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Original Article

# The Effects of STEM Education Activities on Fourth Grade Students' Attitudes to Stem, 21st-Century Skills and Mathematics Success *

Mehmet Akif Bircan [1], Hamza Çalışıcı [2]

## Abstract

In the study, the effects of STEM activities applied to primary school fourth grade students on students' attitudes towards STEM, 21st century skills and mathematics achievement were analyzed. Sequential exploratory design was used in the research, which was carried out as a mixed method. In the quantitative part of the research, time series design, one of the semi-experimental designs, was used. The study group consists of 34 primary school fourth grade students. Quantitative data were collected with the STEM Attitude Scale, the 21st Century Creativity and Renewal Skills Scale, the Scratch Achievement Test and the Mathematics Achievement Test. On the other hand, qualitative data were collected with a Semi-Structured Interview Form. Descriptive statistics, ANOVA for Repeated Measures, and dependent groups t-test statistics were used in the analysis of quantitative data. Qualitative data were analyzed using descriptive and content analysis techniques and presented in tables. As a result of the research, it was determined that STEM education has a significant effect on the attitudes of primary school fourth grade students towards STEM and their 21st century skills. It has been figured out that the effect of STEM education on increasing the mathematics achievement of primary school fourth grade students is not significant. Students reported that STEM education activities were fun, useful and instructive. With STEM implementations, students' attitudes towards science, technology, engineering and mathematics have changed positively; They stated that 21st century skills such as communication, cooperation, creativity and critical thinking have developed.

## Keywords

STEM
21st century skills
Attitude
Math education
Coding
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[1] Sivas Cumhuriyet University, Faculty of Education, Department of Primary Education, Turkey, bircanmehmetakif@gmail.com

[2] Ondokuz Mayıs University, Faculty of Education, Department of Mathematics and Science Education, Turkey, hcalisici@omu.edu.tr

## Introduction

Today, education studies are carried out to increase the economic level of countries and different education approaches are presented. One of the most important educational approaches revealed by the studies carried out in this direction is STEM. With this educational approach, it is predicted that students will acquire 21st century skills and contribute to the economic development level of their countries in their future professional careers. In addition, it is stated that STEM education will contribute to the progress of countries in science and technology. For this reason, countries put emphasis on STEM education (Ministry of National Education [MoNE], 2018a). Innovation is becoming increasingly significant in the world of the 21st century. In this world, there are transformations in both the nature of science and its methods. These transformations affect the education and training processes. STEM education is becoming widespread due to the idea that it will adapt to these transformations (Aşık, Doğanca Küçük, Helvacı, & Çorlu, 2017). In this context, Çorlu, Capraro, and Caproro (2014) define STEM education as the teaching of knowledge and skills related to it by taking a discipline from STEM fields to the center and associating it with other STEM disciplines. Meng, Idris, and Eu (2014) also define STEM education as an educational approach that establishes a relationship between the fields of science, mathematics, technology and engineering. In our world where there is a rapid change in science and technology day by day, the need for individuals who research, question, examine, use the scientific method to solve the problems they encounter, connect what they have learned with daily life and look at the world from the perspective of scientists is increasing. In this context, STEM education has a critical importance. This education model gives students the ability to solve the problems they encounter at every moment of their education life, from preschool to university, with an interdisciplinary perspective (Altunel, 2018). In addition, in the activities developed in this model, it is aimed that students learn science and mathematics knowledge and grasp 21st century skills (Aydeniz & Bilican, 2017). 21st century skills are defined as the skills that individuals need to acquire in order to be successful in the business and social life of the future. There are many different classifications and definitions in the literature about what these skills are (Çepni & Ormancı, 2017). The classification made by the Partnership for 21st Century Skill (P21, 2009) is the most widely accepted. Accordingly, it is possible to divide 21st century skills into four main categories; i. basic subjects and 21st century themes (basic subjects such as English, mathematics, history, geography, economics, global awareness, financial, economic, business and entrepreneurial literacy, civic literacy, health and environmental literacy) ii. learning and innovation skills (creativity and innovation, communication and collaboration, critical thinking and problem solving) iii. information, media and technology skills (information, media, communication and technology literacy) iv. life and career skills (resilience and adaptation, entrepreneurship, social and intercultural skills, leadership, productivity and accountability) (P21, 2009). Coding; It can be considered as a 21st century skill included in information, media and technology skills. In addition, in the report "Computing our future" published by European Schoolnet (2015), this skill is expressed as a key 21st century skill that young people should acquire, since many professions in the business world require coding skills.

Due to the reasons mentioned above, this educational approach, which emerged in the United States and became widespread, has become the education policies of governments in many countries, especially in the European Union countries (Akgündüz et al., 2015). In this context, studies on STEM education have been carried out in our country in recent years. In this direction, a report on STEM education has been published by the MoNE (2016). In this report, STEM education helps students develop positive attitudes towards science, technology, engineering and mathematics disciplines; It is argued that it will have a positive effect on the development of 21st century skills and the increase in the scores obtained in international exams such as PISA and TIMSS. The report in question presents a roadmap for the transition to STEM education and emphasizes the integration of this educational approach into curricula at every stage of education, from pre-school to university.

Since primary school students' attitudes towards STEM are extremely important, the foundations of STEM education should be laid in primary school (Azgın & Şenler, 2019; Öztürk, 2017). MoNE (2016) stated that with STEM education, students' attitudes towards science, technology, engineering and mathematics can be changed positively; problem solving, creativity and ability to relate what they learn to daily life can be improved; states that their academic achievements in science and mathematics courses can be increased. In countries such as Korea, Japan and China, which perform high success in PISA, the fact that STEM education is provided in the process from primary school to university backs this statement up (İdin & Kaptan, 2017). In addition to these, Yıldırım (2016) emphasizes that STEM education is important for increasing science and mathematics achievement in our country. It is possible to see a concrete indication of the policy changes made in this area in our country in the curriculum updated by the MoNE in 2018. In the renewed science curriculum, starting from the fourth grade of primary school, science, engineering and entrepreneurship practices were included and engineering and design skills were emphasized. Similarly, it is seen that basic competencies in science/technology and digital competency are included in the mathematics curriculum (MoNE, 2018a, 2018b, 2018c).

When the international literature is reviewed, it is observed that studies on STEM education have started since the 90s (Herdem & Ünal, 2018). McCaslin's (2015) analyzed the effect of STEM education on students' math achievement, Ashford (2016) studied the influence of STEM education on the academic achievement of third, fourth and fifth grade students, and Olivarez (2012) researched the outcome of STEM education on eighth grade students' science, math, and reading skills. Again, So, Chen, and Chow (2020) studied primary school students' knowledge about STEM career professions and its effect on their interest in STEM career professions; Sun, Hu, Yang, Zhou, and Wang (2021) examined the relationship between primary school students' computational thinking skills and their attitudes towards STEM disciplines. Moreover, research on teachers in the field of STEM education was also carried out; Wei and Mat (2020) analyzed primary school teachers' attitudes towards STEM education, El-Deghaidy and Mansour (2015) studied science teachers' views on STEM education approach, Knowles (2017) examined the effects of STEM teacher education program on teachers' STEM teaching self-efficacy, learning outcomes and awareness of STEM career professions. Recently, many researchers in Turkey have been studying on STEM and have been publishing articles, papers and reports in this field. In this context, a report named "STEM Requirement in Turkey Towards 2023" has been prepared by the Turkish Industrialists' and Businessmen's Association (TÜSIAD). In this report, the critical role of STEM fields was underlined and attention was drawn to the importance of STEM skills, which form the basis of innovation, in terms of economic growth (TÜSIAD, 2017). In the STEM Education Turkey Report prepared by Akgündüz et al. (2015), the current situation of STEM education in the world and in Turkey has been revealed. Altunel (2018), on the other hand, talked about STEM education, the advantages and disadvantages of this educational approach and how it can be applied in Turkey in his article titled "STEM Education and Turkey: Opportunities and Risks". In our country, STEM centers are opened by provincial directorates of national education, municipalities, universities and non-governmental organizations. In these centers, student trainings are organized for the STEM education approach or professional development programs are implemented for teachers (Bircan, Köksal, & Cımbız, 2019). However, most of the research and studies on the STEM education approach in Turkey are for middle school and higher level students, and the research and studies on STEM education at primary school level are limited (Acar, 2018; Yavuz, 2018). Herdem and Ünal (2018) analyzed 38 studies in the field of STEM. It was stated that 9% of the studies examined in this analysis were carried out at primary school level and in-class STEM activities were carried out in science lessons. Karakaya, Yantırı, Yılmaz, and Yılmaz (2019) analyzed primary school students' opinions on STEM activities, Azgın and Şenler (2019) dealt with primary school third and fourth grade students' STEM career interests and attitudes towards STEM, Balçın and Topaloğlu-Yavuz (2019) studied primary school students' opinions on engineers and scientists, Tabaru (2017) researched the effect of STEM-based activities applied in primary school fourth grade science course on students' scientific process skills, academic achievement and problem solving skills, Yavuz (2018) focused on the effect of fourth grade science course taught with STEM-based implementations on students' STEM professions, perceptions and attitudes. Similarly, Acar, Tertemiz, and Taşdemir (2018) reported the effect of STEM education on the academic achievement of fourth grade students in science and mathematics and their views on STEM education, Acar (2018) examined the effect of STEM education on the academic achievement, critical thinking and problem solving skills of primary school fourth grade students in science and mathematics courses; Öztürk (2017) analyzed the awareness, competencies and attitudes of teachers and primary school fourth grade students about the STEM approach. When the above-mentioned studies are analyzed, it is observed that the studies on STEM education at primary school level are mostly focused on science education, and the studies on mathematics education are not sufficient. For this reason, it is believed that this research will contribute to the field, as it is about STEM education approach implementations in mathematics lessons in the fourth grade of primary school. In addition to this, no research has been found that associates coding education at primary school level with mathematics education. In this respect, it is believed that the research will create a model for researchers who want to work on coding education in primary school mathematics courses and for teachers who wish to apply this education in their classrooms.

