitative data was transferred to the SPSS 22.0 program. The normality analyses of the data obtained for each variable were examined. Qualitative data obtained through learning diaries were analyzed with the help of field experts and analyzed using the content analysis method. Qualitative data were coded by the researcher and grouped into three categories and quotations from student opinions were presented.

Results

The Effect of Computer-Supported STEM Applications on Student Success

Descriptive data and covariance analysis results of student achievement in experimental and control groups by school are presented.

Descriptive Data of Students' Achievement Status by Schools

The descriptive data obtained are presented in Table 6.

Table 6. Descriptive Data of Mathematics Achievement Scores of Groups by Schools

Groups	**School 1**			**School 2**		
	n	$\bar{x}$	ss	n	$\bar{x}$	ss
Experimental Group	23	11.78	1.93	22	11.14	1.70
Control Group	24	9.5	2.10	20	10.15	1.53

When Table 6 is examined, it was revealed that the achievement scores of the experimental group students in School 1 ($\bar{X}$ = 11.78, SD = 1.93) were higher than the achievement scores of the students in the control group ($\bar{X}$ = 9.5, SD = 2.10).

Also in School 2, it was observed that the achievement scores of the students in the experimental group ($\bar{X}$ = 11.14, SD = 1.70) were higher than the achievement scores of the students in the control group ($\bar{X}$ = 10.15, SD = 1.53).

Achievement Status of Students by Schools Ancova Test Findings

In the study, covariance analysis was performed to compare the success of the students in the experimental and control groups. The findings for the groups in School 1 are presented in Table 7.

Table 7. Covariance Analysis Results of the Differences in Mathematics Achievement Scores of the Groups in School 1

Source of variance	Sum of squares	Sd	Mean of squares	*F*	*p*	η 2
Pre-test	80.775	1	80.775	34.46	.000	.439
Group	68.022	1	68.022	29.019	.000	.397
Error	103.138	44	2.344			
Total	5543.00	47				

When the results of covariance analysis in Table 7 are examined, the achievement scores of the groups (F (1-44) = 29.019; p<.05) show a significant difference in favor of the experimental group. Accordingly, it was found that the achievement scores of the students in the experimental group ($\bar{X}$ = 11.78, SD = 1.93) were statistically significantly higher than the achievement scores of the students in the control group ($\bar{X}$ = 9.5, SD = 2.10). The results of the covariance analysis of the data obtained for the groups in School 2 are presented in Table 8.

Table 8. Covariance Analysis Results of the Differences in Mathematics Achievement Scores of the Groups in School 2

Source of variance	Sum of squares	Sd	Mean of squares	*F*	*p*	η 2
Pre-test	52.055	1	52.055	38.242	.000	.495
Group	14.509	1	14.509	10.659	.002	.215
Error	53.086	39	1.361			
Total	4894.000	42				

When the results of the covariance analysis in Table 8 are examined, the achievement scores of the groups in School 2 (*F* (1-39) = 10.659; p<.05) show a significant difference in favor of the experimental group. Accordingly, it was found that the achievement scores of the students in the experimental group ($\bar{X}$ =11.14, SD=1.70) were statistically significantly higher than the achievement scores of the students in the control group ($\bar{X}$ = 10.15, SD = 1.53).

The Effect of Computer-Supported STEM Applications on Students' Computational Thinking

The descriptive data of the CTSL of the experimental and control groups in School 1 and School 2 and the independent groups t-test findings are presented in Table 9.

Table 9. T-test Findings on the CTSL Scale of School 1 and School 2

	Groups	**School 1**						**School 2**					
		n	x̄	ss	t	df	p	n	x̄	ss	t	df	p
Creativity Dimension	Experimental	23	15.7	2.62	2.32	45	.025	22	15.5	3.19	1.58	40	.121
	Control	24	13.8	3.08				20	13.8	3.94			
Algorithmic Thinking Dimension	Experimental	23	15.7	3.11	2.46	45	.018	22	16.2	2.00	2.61	40	.013
	Control	24	12.6	4.14				20	14.3	2.75			
Collaboration Dimension	Experimental	23	15.5	2.50	2.09	45	.042	22	16.4	2.68	2.46	40	.018
	Control	24	14.1	2.21				20	14.3	2.87			
Critical Thinking Dimension	Experimental	23	14.5	4.19	2.07	45	.044	22	15.6	2.95	2.53	40	.015
	Control	24	12.2	3.44				20	13.2	3.29			
Problem-Solving Dimension	Experimental	23	18.2	5.97	2.31	45	.025	22	18.5	5.55	2.23	40	.031
	Control	24	14.5	4.86				20	14.8	5.30			

