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# The Effect of Arduino-Based E-STEM Education on Students' Entrepreneurial Skills and STEM Attitudes

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**ABSTRACT** The research aims to determine the effect of Arduino-based E-STEM education on entrepreneurship skills and STEM attitudes of 4th-grade students within the scope of science and social studies education. This research was designed within the framework of the nested pattern of the mixed research method. "Single group pre-test-post-test experimental design" was used in the quantitative phase of the research. The sample consists of 20 fourth-grade students. "Science-Based Entrepreneurship Scale", "STEM Attitude Scale," and "Semi-Structured Interview Form" were used as data collection tools. The qualitative data obtained were analyzed with content analysis, and the quantitative data were analyzed with the SPSS 26.00 package program. When quantitative data were analyzed, It was determined that Arduino-based E-STEM education increased students' entrepreneurial skills (Z=-2.507, p: .012) and had a positive effect on their attitudes towards STEM (Z=-3.060, p: .001). When qualitative data were analyzed, the students reported growing interest in engineering and technology-related careers. They described how engineers use engineering design processes in the project preparation process, collaborate and support one another, take on responsibilities for the team, and feel a sense of accomplishment when the team succeeds.

**Keywords** E-STEM education, Entrepreneurship, STEM attitude, Arduino

## 1. INTRODUCTION

Especially in the last century, knowledge production in all fields is faster and more abundant. Individuals are expected to select knowledge from the available information efficiently and apply it effectively in their professional and personal lives. They also need adequate skills to adapt to the changing needs of society. Knowledge has become even more vital in the 21st century, and people need to have such skills (so-called 21st-century skills) to adapt to all aspects of life. In general, 21st-century skills include collaboration, communication, digital literacy, citizenship, problem-solving, critical thinking, creativity, productivity, and entrepreneurship. These skills have been called 21st-century skills to indicate that they are relevant to current economic and social developments rather than the skills of the last century, which were characterized by an industrial mode of production (Van Laar, Van Deursen, Van Dijk, & De Haan, 2017). One of these skills, entrepreneurship, has become one of the most essential concepts in the world over the last three decades. The focus of economic development has shifted to entrepreneurship to a greater extent. This increasing interest in the role of entrepreneurship in every field, especially in the economy, has brought entrepreneurship to a critical point and has been accepted by researchers from all segments that individuals who make up the society should embody this phenomenon (Raposo & Paço, 2011).

### 1.1 Entrepreneurship

Entrepreneurship involves the capture of ideas and the transformation of these ideas into products or the establishment of an enterprise that will offer services and products to the market. In other words, entrepreneurship can be defined as "the process of creating opportunities for an individual or a group to fulfill all the necessary facts to create value and growth, regardless of the resources they have (Küçükaltan, 2009). In order to create this process of delivering these opportunities, more technical applications and consistent learning approaches for innovation and creativity should be used in educational practices. Therefore, it is expected to produce the necessary tools for industrialization and national development by expanding habits of scientific attitudes that help students steadily acquire constructive reasoning skills and become more

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reliable in questioning real-life problems. Entrepreneurship and innovation are critical contributors to a country's economic prosperity. The most natural strategy to promote real-life applications that enhance students' productivity is reinforcing and developing students' skills through an integrated disciplinary approach. Interestingly, integrated curricula, in general, and STEM education can enhance student learning opportunities by connecting classroom objectives and tasks to the most relevant real-world applications outside of school (Eltanahy, Forawi, & Mansour, 2020).

Entrepreneurship includes skills that can be developed in the school environment, such as generating different ideas, evaluating opportunities, innovating, having the will to succeed, taking risks in achieving goals, being determined and persistent, and carrying out various projects and organizations. Starting the necessary work at an early age is crucial to raising individuals with developed entrepreneurial skills. The importance of entrepreneurship education has come to the fore at all levels of curricula (Yazıcı, Hacıoğlu, & Sarı, 2022). Research shows that STEM education can be practical in developing entrepreneurial characteristics (Davis, 2019; Eltanahy et al., 2020; Jin, Li, Yang, & Song, 2015).