### *The Purpose of the Study*

Based on the information mentioned above, the aim of this research is; to determine the effects of STEM education activities on primary school fourth grade students' attitudes towards STEM, 21st century skills and mathematics achievement. Depending on the general problem of the study, the sub-problems can be listed as follows;

1. Do STEM education activities have an effect on primary school fourth grade students'
   a. attitudes towards STEM
   b. 21st century skills
   c. achievement in Mathematics?
2. What are the students' views on the effect of STEM education activities on primary school fourth grade students'
   a. attitudes towards STEM?
   b. 21st century skills
   c. achievement in Mathematics?

### *Limitations and Assumptions of the Study*

The research was carried out with a study group of 34 students for a total of 27 hours for nine weeks. The STEM activities applied in the research include the acquisitions included in the primary school science and mathematics curriculum. These can be expressed by the limitations of the study. In addition, in the research, it was assumed that the students gave sincere answers to the data collection tools and that the expert opinions were sufficient for the development of the data collection tools.

## Method

### *Model of the Research*

The research was carried out with a sequential explanatory design, one of the mixed research designs. In the sequential explanatory design, quantitative data are collected in the first step. Then, a qualitative data collection process is designed to elaborate or explain the quantitative data (Creswell & Plano Clark, 2011). For this reason, this pattern is called “explanatory”. Since the collection of quantitative and qualitative data follows a sequence, the pattern is called "sequential". For this reason, in the first stage of the research, quantitative data were collected and qualitative data collection stage was designed and implemented in line with the findings obtained. Finally, the obtained quantitative and qualitative data were interpreted together.

In the quantitative part of the study, time series design, one of the semi-experimental designs, was used to determine the effects of STEM activities on students' attitudes towards STEM and 21st century skills depending on time. In addition, one group pretest-posttest design, one of the quasi-experimental designs, was used to determine the effect of STEM activities on students' mathematics achievement and coding skills.

In the qualitative part of the research, semi-structured interview data were used to examine the students' views on the applied STEM education activities in depth.

***Study Group***

Before the actual implementation of the research, a pilot implementation was made. The pilot implementation was carried out in the spring term of the 2017-2018 academic year and the study group of this implementation consists of 31 students studying in three different primary schools in the city center of Tokat. The study group of the main implementation carried out in the 2018-2019 academic year consists of 34 students studying in the fourth grade of a primary school in the city center of Tokat. 12 of these students are girls and 22 of them are boys. In order to determine the study group of the research, interviews were held with school administrators and form teachers in primary schools close to the place where the implementation will be made. Afterwards, a meeting was held with the parents of students in whose teacher stated that he/she could participate in the study with her students. At this meeting, the parents were informed about the content, duration and place of the implementation. After the approval of the parents, the working group was determined by obtaining permission from the relevant institutions. All of the students studying in this class participated in the quantitative part of the study. Qualitative data were obtained from 6 students selected by purposive sampling from this group. In the selection of these students, the scores obtained from the STEM Attitude Scale (SAS) applied to the students before the study were taken into consideration. The group formed by the selection of two students each with low, medium and high scores from this scale formed the study group for the qualitative data of the study. A code as [S2] was given to the students from whom the qualitative data were collected. Here, the number 2 represents the student whose interview order is 2.

***Data Collection Tools***

The data collection tools used in the research are given under two headings as quantitative and qualitative data collection tools.

***a) Quantitative data collection tools***

*STEM Attitude Scale (SAS)*: In the study, STEM Attitude Scale, which was developed by Unfried, Faber, Stanhope, and Wiebe (2015), and adapted into Turkish and prepared for primary school fourth grade students in the article that titled as "Determination of Beliefs and Attitudes of Primary School Fourth Grade Teachers and Students towards STEM Education" by Öztürk (2017) was used in this research. As a result of the Turkish adaptation of the scale, the Cronbach Alpha values were; 0.64 for the mathematics dimension, 0.81 for the science dimension, 0.81 for the engineering and technology dimension and 0.84 for the 21st century skills dimension. The STEM attitude scale used consists of 37 items. The scale consists of 4 sub-dimensions named Mathematics Attitudes (MA), Science Attitudes (SA), Engineering and Technology Attitudes (ETA), and 21st Century Learning (CA). There are 8 items in the first dimension, 9 items in the second dimension, 9 items in the third dimension and 11 items in the fourth dimension. The five-point Likert scale is listed as “Strongly Disagree”, “Disagree”, “Undecided”, “Agree” and “Strongly Agree”. As a result of the reliability analysis of the scale's implementation group, the Cronbach Alpha reliability coefficients were calculated as 0.86 for the pretest, 0.78 for the midtest-1, 0.85 for the midtest-2 and 0.77 for the posttest.

*21st Century Learning and Renewal Skills Scale (CLRS)*: The scale was developed by Belet-Boyacı and Atalay (2016) for primary school fourth grade students and consists of 39 items. 20 of the questions in the scale are about creativity and innovation skills (CIS), 12 of them are about critical thinking and problem-solving skills (CTP), and 7 of them are about cooperation and communication skills (CCS). The Cronbach's Alpha reliability coefficient of the whole scale consisting of three factors was calculated as

0.95. As a result of the reliability analysis of the scale's implementation group, the Cronbach Alpha reliability coefficients were calculated as 0.84 for the pretest, 0.77 for the midtest-1, 0.75 for the midtest-2 and 0.77 for the posttest.

*Scratch Achievement Test (SAT)*: STEM activities developed within the scope of the experimental study include coding training and implementations in the Scratch programming language. For this reason, students should have knowledge and skills about the interface, tools, code blocks and how to use code blocks of the Scratch program. In this direction, before the pilot implementation, the "Scratch Achievement Test" was developed by the researchers in order to determine whether the students gained the knowledge and skills mentioned in this program. During the development of the test, these steps were followed in order; 1) Determining the purpose of the test, 2) Determining the features to be measured by the test, 3) Writing the test items, 4) Reviewing the items, 5) Preparing the trial form, 6) Conducting the pilot implementation, 7) Scoring the pilot implementation results, item analysis and item selection and 8) Creating the final test (Turgut & Baykul, 2012). In determining the features to be measured with the test, the achievements included in the program prepared by Lero-The Irish Software Research Centre (2018) in order to teach coding with Scratch to primary school students were taken as basis. Then, the test draft was created by preparing questions to include each acquisition. In order to increase the content validity of the created test, the opinions of 3 information technology experts and 1 Turkish language expert were consulted. The 40-question achievement test, which was created by making necessary corrections on the test in line with the opinions received, was applied to 174 students studying in the 5th grade of three different secondary schools in the center of Tokat. The item distinctiveness and item difficulty indexes of the questions in the test were examined. In line with the results obtained from the item analysis, 20 items were taken to the test and the test was given its final form. The statistics of the items in the test are presented in Table 1.

**Table 1.** Statistics of the Items in the Scratch Achievement Test

| Item Number | Difficulty Index | Index of Distinctiveness | Item Number | Difficulty Index | Index of Distinctiveness |
|---|---|---|---|---|---|
| 1 | 0,40 | 0,45 | 11 | 0,83 | 0,41 |
| 2 | 0,68 | 0,64 | 12 | 0,76 | 0,31 |
| 3 | 0,77 | 0,39 | 13 | 0,46 | 0,52 |
| 4 | 0,63 | 0,58 | 14 | 0,84 | 0,35 |
| 5 | 0,68 | 0,45 | 15 | 0,52 | 0,43 |
| 6 | 0,83 | 0,39 | 16 | 0,85 | 0,35 |
| 7 | 0,60 | 0,47 | 17 | 0,75 | 0,56 |
| 8 | 0,73 | 0,45 | 18 | 0,37 | 0,35 |
| 9 | 0,80 | 0,35 | 19 | 0,86 | 0,31 |
| 10 | 0,49 | 0,56 | 20 | 0,85 | 0,31 |

The KR-20 internal consistency coefficient of the developed test was calculated as 0.80. The reliability coefficient of the test being 0.70 and higher is generally considered sufficient for test reliability (Büyüköztürk, 2004). Accordingly, the achievement test developed was accepted as reliable and was used in the research.

Some of the items belonging to the scale are given in Figure 1.

"It is a way designed to solve a particular problem or achieve a goal."

1- Which of the following terms best describes the above statement?

A. Problem
B. Coding
C. Algorithm
D. Scratch

3- Which of the following code blocks should be used to move the puppet to the left when pressing the left arrow key in the Scratch program?

A) B) C) D)

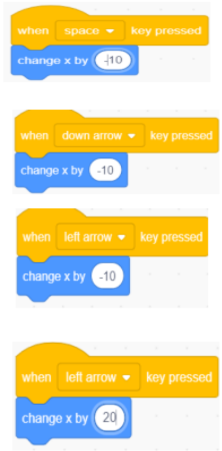


**Figure 1.** Sample Items of the Scratch Achievement Test

*Mathematics Achievement Test (MAT)*: STEM activities developed within the scope of the experimental study include the acquisitions of the subject of Measuring Time belonging to the Measurement Unit of the Primary School Mathematics Curriculum. A "Mathematics Achievement Test" was developed by the researchers in order to determine the academic success of the students in the time measurement unit. This test was developed prior to pilot implementation. In the development of this test, the steps followed in the development of the Scratch Achievement Test were followed. In determining the features to be measured with the test, questions about each acquisition were prepared based on the acquisitions related to the subject of Measuring Time. First of all, two experts working in the field of mathematics were consulted about the created test draft. Necessary corrections were made on the questions in line with the opinions of the experts. After correcting the items, the 40-question achievement test was applied to 126 5th grade students studying at three different secondary schools in the city center of Tokat. The item distinctiveness and item difficulty indexes of the questions in the test were analyzed. In line with the results obtained from the item analysis, 19 items were tested. The statistics of the items in the test are presented in Table 2. The KR-20 internal consistency coefficient of the Mathematics Achievement Test was calculated as 0.90.