When the t-test findings in Table 9 are examined, it was revealed that the scores of the students in the experimental group ($\bar{X}$ =15.7, SD=2.62) in the creativity dimension at School 1 were statistically significantly higher than the achievement scores of the students in the control group ($\bar{X}$ = 13.8, SD=3.08). (t(45)=2.32, p<.05). In School 2, it was observed that the creativity scores were higher in favor of the experimental group, but the scores of the students in the experimental group ($\bar{X}$ = 15.5, SD = 3.19) did not have a statistically significant difference from the scores of the students in the control group ($\bar{X}$ = 13.8, SD = 3.94) (t(40))=1.58, p>.05).

In the algorithmic thinking dimension, the achievement scores of the students in the experimental group ($\bar{X}$ = 15.7, SD=3.11; $\bar{X}$ = 16.2, SD=2.0) in School 1 and School 2, respectively, compared to the achievement scores of the students in the control group ($\bar{X}$ = 12.6, SD=4.14; $\bar{X}$ = 14.3, SD=2.75).) was statistically significantly higher (t(45)=2.46, p<.05; t(40)=2.61, p<.05).In the collaboration dimension, the achievement scores of the students in the experimental group ($\bar{X}$ = 15.5, SD=2.50; $\bar{X}$ = 16.4, SD=2.68) were statistically significantly higher than the achievement scores of the students in the control group ($\bar{X}$ = 14.1, SD=2.21; $\bar{X}$ = 14.3, SD=2.87). (t(45)=2.09, p<.05; t(40)=2.46, p<.05).In the critical thinking dimension, the achievement scores of the students in the experimental group ($\bar{X}$ = 14.5, SD=4.19; $\bar{X}$ = 15.6, SD=2.95) were statistically significantly higher than the achievement scores of the students in the control group ($\bar{X}$ = 12.2, SD=3.44; $\bar{X}$ = 13.2, SD=3.29) (t(45)=2.07, p<.05; t(40)=2.53, p<.05).

In the problem-solving dimension, the achievement scores of the students in the experimental group ($\bar{X}$ = 18.2, SD=5.97; $\bar{X}$ = 18.5, SD=5.55) were statistically significantly higher than the achievement scores of the students in the control group ($\bar{X}$ = 14.5, SD=4.86; $\bar{X}$ = 14.8, SD=5.30) (t(45)=2.31, p<.05; t(40)=2.23, p<.05).

Qualitative Findings Through Learning Diaries

Findings reached in line with the student statements in the learning diaries; have been grouped under the categories of "effects of STEM applications on learning", "opinions about computer-supported materials" and "negatives experienced in the application process". While quoting student opinions, students were coded as “S1, S2 ... S45”. The codes and frequency values reached for the category of "Effect of STEM Applications on Learning" are presented in Table 10.

Table 10. Findings on the Effect of STEM Applications on Learning

Code	***f***
Making learning easier	16
Making learning fun	36
Providing concretization	29
Reinforcing what has been learned	11
Providing active learning	20
Providing meaningful learning	30
Increasing the desire to learn	38
Speeding up the learning process	14
Reflecting learnings to real life	22

In the interviews, students generally stated that they provided faster, easier, and fun learning in the learning process carried out with STEM applications. Some quotes from students' views on the effect of computer-supported STEM applications on learning are as follows:

“While learning these subjects, doing activities like this teaches very well, I think the lessons are very entertaining. Scale, using a computer, etc. is different, it's very fun” (S23).

“My math is not very good, but now I think the subject of proportion is easy. I'm starting to like math classes” (S9).