### 1.2 STEM and Entrepreneurship

There are many different formats of the STEM approach. One of the most important 21st-century skills is E-STEM, which was created by adding entrepreneurship to STEM (Özdemir, Okuşluk, Yazar, & Gök, 2018). Some entrepreneurship processes that overlap diametrically with the engineering design that E-STEM education is based on are observing the environment, discovering needs, articulating ideas, choosing one of the ideas, creating a product, testing the product, adapting it to the environment, and marketing. For example, in engineering, students cannot solve problems without action, creativity, understanding of the context, or a personal attitude that enables them to deal with uncertainty. So, problem-solving in engineering requires action, and ideas cannot be achieved without creativity. The outside world is needed to understand customers' needs. These processes also constitute the dimensions of entrepreneurship (Dahl & Grunwald, 2021). In entrepreneurial contexts, understanding how ideas, opportunities, or problems are not discovered but generated is crucial when teaching entrepreneurial thinking because it provides a sense of agency for entrepreneurial actors. Similarly, in E-STEM education, ideas or problems can be generated from students' everyday lives and passions, often related to broader societal issues (Davis, 2019).

### 1.3 Arduino-Based E-STEM Education

One of the most critical factors ensuring active student participation in science lessons is including technological tools in the lesson environment. Within the scope of these educational technologies, robotic coding applications have also begun to be used in learning environments. In this context, various tools such as coding robots, intelligent objects, do-it-yourself kits and sets, virtual robot coding platforms, and programming languages have become widespread in teaching environments. Arduino is one of the leading robotic coding tools (Güven & Sülün, 2023). Arduino is a microcontrol unit. It is similar to the processor found in computers. It has a microcontroller used to control electronic devices. This microcontroller is programmed to perform the desired tasks. Arduino can offer rich learning environments that will enable students to acquire skills such as creating new things, algorithmic thinking, collaborative work, original and creative thinking, problem-solving, and engineering design skills (Perenc, Jaworski, & Duch, 2019). Finally, incorporating these devices and technologies into classrooms trains people who create projects, document them, and make them available online by sharing information about how they created them. These people have adopted Arduino to create and design their projects. This encourages more and more young students to pursue entrepreneurship and technology by giving them the feeling that they can understand how software and hardware come together to produce new technologies. In this regard, physical calculation activities with Arduino in STEM education can lead to meaningful results in terms of entrepreneurship in students (García-Tudela & Marín-Marín, 2023).

E-STEM applications in science education have been reported to improve students' participation, performance, and behavioral patterns in related courses. Furthermore, the necessity of participating in entrepreneurship education within the discipline of science education was emphasized, and it was seen that entrepreneurial traits could be acquired through science education (Bolaji, 2012). It has also shown that students' entrepreneurial traits can be easily developed in technology, Physics, Chemistry, and Biology because the links between real life and school subjects are evident in science education (Akinsola & Ogunleye, 2003). In science education, they need to understand and appreciate modern society's dependence on science and the current changes due to the development of science and technology. Science education should also be of such a nature that students acquire the social use of entrepreneurial skills in everyday science work in the classroom, outside the classroom, and in society in general (Agommuoh & Ndirika, 2017). In addition to science education, supporting students' interests in line with their skills from primary school onwards, enabling them to gain skills related to the profession or field of activity they want, shapes their future lives, and gives them a sense of self-confidence. In this way, we gain values produced socially and individually, have a sense of responsibility, and do not worry about the future. Social studies courses appear to be a favorable opportunity to gain these characteristics. It is seen that the Social Studies course is a suitable tool for developing entrepreneurship skills (Tarhan & Kılıç, 2017). For this purpose, the Ministry of National Education includes entrepreneurship among the skills it wants students to gain in the social studies curriculum. In this context (Ministry of National Education [MoNE], 2018);

1. The value of responsibility and the acquisition of skills such as cooperation, innovation, entrepreneurship, and research by students,

2. Values such as patriotism, sensitivity, and responsibility towards the natural environment, as well as skills such as entrepreneurship, innovation, and research, are also aimed to be acquired by students.

### 1.4 Importance of the Research

When the literature is examined, it is seen that there is no study conducted with Arduino-based E-STEM applications for in-depth understanding of primary school students' attitudes towards STEM and entrepreneurial skills within the scope of science and social studies education, and there is a minimal number of studies conducted with E-STEM education in this field (Mwasiaji, Mambo, Mse, & Okumu, 2022; Yazıcı et al., 2022; Şirin & Çelikkıran, 2021).