**Table 2.** Statistics of the Items in the Mathematics Achievement Test

| Item Number | Difficulty Index | Index of Distinctiveness | Item Number | Difficulty Index | Index of Distinctiveness |
|---|---|---|---|---|---|
| 1 | 0,68 | 0,63 | 11 | 0,54 | 0,51 |
| 2 | 0,70 | 0,54 | 12 | 0,56 | 0,75 |
| 3 | 0,76 | 0,51 | 13 | 0,50 | 0,69 |
| 4 | 0,52 | 0,33 | 14 | 0,45 | 0,66 |
| 5 | 0,59 | 0,60 | 15 | 0,51 | 0,78 |
| 6 | 0,57 | 0,51 | 16 | 0,54 | 0,75 |
| 7 | 0,64 | 0,78 | 17 | 0,52 | 0,72 |
| 8 | 0,52 | 0,51 | 18 | 0,42 | 0,69 |
| 9 | 0,54 | 0,51 | 19 | 0,45 | 0,81 |
| 10 | 0,55 | 0,51 | | | |

Two sample items in the Mathematics Achievement Test are given in Figure 2.

3- In the equation "135 seconds = ….. minutes ….. seconds" , which ones should come in the blanks, respectively?

A. 2 and 15
B. 2 and 25
C. 20 and 15
D. 21 and 31

13- Waking up at 07:45, Yasemin gets on the school bus 45 minutes later. After a 35-minute journey, she reaches the school. How many minutes early did Yasemin arrive at school, since the class will start at 09:30?

A. 40 minutes
B. 30 minutes
C. 20 minutes
D. 15 minutes

**Figure 2**. Sample Items of the Mathematics Achievement Test

***b) Qualitative data collection tools***

*Interview Form for STEM Education Activities (IFSE)*: A semi-structured interview form was prepared by the researchers in order to learn the students' views on the applied STEM activities in depth. In the preparation of the questions in the form, the quantitative data of the students were taken as basis. First of all, questions that were not clear or that were thought to measure the same information were removed from the draft form submitted to the opinion of field experts, and the form was finalized. The interview form consists of 11 items. After the activities were completed, the interviews were held in the classroom where the trainings were held.

***Implementation Process***

First of all, a pilot implementation was carried out in order to test the operability of the program covering the STEM education activities to be implemented, to identify the problems that may be encountered in the process and to take precautions. The pilot and main implementation of the research was carried out in the Distance Education Class of the Public Education Center in the city center of Tokat. In choosing this class as the place of application; It has been effective that each student has a sufficient number of computers that can be used, sufficient technical infrastructure for the implementations to be carried out, and an easily accessible location. The pilot implementation was carried out as after-school activities in the spring term of the 2017-2018 academic year. The timeline of the actual implementation which was in the 2018-2019 academic year is presented in Table 3.

**Table 3.** Timeline of the Study

| | Date | Activities |
|---|---|---|
| 1st Week | 05.02.2019 | Pretests |
| 2nd Week | 12.02.2019 | Lesson Plan-1 |
| 3rd Week | 19.02.2019 | Lesson Plan -2 |
| 4th Week | 26.03.2019 | Lesson Plan -2/ Mid-tests |
| 5th Week | 05.03.2019 | Lesson Plan -3 |
| 6th Week | 12.03.2019 | Lesson Plan -3 |
| 7th Week | 19.03.2019 | Lesson Plan -3/ Mid-tests |
| 8th Week | 26.03.2019 | Lesson Plan -4 |
| 9th Week | 02.04.2019 | Lesson Plan -4 |
| 10th Week | 09.04.2019 | Lesson Plan -4/ Post Tests |
| 11th Week | 16.04.2019 | Interviews |

In the first week of the implementation, students were informed about the process by introducing the environment where the activities would take place. 4 lesson plans developed by the researchers were applied during the next 9 weeks. Lesson plans include the achievements of the Human and Environment unit of the primary school fourth grade Science course curriculum and the measurement unit of the primary school fourth grade Mathematics course. In the process of preparing the plans, the lesson plans of the Scratch program prepared by Lero-The Irish Software Research Centre (2018) were analyzed in order to enable students to gain coding skills by using the Scratch program and to apply what they learned in other lessons in this field. By integrating the achievements here into the prepared lesson plans, lesson plan drafts were created and these drafts were tested in the pilot implementation. In this direction, the lesson plans were rearranged and the study plan was revised for the actual implementation. It is possible to summarize the changes made in lesson plans and activities as follows;

- In the introduction part of the developed lesson plans, students were asked to create a mind map using the MindMup application. However, this application was excluded from the activities because it took too much time.
- It was observed that the students had difficulties in fulfilling the game design tasks in the deepening part of the lesson plans. For this purpose, instead of introducing the codes independently in the explanation part, it was preferred to explain through an example game design. Thus, it is aimed to make students comprehend how they can use them in a game design while teaching the codes.
- Since it was monitored that the students were lacking in skills such as downloading visual or audio files using search engines and creating folders on the computer during the game design process, these points were also included in the lesson plans.

By making the amendments mentioned above, the lesson plans were finalized and the plans were applied for 27 hours during the nine weeks in the implementation process. Lesson plans were prepared based on the 5E learning model STEM integration stages developed by Selvi and Yıldırım (2017). Accordingly, in the introduction part of the lesson plans, activities that will attract students' attention to the subject they will learn and activities that will enable them to comprehend the subject themselves are included in the discovery part. At this stage, especially activities that will enable students to use information communication tools or interactive learning environments are included. In the explanation part of the plans, both the subjects related to primary school fourth grade science and mathematics course achievements are given, as well as the subjects related to the Scratch program to help students gain coding skills. In the deepening part, using the Scratch program, the students were asked to design their own engineering products such as animation and games related to the science and mathematics course outcomes given in the explanation part. Animations and games made in the evaluation part were evaluated and interactive tests related to course outcomes were solved.

In the first of the four lesson plans prepared, the concept of algorithm was taught to the students and the relationship between problem solving and algorithm was explained. In addition, by giving examples from daily life about the algorithm, it was ensured that the students establish a connection between the learned subject and daily life. Afterwards, students were asked to create their own algorithms and presented their own products. In the second lesson plan, the concepts of artificial and natural environment were introduced to the students, and the codes related to designing animation in the Scratch program were taught. Then, the students were asked to design animations related to the artificial and natural environment using the codes they learned. Thus, science achievement and Scratch achievement were associated. In the third of the lesson plans, the students were taught the subjects related to the environment, the environment-human relationship and environmental pollution, and the codes, tools and interfaces necessary to design a game in the Scratch program. Afterwards, the students were asked to design a game about environmental pollution. The test prepared by using the web 2.0 tool for human and environmental unit acquisitions was solved. Thus, during the first six-week period, students were made to engage in activities that included science, mathematics, technology and engineering achievements within the scope of STEM lesson plans, and a relationship was established between coding and primary school science and mathematics program achievements. At the end of this process, it is aimed that the students gain the basic skills necessary to code using the Scratch program. For this reason, in the first three lesson plans prepared on the basis of STEM education, the interface of the Scratch program was introduced to the students, and the code blocks and how to use these code blocks were explained. In the next stage, the implementation phase of the fourth lesson plan, which was prepared to establish a relationship between STEM education and mathematics, was started. In the fourth lesson plan, subjects related to the mathematics lesson time measurement unit were taught to the students, and game design steps were given through two examples. The codes of a game designed on the subject of measuring time were written together with the students so that they could understand the game design steps. In the next process, the students were asked to design and code their own games on the subject of measuring time together with their teammates. The games designed by the students were evaluated and the test prepared for measuring time was applied to the students using the web 2.0 tool. As a result, in the lesson plans prepared; It is aimed to integrate the STEM education approach into science and mathematics education programs and activities that will provide students with 21st century skills such as communication and cooperation, creativity, problem solving, technology literacy, coding and using information and communication technologies are included. A sample of the developed lesson plans is presented in Table 4.

**Table 4**. Sample Lesson Plan

| **Recommended time** | **9 lesson hours** |
|---|---|
| Concepts | Month-season-week-year, hour-minute-second |
| Mathematics curriculum outcomes | Explains the relationship between time measurement units.<br>Solves the problems in which time measurement units are used. |
| Science curriculum outcomes | Explain the incidents that occur as a result of the movements of the Earth. |
| Engineering outcomes | Designs and delivers the product |
| Technological outcomes | Designs games in Scratch program. |
| 21st century skills | Problem solving<br>Communication skill<br>Collaborative work |
| Tools-equipment | Computers-Projection |
| Introduction | 1- The teacher introduces the game samples prepared in Scratch to the students. The teacher then asks the students the following questions;<br>Have you designed a game before?<br>What should we pay attention to when designing a game?<br>At what stages does a game design take place? |
| Exploring | 1- The teacher asks his students to visit http://scratch.mit.edu and review the games and codes there. He also asks them to think about how to use the game codes at this address in the games they will design themselves.<br>2- The teacher asks the students why we measure time. He tells them to give their answers to this question with the Padlet (Digital clipboard) application. Then, the answers from the students are reflected on the smart board and the answers are discussed together. |
| Explanation | 1- The teacher presents information about the achievements (Mathematics, technology) in this section with the cartoons he prepared. In this section, sample exercises for hour/minute, minute/second and week-month-season-year conversions are solved. (The relationship between the formation of the day, month, season and year with the rotational movements of the earth is mentioned.)<br>2-The teacher explains how to make two sample games that he determined in this section.<br>3- Students are informed about game design stages.<br>4- The teacher designs a "Bubble Shooter" game that includes the achievements of measuring time. By having the students write the same codes together with the teacher, they are provided to understand this game design. |

**Table 4**. Continued

| | |
|---|---|
| Deepening | At this stage, the teacher asks the students to design an instructive game that includes what they learned in the time measurement unit in the Scratch program. In this section, students are divided into groups of 5 people. They are asked to do the game design as a group. |
| Evaluation | 1- The games prepared by the students are introduced to their other friends.<br>2- Prepared games are evaluated with the Scratch Project Rating Scale(http://f.eba.gov.tr/kod/programlamaetkinlikleri/5.S10/5S10.A1.pdf).<br>3- The teacher makes students take the Kahoot test about measuring time. |

In addition, repeated measurements were carried out with the STEM Attitude Scale and the 21st Century Learning and Renewal Skills Scale in the first week, fourth week, seventh week and ten weeks of the practices in order to determine the effects of STEM activities on students' STEM attitudes and 21st century skills during the practices. The research carried out was designed as two modules on the basis of the modular education approach. The most important aim of the first module, which covers the first six weeks of the research, is to provide students with coding skills to prepare their own digital games using the Scratch program. For this reason, the Scratch achievement test was applied at the beginning (1st week) and at the end (7th week) of this six-week period. After the completion of this designed first module of the research, the implementation process of the lesson plans prepared in order to associate STEM education with the subjects and achievements of primary school fourth grade mathematics lesson began. At this stage, it is aimed to determine the effect of STEM activities on students' mathematics achievement. For this reason, the mathematics achievement test was applied at the beginning (7th week) and at the end (11th week) of the second module of the research. In the eleventh week of the research, semi-structured interviews were conducted in order to determine the students' views on STEM activities. The timeline for the implementation of the data collection tools used in the study is presented in Table 5.