“Using the scales was a lot of fun. My group mate weighed some fruits and I weighed other fruits. Then we prepared a salad by calculating the grams together. It was so easy and we had fun” (S24).

“We knew that kiwi and orange had vitamin C the most, but since I am allergic to kiwi, we agreed with my friend, we used all of the oranges in our salad, we did not put kiwi in our plate.” (S37).

“Since I come from Syria, I am having a hard time. These lessons were great. I could do math better. I'm learning faster” (S21).

“The code and frequency values obtained for the "Opinions on Computer-Supported Materials" category are presented in Table 11.

Table 11. Findings of Opinions Regarding Materials

Code	***f***
Easy to use	27
Increasing motivation	33
Offers the opportunity to design/create a product	41
Ensuring effective use of technologies	28
Active participation	39
Creating a fun learning environment	41
Task sharing/social interaction	25

In the interviews, the students stated that computer-supported STEM applications were easy to use that they found the feedback especially remarkable, and that this feedback was fun, guiding, and provided easy learning. Some excerpts from students' opinions on the materials used in the application are as follows:

“While making the flag, my friend did the calculations on paper, so I set it up on the computer. We recalculated when the cross sign appeared, and when all was correct, we took it with our teacher and sent it to the printer. Our flag was up. We pasted it on our table and when we told it to our other teachers, they liked it very much.” (S4).

“It was very enjoyable, I think the examples, and things we did on the computer taught me very well. We had a hard time building a little house. Our group friend made the calculations and told us, what we learned. Then we set them on the computer. We insulated our house with styrofoam the next week, it was enough for the whole house.” (S16).

“First, I solved the things you said on paper, and my groupmate solved it himself. Then we set them together on the computer, I think it was more fun to do it that way. According to the numbers we calculated, the child was gaining weight and getting weaker on the computer, and we understood very well that we were on the right track. I liked them a lot” (S24).

“I think 3D printing is a lot of fun. There is a normal printer in our house, but there is not the other one. I saw it for the first time. It took a long time to build, but I was very surprised when he created the houses, we calculated on it, and we were never bored in the lesson, I could never have imagined that the house would turn out like that. We created it on the computer immediately, and we made thermal insulation, I didn't have any difficulties, it was a lot of fun” (S17).

“The code and frequency values obtained for the “Negatives Experienced During the Implementation Process” category are presented in Table 12.

Table 12. Findings Regarding the Negativities Experienced During the Implementation Process

Code	*f*
Computer-related technical problems	3
Difficulty in creating 3D extensions	10
Disagreement with groupmate	12
Unable to work in computer interface	8

Some of the students stated in the interviews that they had difficulty using computers, especially when creating 3D extensions, and that these situations affected their learning processes. They also stated that they had disagreements with their groupmates in stages such as making mathematical operations and creating products on the computer screen. Some excerpts from the students' views on the negativities experienced during the implementation process are as follows:

> *"In the first days, we were lagging, I could not follow our teacher. I couldn't write while setting numbers. Then our teacher fixed it, and I didn't have any problems for the next weeks." (S26).*

> *"We needed to make an extension to get the things we made from the printers. The teacher wrote the extension text on his board, but we always did it with the teacher because we were afraid of making mistakes. Other things were easier, we had a little difficulty with it." (S33).*

> *"I was offended because my other friends always wanted to use the computer. I'm bored when they always have the computer" (S10).*

> *"Our computer shut down several times, we had to do it again" (S5).*

> *"I calculated our homework very easily with paper and pencil. I'm good at math anyway. But I'm having trouble using the computer. I couldn't set the numbers, but we did it with my groupmate to create the house with the flag. That was harder for me." (S27).*