### 1.5 Purpose of the Study

This study aims to determine the effect of Arduino-based E-STEM education on 4th-grade students' entrepreneurship skills and STEM attitudes within the scope of science and social studies education. In line with this purpose, answers to the following question was sought.

*Does Arduino-based E-STEM education affect students' attitudes toward STEM and entrepreneurial skills?*

## 2. METHOD

### 2.1 Research Model

The mixed method is based on an in-depth explanation of a phenomenon using qualitative and quantitative data. In research based on this method, the questions should be of a quality that can be collected using qualitative and quantitative data collection tools. This research question was sought by correlating qualitative (semi-structured interviews) and quantitative (attitude and entrepreneurship scale) data.

The mixed research method involves collecting data from a single study or studies using qualitative and quantitative data collection tools to analyze and interpret the collected data (Creswell, 2014). Therefore, this study was designed within the framework of a mixed research method. Researchers should consider four basic principles when determining their mixed-method design: determining the priority of quantitative and qualitative stages, determining the level of interaction between quantitative and qualitative stages, determining the timing of qualitative and quantitative stages, and determining how and where to combine qualitative and quantitative data (Teddlie &Tashakkori, 2009).

### The Nested Design

This study was found to be more suitable for a nested design. The nested design is based on collecting and analyzing a secondary data set supporting a study's more dominant one. In this design, the researcher collects qualitative and quantitative data in a single study and analyzes the two data sets separately. These data are qualified to answer different research questions. This design is based on collecting and analyzing a secondary data set supporting a study's more dominant one. In this way, researchers embed a qualitative study into a quantitative experiment to support its experimental elements or to demonstrate differences. Qualitative data can be collected after implementation. The reason for using the qualitative design, which has a secondary, that is, supportive function in studies where the quantitative design is dominant, is the fact that the results obtained from the experimental process can be both related to and different from it, as well as determining whether the results obtained from the experimental process are significant (Dede & Demir, 2015).

**Table 1** Interview questions

| STEM Scale Sub-Dimensions | Questions |
|---|---|
| Personal and social applications of STEM | Did this practice have any impact on your future career choice? Why? |
| Learning science and engineering and linking it to STEM | How has this practice affected your thinking about science and engineering? Can you tell us about it? |
| Learning mathematics and relating it to STEM | Did this application impact your view of mathematics (like it, dislike it, is it easier to learn mathematics, its use in daily life, etc.)? Can you tell us about it? |
| Use of technology and learning | How did this practice affect your view of technology in your daily life (the place of technology in daily life and the use of technology, etc.)? Can you tell us about it? |
| Entrepreneurship Test Sub-Dimensions | |
| Teamwork | What would you say if you needed to evaluate your place in the group work you did with your friends during the implementation process (fulfillment of your duty, harmony within the group, etc.)? Can you tell us about it? |
| Need for success | How did you ensure your work's success (or completion)? Can you tell us about it? |
| Risk-taking | What did you do in case or when you encountered any negativity in your work during the implementation process? Can you tell us about it? |
| Effective communication | Can you tell us a little about the ideas and thoughts you conveyed to your friends and teacher during the implementation process? Can you evaluate yourself for this transfer? |

In the quantitative phase of the study, "One group pretest-posttest experimental design" was used. Single-group pretest-posttest experimental design is a method used in studies where there is no control group. This experimental design was used since no control group existed in this study. Data were obtained after and during the application (STEM-based robotic applications) to this group.

As seen in Table 1, the study's quantitative data were collected using scales before and after the application. The qualitative research data were collected by semi-structured interviews after the application.

### 2.2 Study Group of the Research

The study group of the research consists of a total of twenty fourth-grade students, eleven girls and nine boys. The criterion sampling method determined the research group, one of the purposeful sampling methods. The basic understanding of this sampling method is to include situations that meet a set of predetermined criteria. The criteria or criteria mentioned here can be determined by the researcher (Yıldırım & Şimşek, 2016). In this study, the criterion was that the participants had basic coding and robotics skills before.