**Table 5.** Data Collection Tools Implementation Schedule

| Data Collection Tools | Pretest | Mid-test-1 (4th week) | Mid-test-2 (7th week) | Post test (10th week) | Interview (11th week) |
|---|---|---|---|---|---|
| SAS | x | x | x | x | |
| CLRS | x | x | x | x | |
| SAT | x | | x | | |
| MAT | | | x | x | |
| IFSE | | | | | x |

During the implementation process, the researcher took part as the implementer of the STEM lesson plans and also collected the research data.

*Analysis of Data*

***a) Analysis of quantitative data:*** While analyzing the quantitative data of the research, first of all, the descriptive statistics of the scores obtained from the scales were examined and the normality status was determined. First, the Shapiro-Wilks test was used to check whether the data obtained with the STEM Attitude Scale showed normal distribution. The Shapiro-Wilks test is one of the methods used to determine whether the obtained scores show a normal distribution (Büyüköztürk, 2004).

**Table 6.** STEM Attitude Scale Normality Analysis Results

| | | Statistics | sd | p |
|---|---|---|---|---|
| Pretest | SAS | 0,976 | 34 | 0,63 |
| | MA | 0,958 | 34 | 0,20 |
| | SA | 0,956 | 34 | 0,18 |
| | ETA | 0,950 | 34 | 0,11 |
| | CA | 0,950 | 34 | 0,12 |
| Midtest-1 | SAS | 0,959 | 34 | 0,22 |
| | MA | 0,861 | 34 | 0,00 |
| | SA | 0,923 | 34 | 0,09 |
| | ETA | 0,923 | 34 | 0,02 |
| | CA | 0,901 | 34 | 0,00 |
| Midtest-2 | SAS | 0,896 | 34 | 0,00 |
| | MA | 0,847 | 34 | 0,00 |
| | SA | 0,923 | 34 | 0,02 |
| | ETA | 0,923 | 34 | 0,02 |
| | CA | 0,861 | 34 | 0,02 |
| Post test | SAS | 0,957 | 34 | 0,20 |
| | MA | 0,878 | 34 | 0,00 |
| | SA | 0,933 | 34 | 0,04 |
| | ETA | 0,939 | 34 | 0,05 |
| | CA | 0,920 | 34 | 0,01 |

When Table 6 is analyzed, in the normality test performed with the Shapiro-Wilks test, it is observed that the sub-dimensions of mid-test-1 MA, ETA and CA; mid-test-2 sub-dimensions of SAS and MA, FA, ETA and CA; and post-test MA, SA and CA sub-dimensions do not demonstrate normal distribution characteristics. The Kurtosis-Skewness coefficients of the data obtained with the STEM attitude scale were examined in order to determine the normal distribution characteristics of the data that did not reveal normal distribution in the Shapiro-Wilks test. In cases where the Skewness and Kurtosis values are between -2 and +2, the distribution is considered to be a normal distribution (Almquist, Ashir, & Brännström, 2019; George & Mallery, 2010; Pekbay, 2017). The descriptive statistics values of the STEM Attitude Scale midtest-1, midtest-2, and related sub-dimensions of the posttest are given in Table 7.

**Table 7.** STEM Attitude Scale Descriptive Statistics Values

| | | Skewness Coefficient | Kurtosis Coefficient |
|---|---|---|---|
| Mid-test-1 | MA | -1,16 | 0,64 |
| | ETA | -0,53 | 0,38 |
| | CA | -0,90 | -0,11 |
| Mid-test-2 | SAS | -1,08 | 0,73 |
| | MA | -1,36 | 1,57 |
| | SA | -0,78 | 0,08 |
| | ETA | -0,51 | -0,88 |
| | CA | -1,27 | 1,22 |
| Post test | MA | -1,01 | 1,10 |
| | SA | -0,08 | -1,20 |
| | CA | -0,84 | 0,74 |

When Table 7 is analyzed, it was seen that the pretest, midtest-1, midtest-2 and posttest score distributions, skewness and kurtosis values of the STEM Attitude Scale were within the normal distribution limits (-2,+2).

Shapiro-Wilks test was firstly applied to determine whether the data obtained with the 21st Century Learning and Renewal Skills Scale (YÖYB) showed a normal distribution.

**Table 8.** Normality Analysis Results of the 21st Century Learning and Renewal Skills Scale

| | | Statistics | sd | p |
|---|---|---|---|---|
| Pretest | YÖYB | 0,957 | 34 | 0,20 |
| | YYB | 0,987 | 34 | 0,95 |
| | EPB | 0,951 | 34 | 0,13 |
| | İİB | 0,950 | 34 | 0,12 |
| Mid-test-1 | YÖYB | 0,959 | 34 | 0,22 |
| | YYB | 0,959 | 34 | 0,22 |
| | EPB | 0,961 | 34 | 0,26 |
| | İİB | 0,855 | 34 | 0,00 |
| Mid-test-2 | YÖYB | 0,935 | 34 | 0,04 |
| | YYB | 0,960 | 34 | 0,25 |
| | EPB | 0,941 | 34 | 0,06 |
| | İİB | 0,834 | 34 | 0,00 |
| Post test | YÖYB | 0,954 | 34 | 0,15 |
| | YYB | 0,933 | 34 | 0,03 |
| | EPB | 0,919 | 34 | 0,01 |
| | İİB | 0,877 | 34 | 0,00 |

When Table 8 is examined, in the normality test performed with the Shapiro-Wilks test; It is observed that the mid-test-1 CCS sub-dimension, the mid-test-2 CLRS and CCS sub-dimensions, and the posttest CIS, CTP and CCS sub-dimensions do not show normal distribution.

In order to determine the normal distribution characteristics of the data that did not show normal distribution in the Shapiro-Wilks test, the Kurtosis-Skewness coefficients of the data obtained with CLRS were examined.

The descriptive statistics values of the relevant sub-dimensions of CLRS mid-test-1, mid-test-2 and posttest averages are given in Table 9.

**Table 9.** Descriptive Statistics Values of the 21st Century Learning and Renewal Skills Scale

| | | Skewness Coefficient | Kurtosis Coefficient |
|---|---|---|---|
| Mid-test-1 | CCS | -0,95 | 0,24 |
| Mid-test-2 | CLRS | -0,81 | 0,71 |
| | CCS | -1,36 | 2,15 |
| Post test | CLRS | -0,62 | -0,07 |
| | CTP | -0,70 | 0,93 |
| | CCS | -0,62 | -0,76 |

When Table 9 is examined, it is obtained that the pretest, mid-test-1, mid-test-2 and post-test score distributions of the 21st century learning and renewal skills scale are between the normal distribution limits (-2, +2) for the Skewness and Kurtosis values, except for the midtest-2 CCS sub-dimension.

Shapiro-Wilks was firstly used to determine whether the data obtained with the Mathematics Achievement Test showed a normal distribution.

**Table 10.** Mathematics Achievement Test Normality Analysis Results

| | Statistics | sd | p |
|---|---|---|---|
| Pretest | 0,947 | 34 | 0,106 |
| Posttest | 0,928 | 34 | 0,032 |

When Table 10 is considered, in the normality test performed with the Mathematics Achievement Test Shapiro-Wilks test; It is revealed that the posttest data do not present a normal distribution feature. In order to determine the normal distribution characteristics of the posttest data that did not present normal distribution in the Shapiro-Wilks test from the data obtained with the Mathematics Achievement Test, the Kurtosis-Skewness coefficients were examined.

**Table 11.** Descriptive Statistics Values of Mathematics Achievement Test

| | Skewness Coefficient | Kurtosis Coefficient |
|---|---|---|
| Posttest | -0,388 | -0,850 |

When Table 11 is viewed, it is detected that the posttest score distributions of the Mathematics Achievement Test, Skewness and Kurtosis values are between the normal distribution limits (-2, +2).

Shapiro-Wilks test was firstly applied to determine whether the data obtained with the Scratch Achievement Test demonstrated normal distribution.

**Table 12.** Scratch Achievement Test Normality Analysis Results

| | Statistics | sd | p |
|---|---|---|---|
| Pretest | 0,930 | 34 | 0,03 |
| Posttest | 0,979 | 34 | 0,75 |

When Table 12 is viewed, it is detected that the that the Scratch Achievement Test pretest data do not show normal distribution.

In order to figure the normal distribution characteristics of the pretest data that did not present normal distribution in the Shapiro-Wilks test from the data obtained with the Scratch Achievement Test scale, the Kurtosis-Skewness coefficients were implemented.