Discussion

Studies investigating the effect of STEM education on mathematics achievement (Ashford, 2016; Çakır & Ozan, 2018; Han et al. 2016; Olivarez, 2012; Young et al. 2011), it was stated that STEM education has positive effects on student achievement in parallel with this study, whereas, in some studies (Bicer & Copraro, 2019; Stotts, 2019; Tolliver, 2016), it was reported that STEM education has not a significant effect on success. In the STEM education reports prepared by SRI International (2010) and Young et al. (2011), it is stated that STEM schools have shown promise in terms of academic achievement after 2006. These reports show that the achievement of students in STEM schools in mathematics and science between 2006 and 2009 was statistically significantly higher than that of students in other schools. However, Macun (2019), working on common topics with this study, examined the effect of problem-based STEM activities on the mathematics achievement of 7th-grade students in ratio-proportion and percentages topics and found that STEM activities had a positive impact in favor of the experimental group students. Similarly, McCaslin (2015) examined the effects of STEM-based instruction on students' achievement in subjects such as analysis, geometry, and algebra in a study with fourth-grade students. He found that STEM-based learning had a positive effect on students' achievement. The effect of STEM education on academic achievement may vary depending on how the process is planned and how it is presented to the student. In this study, it is thought that the use of technologies such as computers, two- and three-dimensional printers, and scales in the study are also effective in learning. In addition to the benefits of the use of technological tools in the learning process, such as facilitating learning, shortening the learning period, increasing the quality of learning, and reducing the cost (Daşdemir et al. 2012), these technologies create an active learning environment for students and when students move from passive receiver to active learners, they learn better and have the opportunity to develop their versatile thinking skills (Bransford et al. 2000; Jonassen, 1999). In this study, the positive effect of the learning process supported by STEM applications on the academic success of students can be associated with some technological tools and computer technology factors used in the application process.

When the data obtained with the computational thinking levels scale were examined, it was determined that STEM applications had a significant effect in favor of the experimental groups in the dimensions of algorithmic, critical thinking, collaboration, and problem-solving skills in both schools. In the creativity dimension, it was found that there was a statistically significant effect in favor of the experimental group in School 1, while in School 2, although the creativity scores of the experimental group were higher than the average of the creativity scores of the control group, this difference was not statistically significant. When this situation was examined in the context of the practices carried out, it could not be directly linked to any factor, and it was decided to evaluate the studies carried out on the creativity variable in line with the literature. In the studies conducted in this direction, it is seen that the creativity variable is examined in the context of the gender factor quite frequently (Matud et al. 2007; Özben & Argun, 2005). Considering the characteristics of the study group in School 2, it was thought that the fact that the experimental group consisted entirely of girls and the control group was completely male students, that is, the gender factor was thought to be a factor, and although it was not included in the research questions, this finding was evaluated within the framework of the gender factor. When the literature is examined in this direction, it cannot be said that there is a consistency between the results of the studies examining the gender variable and the creativity variable. However, some studies on this subject (Boling & Boling, 1993; Ruth & Birren, 1985) support this idea. In another study by Lau and Li (1996) in China with 633 students at the 5th grade level, it was seen that the creativity level of male students was higher than that of female students. It is thought that the difference observed in the findings in the creativity dimension in this study may be related to the gender variable.

In the study, the results obtained in all dimensions in both schools, except for the creativity dimension in School 2, show that STEM applications have a positive effect on computational thinking skills. For this reason, it would be appropriate to discuss the results of computational thinking skills within the framework of computational thinking and the STEM approach. Weese, Feldhausen, and Bean (2016), who investigated the effect of STEM education on computational thinking skills, stated in the study they conducted with 5th to 9th-grade students those students who had STEM experiences improved in their self-efficacy towards computational thinking. Again, Psycharis and Kotzampasaki (2019) found that the use of educational games and technological tools supported by STEM had a positive effect on students' self-confidence in using computers and their computational thinking skills. However, Çimentepe (2019), in the study that included STEM activities at the 6th-grade level, found that the experimental group's average score was higher than the control group's mean score, but this difference was not statistically significant when the post-test findings of the experimental and control groups' computational thinking skills were examined.