### 2.3 Data Collection Tools and Process

#### Science-Based Entrepreneurship Scale

The "Science-Based Entrepreneurship Scale" developed by Deveci (2018) was used to determine students' entrepreneurial skills before and after the application. The scale consists of four sub-dimensions: "Risk Taking", "Need for Success", "Teamwork," and "Effective Communication". The scale consists of 13 items and is a 5-point Likert scale (Strongly Disagree, Disagree, Undecided, Agree, Strongly Disagree). The Cronbach alpha reliability coefficients of the scale are 0.7 for the "Risk Taking" factor, 0.58 for the "Need for Success" factor, 0.62 for the "Teamwork" factor, 0.51 for the "Effective Communication" factor, and Cronbach Alpha for the overall scale is 0.76.

#### STEM Attitude Scale

In the study, the STEM attitude scale was developed by Guzey, Harwell, and Moore (2014) and adapted into Turkish by Aydın, Saka, and Guzey (2017). The scale consists of 28 items. The Cronbach Alpha reliability coefficient of the scale adapted to Turkish was 0.94. The scale has four sub-dimensions: Personal and social applications of STEM, learning science and engineering and associating it with STEM, learning mathematics and associating it with STEM, and Using technology and learning. The scale is a 5-point Likert scale (Strongly disagree, Disagree, Undecided, Agree, and Strongly agree).

#### Semi-structured Interview Form

Collecting data through interviews is frequently used, especially in studies conducted in education. The interview technique can vary according to the phenomenon and process the researcher wants to reach (Merriam, 2009). After reviewing the relevant literature, the researchers drafted the semi-structured interview form. In order to check the extent to which the form served the objectives of the research, its comprehensibility, applicability, and academic accuracy, it was submitted to the opinions of experts in the fields of science education, social studies education, and Turkish language education. The interview form was finalized by considering the opinions of the experts. The finalized form consisted of eight questions covering the "Science-Based Entrepreneurship Scale" sub-dimensions" and "STEM Attitude Scale".

### 2.4 Data Analysis

The quantitative data from the Science-Based Entrepreneurship Scale and STEM Attitude Scale were analyzed with the SPSS 26.00 statistical program. Since the application group was less than 30 people, the Wilcoxon test, which is one of the non-parametric tests, was used for the analysis (Şen & Yıldırım, 2021). Qualitative data analysis: The data obtained from the semi-structured open interview questions were analyzed with the content analysis method to determine what changes Arduino-based E-STEM activities created on students' STEM attitudes and entrepreneurship perceptions. The answers given by the students to the open-ended questions in the interview were analyzed, and the situations that evoke the concept of STEM and entrepreneurship were coded. Related codes were brought together to form an ordinary meaning, and categories were formed. Frequency values and sample expressions of codes and categories are given in the findings section by creating a table. Content analysis aims to interpret similar data by associating them with the framework of specific themes and concepts and organizing them clearly and understandably so that readers can understand (Yıldırım & Şimşek, 2016). The main goal of content analysis is to reach concepts and relationships to explain the data obtained. The data obtained from the student interviews were analyzed with the Miles-Huberman interactive model, and different coders coded the data set recommended by Miles and Huberman to ensure reliability. The reliability of the study was calculated using the Miles Huberman formula (Reliability = agreement/agreement + disagreement). In the reliability study explicitly conducted for this research, a 93% consensus (reliability) was achieved with the other coders, and the internal consistency of the research was revealed. When the reliability value is above 70%, the analysis conducted by the researcher is considered reliable (Tavşancıl & Aslan, 2001).

#### Implementation Process

The applications made according to the weeks in the Arduino-based E-STEM application process are shown in Table 2.

**Figure 1** Some student application project example

**Table 2** Practices according to weeks in the arduino-based E-STEM implementation process

| Weeks | Implementation Process |
|---|---|
| Week 1 | Defining the Problem and Researching the Problem |
| Week 2 | Developing Possible Solutions and Choosing the Best One |
| Week 3 | Planning and Prototyping |
| Week 4 | Planning and Prototyping |
| Week 5 | Planning and Prototyping (Testing) |
| Week 6 | Planning and Prototyping (Testing) |
| Week 7 | Preparing the Project Poster |
| Week 8 | Presentation and Presentation |