**Table 13.** Scratch Achievement Test Descriptive Statistics Values

| | Skewness Coefficient | Kurtosis Coefficient |
|---|---|---|
| Pretest | -0,265 | -0,738 |

When Table 13 is viewed, it is detected that the Scratch Achievement Test pretest score distributions, skewness and kurtosis values are between the normal distribution limits (-2, +2).

Parametric tests were used in the analysis of these tests, taking into account the Shapiro-Wilks and descriptive statistics values of the normality assumptions of the data obtained from the Scratch Achievement Test, 21st Century Learning and Renewal Skills Scale, Mathematics Achievement Test and STEM Attitude Scale given above. ANOVA test for Repeated Measures to test whether there is a significant difference between the average scores obtained from the STEM Attitude Scale and the 21st Century Learning and Renewal Skills Scale; The dependent groups t-test was used to test whether there was a significant difference between the average scores obtained from the Scratch Achievement Test and the Mathematics Achievement Test.

***b) Analysis of qualitative data:*** After the activities were completed, the interviews were held in the classroom where the trainings were held. The interviews, which lasted approximately 8-12 minutes, were recorded using a voice recorder. Later on, the audio recordings were transcribed. The data obtained at the end of the semi-structured interviews were analyzed using the Nvivo 11 program. In this process, content analysis and descriptive analysis techniques from qualitative data analysis techniques were applied. In the study, similar data and concepts were brought together under previously created categories and coded. In order to ensure reliability in the coding process, cross-coding was performed with a field expert. Agreement/(Agreement + Disagreement) reliability formula founded by Miles and Hubermann (1994) was used to analyze the consistency between the coders and the compliance rate was found to be 0.80. Afterwards, the negotiation method was used to ensure that the agreement between the coders reached at the expected level (Garrison, Clevelve-Innes, Koole, & Kappelman, 2006). As a result of the negotiation, the codes were rearranged and the compliance rate among the coders increased to 0.96. According to Miles and Huberman (1994), it is sufficient for the compliance ratio to be 0.90. The frequencies of the codes were presented in tables and the data were interpreted within the framework of these findings. In addition, examples of student views are included in the study to support the findings.

## Results

***a) Findings on students' attitudes towards STEM:***

The Repeated Measurements ANOVA test was used to determine whether there was a significant difference in the attitudes and sub-dimensions of the students towards STEM depending on time before, after and during the STEM education activities.

**Table 14**. Repetitive Measurements ANOVA Test Results Regarding the STEM Attitude Scale in General

| | Repeated Measurements | N | $\overline{X}$ | S | sd | F | p | Significant differences |
|---|---|---|---|---|---|---|---|---|
| MA | (1) Pretest | 34 | 3,78 | 0,76 | | | | (2)-(1) |
| | (2) Mid-test-1 | 34 | 4,37 | 0,62 | 2,25 | 13,20 | 0,000 | (3)-(1) |
| | (3) Mid-test-2 | 34 | 4,30 | 0,73 | | | | (4)-(1) |
| | (4) Posttest | 34 | 4,54 | 0,45 | | | | |
| FA | (1) Pretest | 34 | 3,53 | 0,76 | | | | (4)-(1) |
| | (2) Mid-test-1 | 34 | 3,75 | 0,62 | 3 | 4, 23 | 0,007 | |
| | (3) Mid-test-2 | 34 | 3,64 | 0,93 | | | | |
| | (4) Posttest | 34 | 4,00 | 0,71 | | | | |
| ETA | (1) Pretest | 34 | 3,86 | 0,63 | | | | * |
| | (2) Mid-test-1 | 34 | 3,97 | 0,78 | 2,4 | 0,678 | 0,537 | |
| | (3) Mid-test-2 | 34 | 3,93 | 0,88 | | | | |
| | (4) Posttest | 34 | 4,03 | 0,68 | | | | |
| CA | (1) Pretest | 34 | 4,08 | 0,52 | | | | * |
| | (2) Mid-test-1 | 34 | 4,16 | 0,69 | 2,4 | 1,29 | 0,280 | |
| | (3) Mid-test-2 | 34 | 4,10 | 0,84 | | | | |
| | (4) Posttest | 34 | 4,29 | 0,58 | | | | |
| SAS | (1) Pretest | 34 | 3,83 | 0,48 | | | | (4)-(1) |
| | (2) Mid-test-1 | 34 | 4,06 | 0,55 | 2,22 | 5,88 | 0,003 | |
| | (3) Mid-test-2 | 34 | 3,99 | 0,73 | | | | |
| | (4) Posttest | 34 | 4,20 | 0,54 | | | | |

The analysis results in Table 14 indicate that there is a significant difference between the students' pretest, midtest-1, midtest-2, and posttest STEM attitude average scores [$F$ (2.22,73.56)=5.887; $p<0.05$]. According to the results of the Bonferroni test performed to compare the differences between the variables in pairs; It was found to be between pretest and posttest scores ($p<0.05$). The table presents that there is a significant difference between the pretest, midtest-1, midtest-2, and posttest Mathematics Attitude sub-dimension average scores of the students [$F$ (2.25,74.39)=13.20; $p<0.05$]. According to the results of the Bonferroni test performed to compare the differences between the variables in pairs; scores were found to be between pretest and midtest-1, pretest and midtest-2, and pretest and posttest scores ($p<0.05$).

Analysis results in Table 14; It shows that there is a significant difference between students' pretest, midtest-1, midtest-2 and posttest Science Attitude sub-dimension average scores [F (3,99)= 4.23; p<0.05]. According to the results of the Bonferroni test performed to compare the differences between the variables in pairs; It was found to be between pretest and posttest scores (p<0.05). The results of the analysis in the table show that there is no significant difference between the pretest, midtest-1, midtest-2 and posttest Engineering and Technology Attitudes average scores and the 21st Century Learning average scores (p>0.05).

Figure 3 below shows the time-dependent variation of the average scores of STEM Attitudes obtained from the measurements and the average scores of its sub-dimensions.

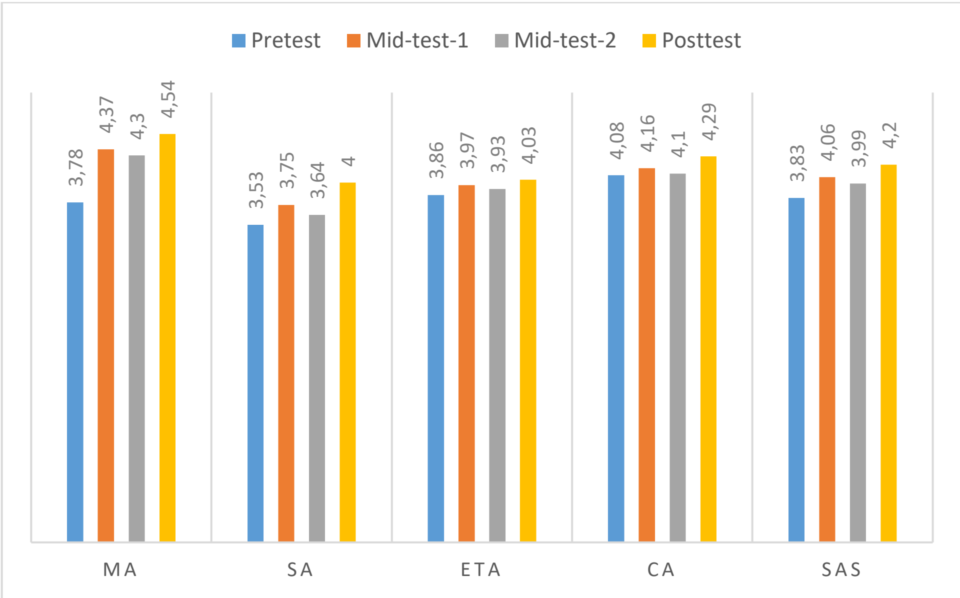


**Figure 3.** Change of STEM Attitude Average Scores over Time

When Figure 3 is analyzed, it is observed that the average STEM Attitude scores of the students increased by around 10% at the end of the program. In addition, it is grasped that students' Mathematics Attitude average scores, Science Attitude average scores, Engineering and Technology Attitude average scores and 21st century learning average scores increased at the end of the program.

***b) Findings on students' 21st century skills:***

The Repeated Measures ANOVA test was used to determine whether there was a statistically significant difference in the 21st century skills of the students depending on the time before, after and during the STEM education activities.

**Table 15.** ANOVA Results of Repeated Measures of the 21st Century Learning and Renewal Skills Scale in General

| | Repeated Measurements | N | $\bar{X}$ | S | sd | F | p | Significant differences |
|---|---|---|---|---|---|---|---|---|
| CIS | (1) Pretest | 34 | 2,33 | 0,24 | | | | |
| | (2) Mid-test-1 | 34 | 2,42 | 0,29 | 3 | 5,44 | 0,002 | (3)-(1) |
| | (3) Mid-test-2 | 34 | 2,49 | 0,31 | | | | (4)-(1) |
| | (4) Posttest | 34 | 2,50 | 0,31 | | | | |
| CTP | (1) Pretest | 34 | 2,22 | 0,20 | | | | (2)-(1) |
| | (2) Mid-test-1 | 34 | 2,37 | 0,27 | 3 | 9,55 | 0,000 | (3)-(1) |
| | (3) Mid-test-2 | 34 | 2,41 | 0,27 | | | | (4)-(1) |
| | (4) Posttest | 34 | 2,48 | 0,35 | | | | |
| CCS | (1) Pretest | 34 | 2,52 | 0,30 | | | | (3)-(1) |
| | (2) Mid-test-1 | 34 | 2,65 | 0,33 | 3 | 6,81 | 0,001 | |
| | (3) Mid-test-2 | 34 | 2,75 | 0,27 | | | | |
| | (4) Post-test | 34 | 2,68 | 0,29 | | | | |
| CLRS | (1) Pretest | 34 | 2,33 | 0,18 | | | | (2)-(1) |
| | (2) Mid-test-1 | 34 | 2,45 | 0,26 | 3 | 9,03 | 0,000 | (3)-(1) |
| | (3) Mid-test-2 | 34 | 2,50 | 0,28 | | | | (4)-(1) |
| | (4) Posttest | 34 | 2,53 | 0,29 | | | | |
| CIS | (1) Pretest | 34 | 2,33 | 0,24 | | | | |
| | (2) Mid-test-1 | 34 | 2,42 | 0,29 | 3 | 5,44 | 0,002 | (3)-(1) |
| | (3) Mid-test-2 | 34 | 2,49 | 0,31 | | | | (4)-(1) |
| | (4) Posttest | 34 | 2,50 | 0,31 | | | | |

The analysis results in Table 15 indicate that there is a significant difference between the students' pretest, midtest-1, midtest-2 and posttest 21st Century Skills average scores [F (3,99)= 9,03; p<0.05]. According to the results of the Bonferroni test performed to compare the differences between the variables in pairs, these significant differences; scores were found to be between pretest and midtest-1, pretest and midtest-2, and pretest and posttest scores (p<0.05).