In this study, it is believed that the use of computer technologies creates a learning environment suitable for the development of computational thinking skills, which includes sub-dimensions such as algorithmic, critical, and creative thinking. In the study, some information was presented to the students and activities where they could find the opportunity to analyze this information, produce solutions to problems, create virtual designs, and develop products. The students had the opportunity to use many technological tools in all of the applications. Thanks to the computer- supported interactive materials provided by these tools, students experienced transforming their mathematical calculations into designs. Then, they went through processes based on computational thinking to transform these designs into products. Thus, they reached their calculations and designs as objects. It is thought that the STEM applications that they completed by taking two- and three-dimensional printouts supported them in this direction. STEM education enables students to understand the basic principles of technology and to think logically, thereby increasing their self-confidence (Morrison, 2006). In this study, it was tried to enable students to apply skills such as technology-oriented algorithmic thinking, and it is thought that the solution strategies they developed in these ways encouraged them to question, critical and creative thinking. It can be interpreted that the implementation of STEM applications in the study based on some developing technologies and computer-supported learning environment parallels these views in the literature and enables the applications to be effective in computational thinking skills.

Conclusion

As a result of this study, it is believed that mathematics lessons supported by STEM applications contribute to easier and more effective learning. It is estimated that perceiving the applications as entertaining and remarkable increases the motivation to learn and has a positive effect on success by providing motivation. It is assumed that the inclusion of computer-supported learning objects and technological tools in the applications will increase the interaction and participation in the lesson and allow students to focus more on the problem situations presented. Students generally stated that sharing tasks made them more enjoyable and easier to complete. This shows that including the cooperative learning method at the secondary school level can be effective in success. It was determined that the students evaluated situations such as thermal insulation and calorie calculation by interpreting them in line with their experiences. It is thought that basing the problem situations presented in STEM applications on real life by their levels provides more meaningful learning by establishing a connection between what students learn in the lesson and their experiences. The qualitative findings showed that some hardware deficiencies, unfamiliarity with creating three-dimensional extensions, and disagreement with a group mate posed limitations, especially in terms of effective participation.

Limitations

(1) The study is limited to three computer-supported materials and the duration of use of these materials for 4 hours each.
(2) A 3D printer was used in one of the STEM applications. Printing through a 3D printer is a time-consuming activity. For this reason, the use of one 3D printer in the study was one of the limiting factors.
(3) Although the developed STEM applications include the unit outcomes and support learning, the course teacher frequently expressed his/her concern about completing the unit. This situation was limiting in some applications.

Recommendations

Recommendations for Future Studies

(1) The positive findings regarding the achievement variable will contribute to the field of mathematics and carry out similar STEM studies within the scope of different units centered on the discipline of mathematics.

(2) This study was carried out in a limited time within the framework of ratio-proportion and percentages topics. Longer, longitudinal studies can be conducted.

Recommendations for Practitioners

(1) Researchers can choose to use Wolfram Mathematica software, which allows them to connect with printers and integrate Science-Engineering-Design calculations with mathematics, both in STEM and other studies.
(2) The technical requirements regarding the computers and printers used may cause unexpected disruptions and loss of time during the application. For this reason, it is important to take the necessary precautions in advance regarding technical problems that may occur in the classroom environment.
(3) In studies conducted with such software and technological tools, it is recommended to provide intensive guidance to prevent the negative effects of students' self-efficacy and anxiety towards these tools.
(4) To provide effective guidance to students in the classroom environment, it is recommended that more than one researcher follow the process during the application.

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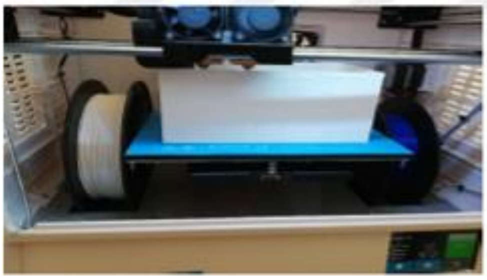
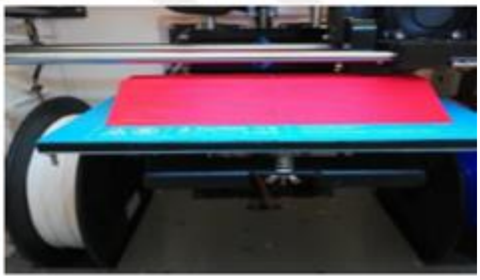
Appendices

A selection of photographs from the implementation





Materials Used in the Control Group