Science-Based Entrepreneurship Scale and STEM Attitude Scale pre-tests were administered to the students before the implementation started. In the first week of the application, the students were divided into three teams: seven people in two teams and six in one team. The names of the teams were determined by the students themselves as "Kuzguncuk Team", "Teknokafa", and "Markopaşa".The students were made to feel the problem by talking about case studies on the problems that disabled people face in their daily lives. Each team was tasked with developing a solution to a challenge that would improve the lives of various impairment groups. Until the second week, the teams were asked to research this issue and identify the problem they would find a solution for. In the second week, due to the teams' research, a problem situation was determined for each team under the teacher's guidance, and they were asked to discuss the solutions to this problem. At the end of the lesson, the students chose the best solution among the solutions they researched and presented. In addition, the necessary materials were determined to create the project they would develop. In the third week, students made the necessary planning and division of labor before creating their projects. They made draft drawings before the project (Figure 1). The Kuzguncuk Team team planned to make a disabled parking lot system with barriers that can be opened with special cards that can only be used by people with disabilities, based on the problem of others parking in the parking lots of people with disabilities. Based on the problems experienced by the visually impaired people due to not seeing the obstacles in front of them, the Teknokafa team aimed to design glasses that measure distance and sing in different notes as they approach the distance level. The Markopaşa team planned to make a vibrating wristband that would enable people who are deaf or hard of hearing to be aware of a dangerous situation while sleeping. In the fourth week, they started to design the product with their teammates by using the necessary materials for the project. In the fifth and sixth weeks, they completed and tested the prototypes of the products they developed by correcting their deficiencies and writing the coding part. In the seventh week, students tested the products and made minor changes. In addition, they prepared a project poster to present the resulting product. The poster asked them to determine the project's purpose, target audience, slogan, cost calculation, estimated sales amount, and profit. In the eighth week, the product they produced at the project's end was presented with the project poster. After the presentations, the Science-Based Entrepreneurship Scale and STEM Attitude Scale post-tests were administered.

## 3. RESULT AND DISCUSSION

### 3.1 Findings related to the STEM Attitude Scale

As a result of the Wilcoxon Test conducted to determine whether there was a significant difference between the STEM attitude pre-test and post-test mean scores of the students in the treatment group, a statistically significant difference was found in favor of the post-test (Z=-3.060, p: .001).

### 3.2 Findings related to the Science-Based Entrepreneurship Scale

As a result of the Wilcoxon Test conducted to determine whether there was a significant difference between the Science-Based Entrepreneurship pre-test and post-test mean scores of the students in the treatment group, a statistically significant difference was found between the ranking averages in favor of the post-test (Z=-2.507, p: .012).

### 3.3 Findings from Semi-structured Interviews

Table 3 below shows the findings of the data obtained from the interview consisting of questions covering the sub-dimensions of the SEM Attitude Scale.

Table 3 shows the analysis of student's opinions on the effect of Arduino-based E-STEM education on their STEM attitudes. After the application, students' opinions on STEM attitudes were taken, and themes and codes were obtained from analyzing student responses. The themes that emerged from the analysis of student responses are "Career Choice", "Science", "Engineering", "Mathematics," and "Technology". The codes that emerged in the answers on the theme of Career Choice were that the interest in professions related to engineering and technology increased, affected the choice of profession, and did not affect the choice of profession. The students who took part in the application process mostly expressed that their interest in professions related to engineering and technology increased and that it affected their choice of profession in this direction. S-21 expressed his views about this situation as follows.

**Table 3** Findings related to the data arising from the interview consisting of questions covering the sub-dimensions of the SEM attitude scale

| Themes | Codes | F (frequency) |
|---|---|---|
| Choosing a Profession | Increased interest in professions related to engineering and technology. | 8 |
| | It influenced my choice of profession. | 7 |
| | It did not affect my choice of profession. | 6 |
| Science | Positive attitude towards science | 12 |
| | Establishing the relationship between science lessons and daily life | 5 |
| | To be able to use the information learned in the science course in the process of project preparation | 3 |
| Engineering | Learning the job description of the engineering profession | 9 |
| | Positive attitude towards engineering | 8 |
| | Using the engineering design process in project preparation | 6 |
| Mathematics | Using mathematics in the project preparation process | 11 |
| | Positive attitude toward mathematics | 8 |
| | Recognizing the relationship between coding and mathematics | 7 |
| | Establishing the relationship between mathematics and daily life | 5 |
| Technology | Learning what can be done with Arduino Card | 8 |
| | Learning sensors | 6 |
| | Understanding the working logic of technological products encountered in daily life | 4 |
| | Using technology for the benefit of society | 3 |
| | Learning new technological applications | 1 |

S-21. Since artificial intelligence and robotics will develop a lot in the future, I want to be an artificial intelligence and robotics engineer.