The results of the analysis in the table present that there is a significant difference between the average scores of the students' pretest, midtest-1, midtest-2 and posttest Creativity and Renewal Skills [$F(3, 99) = 5{,}44$; $p < 0{,}05$]. According to the Bonferroni test results performed to compare the differences between the variables in pairs, it was found that these significant differences were between pretest and midtest-2 and pretest and posttest mean scores (p<0.05). The analysis results in Table 15 indicate that there is a significant difference between the students' pretest, midtest-1, midtest-2 and posttest Critical Thinking and Problem Solving Skills average scores [F (3,99)=9.55; p<0.05]. According to the results of the Bonferroni test performed to compare the differences between the variables in pairs, these significant differences were found to be between pretest and posttest, pretest and midtest-1 and pretest and midtest-2 mean scores (p<0.05).

The results of the analysis in the table show that there is a significant difference between the pretest, midtest-1, midtest-2 and posttest Collaboration and Communication Skills average scores of the students [F (3,99)=6.81; p<0.05]. According to the results of the Bonferroni test performed to compare the differences between the variables in pairs, it was found that this significant difference was between the pretest and midtest-2 mean scores (p<0.05).

In Figure 4 below, the variation of the average scores of 21st century skills obtained from the measurements over time is presented.

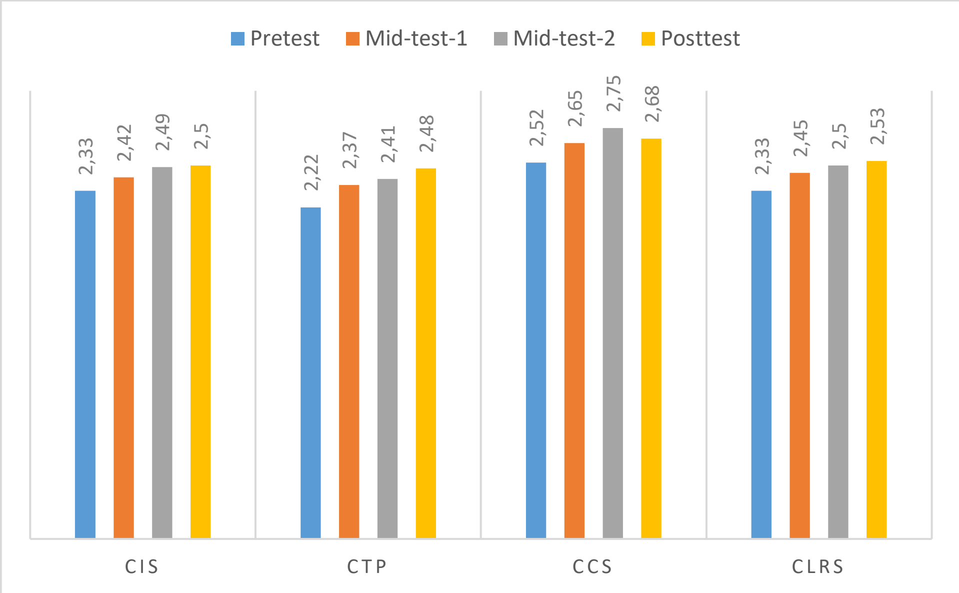


**Figure 4.** Time-Dependent Change of 21st Century Skills Average Scores

When Figure 4 is analyzed, it is demonstrated that the students' 21st century skills average scores increased at the end of the program. It is observed that the average scores of creativity and innovation, critical thinking and problem solving skills among these skills increase in every three-week period during the program, while the average score of communication and cooperation skills is higher at the end of the seventh week than at the end of the tenth week.

Before and after the program applied to determine whether there is a statistically significant difference between the pretest and posttest scores of students' coding skills; Data were obtained with the scratch success test. The dependent groups t-test was used to determine whether there was a statistically significant difference between the average scores obtained from these two measurements.

**Table 16.** Dependent Sample t-test Results for the Scratch Achievement Test

| **Measurements** | **N** | $\bar{X}$ | **S** | **sd** | **t** | **p** |
|---|---|---|---|---|---|---|
| Pretest | 34 | 6,32 | 2,34 | 33 | 14,31 | 0,000 |
| Posttest | 34 | 13,85 | 2,85 | | | |

The analysis results in Table 16 show that there is a significant difference between the pretest and posttest Scratch Achievement Test scores of the students in the experimental group ($p<0.05$).

***c) Findings on students' mathematics achievement:***

Mathematics Achievement Test was applied in the seventh and tenth weeks of the program in order to determine whether there is a significant difference in the mathematics achievement scores of the students before and at the end of the STEM education activities. The dependent groups t-test was used to determine whether there was a statistically significant difference between the mean scores obtained from these two measurements.

**Table 17.** Dependent Sample t-test Results for Mathematics Achievement Test

| Measurements | N | $\bar{X}$ | S | sd | t | p |
|---|---|---|---|---|---|---|
| Pretest | 34 | 12,14 | 4,59 | 33 | -0,697 | 0,491 |
| Posttest | 34 | 13,05 | 4,73 | | | |

In Table 17, the pretest and posttest academic achievement scores of the students to whom STEM education activities were implemented are given. The results of the analysis show that there is a positive difference between the pretest and posttest mathematics achievement scores of the students, but this is not significant (p>0.05).

***d) Student views on the effects of STEM education activities on students' attitudes towards STEM:***

In Table 18, the codes obtained from the analysis of students' views on the effects of STEM education activities on STEM attitudes are presented.

**Table 18.** Data Obtained on the Effects of STEM Education Activities on Students' Attitudes towards STEM

| Categories | Codes | f |
|---|---|---|
| Science | Positive impact | 13 |
| | Negative impact | 0 |
| | No impact | 2 |
| Technology | Positive impact | 29 |
| | Negative impact | 0 |
| | No impact | 1 |
| Engineering | Positive impact | 19 |
| | Negative impact | 1 |
| | No impact | 6 |
| Mathematics | Positive impact | 19 |
| | Negative impact | 0 |
| | No impact | 1 |

When Table 18 is examined, it is seen that the students mostly evaluated that the activities carried out had a positive impact on their attitudes towards science (f=13), technology (f=29), engineering (f=19) and mathematics (f=19). The students used expressions such as "I liked it", "I liked it more", "it affected positively", "it has increased positively", "it has improved" and "I was more interested". Some student statements regarding this are as follows:

*"I was a little bad in science like math, but when my teacher did it, the same thing happened again, it affected me positively, improved it and made me love science." [S4]*

*"The effect on technology, for example, I learned that codes are made with technology, that there is code behind the computer, I was interested, it increased my interest." [S6]*

*"I wanted to be a kindergarten teacher. Now I want to be more AI creator." [S3]*

*"I didn't like math. It made me love it even more now." [S1]*

In addition, some students stated that the activities carried out did not have any impact on their attitudes towards science (f=2), technology (f=1), engineering (f=6) and mathematics (f=1). The students used expressions such as *"it had no impact"* and *"I liked it anyway"*.

*"I already loved science; I will have a job related to it when I grow up. I also liked technology, I was interested before, it didn't change because of it" [S5]*

*"I don't want to be an engineer or something. I'm not very interested in it." [S1]*

Experimental group students stated that the fact that the activities carried out were fun, required to work in cooperation, and provided the opportunity for gamification and competition were effective in changing their attitudes towards mathematics and science in a positive way. The following dialogue supports this statement:

> Teacher: *How did the activities we carried out in the course you attended affect your feelings and thoughts about mathematics?*
>
> S1*: I liked mathematics a little more.*
>
> Teacher*: Why did you like math more?*
>
> S1: *We played more fun games. Then we all did these things together.*
>
> Teacher*: How did the activities we carried out in the course you attended affect your feelings and thoughts about science?*
>
> S1: *It is the same with it. Making it together and having more fun.*

The students stated that associating the curriculum subjects related to science and mathematics with other disciplines such as technology and coding and ensuring their connection with real life contributed to the positive change in their attitudes towards science and mathematics. Student statements regarding this finding are as follows:

> *"There is mathematics in our life. I learned that there is math in our games. There is mathematics in the animations and games we make. Because of these, I started to like mathematics more. I'm better with computers, which leads me to math. That's why it made me love math more." [S6]*
>
> *"We made a game about environmental pollution. There're factory fumes. Making games about environmental pollution and nature pollution made me love science more." [S3]*

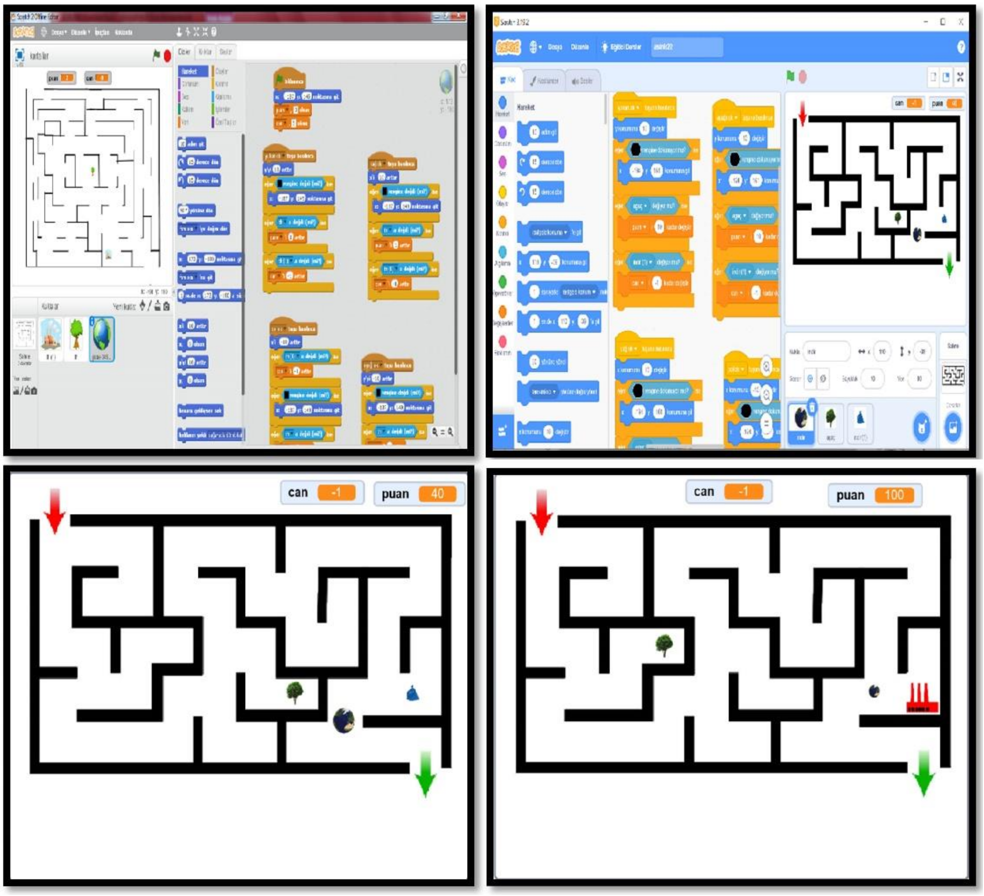


**Figure 5**. Screenshots of the Labyrinth Game Designed by the Students on the Subject of Environmental Pollution in Science Lesson

In Figure 5, there are screenshots of the games that S3 expressed. While designing this game with their group friends, the students determined the factors causing environmental pollution in the world and designed a game by transforming them into characters. In this process, it enabled the students to design their own unique games by establishing a link between the science lesson achievements and coding achievements.

In addition, the fact that the activities carried out contributed to the students' reinforcing the subjects they learned in school about science and mathematics also led to a positive change in their attitudes towards science and mathematics. The following statements of [S5] and [S4] support this finding:

*"It helped me understand math more easily." [S5]*

*"I was a little bad in science, like math. But when my teacher did the activities, the same thing happened again. It had a positive impact, improved it and made me love science." [S4]*

The students who are implemented STEM education stated that the development of these skills by acquiring new information about using technology, learning what engineering is and what engineers do evoke a positive change in their attitudes towards technology and engineering.

*"For example, I did not know environmental engineering. I learned what engineering is." [S5]*

*"I learned that codes are written with technology. I learned that the codes are running in the background of the computers. I had so much fun. This increased my interest (in technology). Before, I wanted to be a civil engineer. Now I want to be a computer engineer." [S6]*

***e) Student views on the effects of STEM education activities on students' 21st century skills:***

In Table 19, the codes obtained from the analysis of students' views on the effects of STEM education activities on 21st century skills are presented.

**Table 19.** Data Obtained on the Effects of STEM Education Activities on Students' 21st Century Skills

| Categories | Codes | f |
|---|---|---|
| Creativity Skills | Positive impact | 21 |
| | Negative impact | 0 |
| | No impact | 0 |
| Problem Solving Skills | Positive impact | 10 |
| | Negative impact | 0 |
| | No impact | 1 |
| Cooperation and Communication Skills | Positive impact | 20 |
| | Negative impact | 0 |
| | No impact | 2 |
| Critical Thinking Skills | Positive impact | 17 |
| | Negative impact | 0 |
| | No impact | 3 |

When Table 19 is analyzed, it is observed that the students mostly evaluated that the activities carried out positively affected their creativity skills (f=21), problem-solving skills (f=10), cooperation and communication skills (f=20), and critical thinking skills (f=17). The students used expressions such as *"I designed"*, *"I disassemble and put on things"*, *"I come up with new ideas"*, *"I solve it more easily"*, *"I produce different solutions"*, *"it developed"* and *"it contributed"*. The following student statements support this finding:

*"I didn't have a lot of creativity before. So I couldn't think too much beforehand. I couldn't develop much, but now we can think and develop new ideas. It has had an impact on creativity." [S4]*

*"I used to be able to find the first way around a problem. I could never find the 2nd way. But now I'm thinking of the 2nd way. I mostly find the 2nd way. I find the second one too." [S3]*

*"We have been developed more, we have overcome difficulties together with group work with our friends, it has contributed to our cooperation skills. I used to be an introvert, but when I started communicating with my friends, my introversion went away and my communication skills improved." [S6]*

*"For example, now I ask my mother and family, I ask the internet, I look at the library, I question the truth of the information. While I used to only use the internet, now I look at other resources." [S6]*

*"I used to just play games. Now I'm designing games and playing the game I designed myself." [S1]*

The students who were implemented STEM education stated that the activities contributed to the development of cooperation and communication skills because they required cooperation and group work and enabled them to find solutions to the problems they encountered in cooperation.

*"We overcame the difficulties together with group work with our friends. It has contributed to our cooperation skills." [S6]*

*"Our team spirit has improved. The work we did together went well." [S5]*

**Figure 6**. Images from Students' Group Work

As seen in Figure 6, the students created their game designs in groups. While creating these designs, they first planned the games on paper and completed the game design processes in cooperation. This has contributed positively to the development of students' cooperation and communication skills. In addition, in the process of designing the games, the students developed their critical thinking skills by using methods such as discussion and trial and error in order to find the right codes with their groupmates.

After the concept of algorithm was taught to the students, they were asked to develop algorithms related to science and mathematics. Examples of these algorithms are shown in the images given in Figure 7 below. With these studies, the students made a connection between the algorithms related to the subjects they studied in science and mathematics lessons. In addition, students' problem-solving skills have been developed as well as learning algorithms and algorithmic processing steps. The statements of S6 that support this fact are as follows:

> *"When I learned that we were progressing in the form of algorithms, I started to solve problems better. Usually I wouldn't always start over, I used to think. Now I am going in order."[S6]*

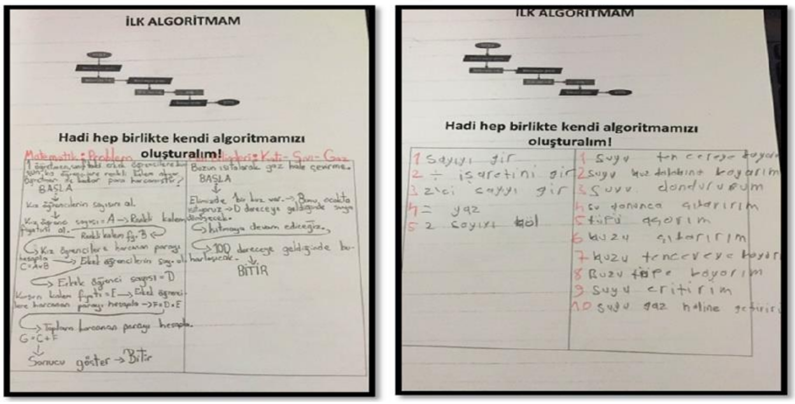


**Figure 7**. Examples of Algorithms Designed by Students for Mathematics and Science

The fact that there were sections in the activities that required students to design and make a new product had a positive effect on the development of students' creativity skills. Students explained this situation with the following statements:

> *"I used to just play games. Now I'm designing games and playing the game I designed myself." [S1]*

> *"Our creativity developed as we made games in the course." [S4]*

> *"After the course, my desire to design a new product increased." [S5]*

In addition to all these, the students stated that their critical thinking skills improved as they tried to find solutions to the problems encountered with the group members in the activities and learned to search for information from various sources. Student statements that support this statement are as follows:

*"I didn't know there was code behind games. I learned by researching the codes of the games I made myself. This made me look for more resources." [S6]*

*"I can access information from the computer. I can use that information in my mind. I can design a game in my mind." [S4]*

*"We made a mistake while we were finishing the game. I looked and I fixed the error. Then it started working. I came up with a different solution." [S4]*

***f) Student views on the effects of STEM education activities on students' mathematics achievement:***

In Table 20, the codes obtained from the analysis of the students' views on the effects of STEM education activities on their mathematics achievement are presented.