Based on the students' opinions, they learned what different engineering fields, such as Software Engineering, Artificial Intelligence Engineering, Robotics Engineering, and Computer Engineering, do during this application process. Their interest and attitudes towards these professions increased. Apart from these opinions, S-5, who thought that this application process did not affect the student's choice of profession but stated that he learned what engineering was and started to be interested in it, expressed his opinion.

S-5. It did not affect my choice of profession. I planned to be a soccer player but became interested in this field. I learned exactly what engineering is. As this practice is implemented in schools, better engineers will emerge in our country. It will contribute to the future of the country. Designers will do better things in the future.

When we look at the emerging codes belonging to the science theme, students expressed that they developed positive attitudes towards science at the end of this application process, they were able to establish the relationship between science lessons and daily life, and they were able to use the information they learned in science lesson in the project preparation process. Among these codes, the most common opinion expressed by the students was that their interest in science courses increased after this application process. S-13, one of the students related to the science theme, expressed his views as follows.

S-13. Science lessons become more enjoyable because we combine the problems in daily life with these subjects and think more solution-oriented. I realized that we often use science and engineering knowledge when solving a problem. While preparing our project, we also benefited from the information we learned in science class.

When the codes of the engineering theme were examined, it was seen that the students learned what the engineering profession does, learned about different engineering fields, increased their interest and attitudes toward the engineering profession, and used engineering design processes in the project preparation process. The view of S-2, one of the students related to the engineering theme, is as follows:

S-2. Before, I did not know what engineers do. Then, I realized that it was not something complicated but something fun. I like science and engineering more now. While doing our project, we made design drawings and prototypes like engineers. We did the work of engineers.

When the codes belonging to the mathematics theme are examined, it is seen that the students actively used mathematics in the project preparation process, developed positive attitudes towards mathematics, realized the relationship between coding and mathematics, and established the relationship between mathematics and daily life. S-1, one of the students related to the theme of mathematics, expressed his views as follows:

S-1. In our project, we used mathematics to calculate costs. We learned that mathematics is not only four operations. We learned that mathematics is part of daily life, and we also learned things like Arduino. We also used mathematics while coding on Arduino. For example, in calculating how many degrees the servo motor will turn, will it turn 90 degrees or 45 degrees? Here, we learned by applying angles. Using the ultrasonic distance sensor, we learned by estimating the distance and practicing the distances. It is enjoyable to use math with coding this way.

Based on the students' opinions, they used mathematical knowledge mostly in cost calculation during the project preparation process. The students in the application process stated that the situations in which they established the relationship between coding and mathematics were writing the estimated length measurement of the ultrasonic distance sensor, deciding how many degrees the servo motor should rotate, and understanding the logic of 1 and 0 in coding. During this application process, the students' seeing that mathematics has an equivalent in daily life positively affected their attitude and motivation toward mathematics.

When the codes related to the technology theme are examined, it is seen that the students learned what Arduino is and realized what can be done with this card during this application process, learned what many sensors do and used these sensors in their projects, understood how many technological products they encounter in daily life work, expressed ideas about how technological tools can be used for the benefit of society and learned new technological applications. S-13 expressed his views about these situations as follows.

S-13. I realized what you can do with electronic cards such as Arduino. I learned how most of the technologies I see used in daily life work and which sensors they have. My interest in technology has increased even more after this application. I realized that most things in daily life are done with coding. I understood the logic of the working principle of the mechanisms I encounter in daily life.

Below are the findings of the data obtained from the interview consisting of questions covering the sub-dimensions of the "Science-Based Entrepreneurship Scale".

Table 4 shows the analysis of students' views on the entrepreneurship skills of Arduino-based E-STEM education. Students' opinions on entrepreneurship skills were taken after the application, and themes, sub-themes, and codes were obtained from analyzing student responses. The themes that emerged from the analysis of student responses are "Teamwork", "Effective Communication", "Self-Control", "Need for Success", "Risk Taking", "Innovation", "Time Management," and "Marketing".