**Table 20.** Data on the Effects of STEM Education Activities on Students' Mathematics Achievement

| Categories | Codes | f |
|---|---|---|
| Mathematics | Positive impact | 10 |
| | Negative impact | 0 |
| | No impact | 0 |

When Table 20 is analyzed, it is observed that the students generally evaluate that the activities carried out have a positive effect on their academic achievement in mathematics. The following student statements support this finding:

*"We learned things about measuring time." [S2]*

*"For example, we solved math problems with Kahoot. We improved our math better." [S5]*

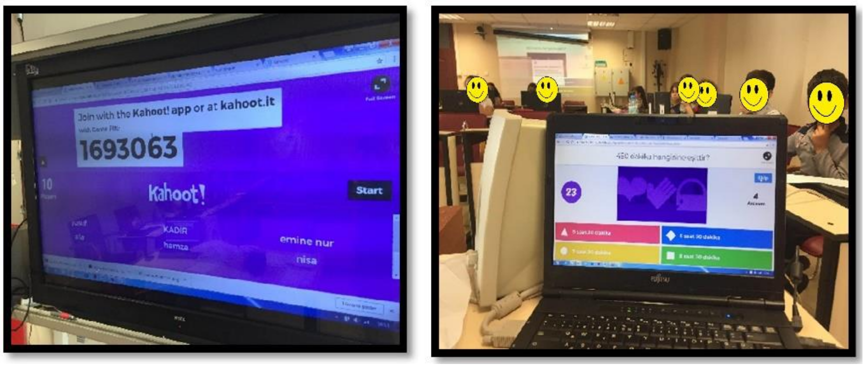


**Figure 8.** Kahoot Activities Related to the Time Measurement Unit

In Figure 8 above, there are images taken from the classroom and the teacher's screen during the kahoot activity for the time measuring unit. With the Kahoot activity, students' achievement levels in mathematics acquisition were determined, while on the other hand, it was tried to develop their competence in using technology and learning with technology.

The fact that the activities carried out were interesting and fun, increasing the motivation to learn mathematics, made the students love mathematics and positively affected their mathematics achievement. Student statements supporting this finding are as follows:

*"It was fun working with numbers in the bubble popper. "[S2]*

*"The Kahoot event was very nice. There were questions about measuring time. We tested ourselves. We have improved ourselves in this regard." [S3]*

*"This course made me love math even more and led to an increase in my math performance. My math has improved because games are always about math. For example, there was always mathematics in the balloon game. " [S6]*


**Figure 9**. Screenshots of the Balloon Game Designed by the Students on Mathematics Time Measurement

In Figure 9, there are screenshots of the interfaces of the time measurement games developed by the groups. The students designed games about measuring time in mathematics lesson with their group friends. In this process, students were provided to design their own unique games by establishing a link between the achievements of mathematics lessons and the achievements of coding. This situation contributed to the development of positive attitudes towards mathematics by enabling students to learn through games.

In addition, the fact that the coding activities carried out were related to mathematics and that it allowed students to associate mathematics with other disciplines and daily life positively affected mathematics achievement. Students expressed this situation as follows:

*"I used to have a hard time in math. But when I came here (at math) I got better. The fact that what we did there (games and animations) was based on mathematics made me love mathematics even more." [S4]*

*"Before the course, I couldn't use math and science together. But now I can use both together. For example, where I will use the cables is about science, and the length of the cables is about mathematics." [S5]*

The fact that the activities carried out improved the problem-solving skills of the students also positively affected their academic achievement in mathematics.

*"I used to not be able to solve difficult math problems. But now I'm trying to solve even more difficult problems. Because coding is not something to be learned right away. Coding is not memorized. It is necessary to understand the logic of coding." [S4]*

## Discussion, Conclusion and Recommendations

As a result of the research, it was uncovered that STEM activities were effective in changing primary school fourth grade students' attitudes towards science, technology, engineering and mathematics in a positive way. Kavacık (2019) and Akın (2019) stated that STEM activities had a positive effect on students' attitudes towards the four disciplines mentioned. In the study conducted by Yıldırım (2016), it was argued that STEM education activities implemented to seventh grade students led to a positive change in students' awareness and attitudes towards science, technology, engineering and mathematics. In the same way, Alıcı (2018) claimed that STEM activities caused a positive increase in students' attitudes towards these four disciplines and that students expressed in this direction. Parallel to this finding, the fact that primary school fourth grade students mostly expressed positive opinions about STEM education activities supports this statement. There are other findings in national and international studies that support this finding. Çoban, Akgün, and Tokur (2019) underlined that students who participated in STEM activities mostly expressed positive opinions about the activities. On the other hand, Güldemir and Çınar (2017) found that students mostly indicated positive opinions about STEM activities in their research to determine the opinions of teachers and students about STEM activities. Aydın and Karslı Baydere (2019) stated that during the STEM activities, the students had fun and their interest in the lessons increased. Şimşek (2019) affirmed that students mostly expressed positive opinions about STEM activities with expressions such as fun, exciting and contributing to learning. Students participating in the research conducted by Tozlu, Gülseven, and Tüysüz (2019) also described STEM activities as enjoyable. Acar (2018) expressed that primary school fourth grade students participate in STEM activities with pleasure. Özçakır Sümen (2018) articulated that STEM activities make mathematics teaching enjoyable.

The students participating in the research stated that their interest in engineering professions increased after the activities. In parallel with this finding, in the study conducted by Tseng, Chang, Lou, and Chen (2013), many of the students emphasized that STEM is important in science and engineering disciplines and stated that having professional knowledge would be beneficial in their future career choices. Hayden, Ouyang, Scinski, Olszewski, and Bielefeldt (2011) also concluded that STEM summer camp has a positive impact on students' attitudes towards engineering professions. Yavuz (2018), Gülhan and Şahin (2016) also argued that STEM activities applied in science lessons have a positive effect on students' orientation to career professions in this field.

MoNE (2016) emphasizes that STEM education is important for students to gain 21st century skills. STEM education contributes to the development of problem-solving skills by providing students with the ability to solve daily life problems (Morrison, 2006; Tseng et al., 2013). Şahin, Ayar, and Adıgüzel (2014) examined the effects of after-school activities involving science, technology, engineering and mathematics on students and argued that STEM activities can improve students' 21st century skills. Parallel to these statements, as a result of the research, it was concluded that STEM education activities are effective in the development of students' 21st century skills. In addition, the students participating in the research stated that STEM education activities contributed to the development of 21st century skills such as problem solving, cooperation and communication, critical thinking and creativity. In addition, there are research results that support these statements. Yıldırım (2016) concluded in his research that STEM activities improve students' 21st century skills such as cooperation and creativity. Akgündüz and Akpınar (2018) found that students' creativity and critical thinking skills improved with STEM applications. Teachers participating in the research conducted by Özçakır Sümen (2018) claimed that STEM education will improve many 21st century skills of students. Khanlari (2013) found that STEM education including robotic activities and Eguchi (2014) robotics and programming teaching are effective tools in the development of students' 21st century skills such as cooperation and teamwork, communication, social responsibility and productivity. Wagner (2008), on the other hand, recited that STEM education improves students' communication skills, curiosity and imagination, and 21st century skills. In addition to these, it is found out in the research that STEM activities improve students' coding skills. It can be considered natural to have such a result, since the STEM activities applied in the research include the acquisitions for teaching the Scratch program. Coding skill also positively affects the development of other 21st century skills (Kanbul & Uzunboylu, 2017). Based on this information, it is possible to talk about the effect of coding activities on the findings obtained in the research regarding the development of 21st century skills of students.

In the STEM education report of the MoNE (2016), it is pointed out that STEM education is important in increasing the success of mathematics in our country's national and international exams. In the study, it was concluded that although STEM education activities had a positive effect on the mathematics achievement of the primary school fourth grade students participating in the research, this was not significant. At this point, it should be underlined that the result is limited to the achievements of the time measurement unit of the mathematics course. While 6 hours of class time is allocated for this unit in the MoNE (2018c) mathematics curriculum, 9 hours are allocated for the implementation of the STEM lesson plans applied within the scope of the research. However, this period includes not only explaining the subject and doing sample exercises or solving questions, but also performing STEM education practices enriched with different activities. For this reason, there were not enough questions about the time measurement unit gains during the implementation. This may be a reason why the education provided does not have a significant positive impact on students' mathematics achievement.

There are research findings in the literature that support these statements. James (2014) compared the academic achievement of students in a secondary school with a mathematics curriculum according to the STEM education approach and a middle school with a traditional mathematics curriculum, and found that STEM education has no impact on mathematics academic success. As a result of his research, Hangün (2019) determined that eight-week robot programming education did not have a significant positive contribution to the mathematics academic achievement of 6th grade students in secondary school. On the other hand, there are also research results showing that STEM education activities do not have a significant positive impact on academic success in science courses (Bahşi & Açıkgül-Fırat, 2020; Güven, Selvi, & Parlak, 2018; Hiğde, 2019; Neccar, 2019). In addition, there are research findings that STEM education increases students' mathematics achievement. For example, Yıldırım and Altun (2015) claimed in their study that STEM education increases academic achievement positively. Venville, Wallace, Rennie, and Malone (2000) argued that STEM activities increase students' knowledge and skills in the field of mathematics by enabling them to use their mathematical knowledge. In the research conducted by Özdemir (2018), it was concluded that STEM applications positively affect the vocational mathematics achievement of vocational high school students. Wade-Shepherd (2016) found that students in STEM-based schools have higher science and mathematics achievements than those in traditional schools. In the same way, McClain (2015) determined that students studying at STEM school had higher mathematics achievement than students studying at other schools. In the research conducted by Özçakır Sümen (2018), STEM education, which emphasizes problem solving and technology, was implemented and it was concluded that the implemented activities increased the success in mathematics. Thomas (2013) concluded that STEM-based mathematics teaching has a positive effect on students' mathematics achievement and attitudes. Acar et al. (2018) also stated that STEM education positively affects the academic success of fourth grade students in science and mathematics and their thoughts on choosing one of the STEM careers fields in the future.

In the study, coding education given at primary school level was associated with mathematics education, and a STEM lesson plan was prepared for associating coding education with mathematics subjects. In addition, it was observed that the coding education given had a positive effect on the students' attitudes towards science, mathematics and technology.

As a result, it was found out that STEM education activities transformed primary school fourth grade students' STEM attitudes positively, developed their 21st century skills and had a positive impact on increasing their mathematics achievement. In line with these findings, the following recommendations can be made: 1) in order to detect the effect of STEM education on mathematics achievement, this study, which is limited to the achievements of a subject, can also be designed for different unit and subject acquisitions, 2) based on the finding that STEM research rest on coding education is limited at primary school level, more research can be conducted for this education level, 3) STEM research based on coding education can be carried out in different courses at different educational levels, 4) studies can be conducted with larger study groups to figure the impact of STEM education on mathematics achievement.

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