When the positive codes belonging to the theme of teamwork are examined, it is seen that most of the students stated that they worked in harmony, cooperation, and solidarity with the team during the project preparation process and that the individuals in the team contributed to the team by taking responsibility. A few of the students expressed disharmony within the team in this process, that there were people who did not take responsibility, and that

**Table 4** Findings related to the interview data consisting of questions covering the sub-dimensions of the "Science-Based Entrepreneurship Scale"

| Themes | Sub Theme | Codes | f (frequency) |
|---|---|---|---|
| Teamwork | Positive Codes | Team Cohesion | 12 |
| | | Cooperation | 8 |
| | | Solidarity | 6 |
| | | Taking Responsibility | 5 |
| | Negative Codes | Disharmony within the team | 5 |
| | | Not taking responsibility | 3 |
| | | Being undecided | 2 |
| Effective Communication | Positive Codes | Ability to communicate positively | 15 |
| | | Respect for different ideas | 6 |
| | | Resolving conflicts with correct communication | 3 |
| | Negative Codes | Difficulty communicating | 4 |
| | | Team members not listening to each other | 3 |
| | | Ignoring different opinions | 1 |
| Need for Success | Positive Codes | Completing his/her role in the team | 14 |
| | | Realizing what you can do | 5 |
| | | Feeling a sense of achievement from Contributing to the team | 3 |
| | Negative Codes | Failure to complete the assigned task | 1 |
| Risk Taking | Positive Codes | Trying practical solutions to reach a Solution quickly | 4 |
| | Negative Codes | Not Taking Risks | 16 |
| Innovation | Positive Codes | Making original designs | 5 |
| | | Offer different solutions | 3 |
| | | Using a product for a different purpose then the existing one | 1 |
| Time Management | Positive Codes | Good use of time | 10 |
| | | Delivery of the project within the given time | 8 |
| | | Planned Work | 5 |
| | Negative Codes | Failure to deliver the project within the Given time | 3 |
| Marketing | Positive Codes | Product Promotion | 13 |
| | | Cost Calculation | 11 |
| | | Determine the Estimated Sales amount and The profit to be generated | 5 |

being indecisive created problems in the team, which were evaluated as negative codes. The opinions of S-6 and S-18, who stated that they worked in harmony within the team, are as follows.

Ö-6. We did our project in teamwork. We first made the designs on our own. Then, we unanimously decided which was the best design. Moreover, we all chose the best one as a team. So we worked in harmony. I like working as a team very much. Besides, I would not have finished it so quickly if I had worked alone.

S-3 stated that they could not work in harmony within the team because the team members did not listen to each other, the team leader could not manage the process well and acted biasedly.

S-3. We had some problems with the team. No one was listening to each other. I said let us talk in turns, but they did not listen. The team leader did not say anything, either. He only did what his favorite friends said.

When the codes belonging to the theme of Effective Communication are examined, it is clear that students had positive and negative experiences in terms of communication. When we look at the positive codes related to this theme, most of the students stated in their opinions that they were able to communicate positively during this application process, that they respected different ideas within the team, and that they were able to solve the conflicts they experienced among themselves by using the correct communication language. S-5 expressed his views that they communicated effectively during the implementation process.

S-5. I think I communicated well with my friends. We found excellent ideas. Everyone listened to each other's ideas very well. We respected each other's ideas. Furthermore, we decided together which idea should be implemented first. When we encountered a problem, we were able to solve it by talking politely.

The students who experienced negative communication stated that they had communication problems due to their teammates not listening to each other and ignoring different ideas. S-12 expressed his opinion about this situation as follows.

S-12. We had problems with communication. Some people did not listen to each other's ideas. Our friend always wanted to talk and tried to get his way. She did not listen to anything we said. She also said that girls cannot do anything. That made us feel bad.

When the codes belonging to the theme of Need for Success are examined, the majority of the students stated in their opinions that they completed the task assigned to them in the team in this process, realized what they could do, and felt the sense of success of contributing to the team with their work. S-9 expressed their opinions about this situation as follows.

S-9. I did everything I could to make my work successful. I helped while cutting the cardboard. I helped in the coding part. I also guided my friends. I did the cost calculation because I am good at mathematics. I like doing a job related to mathematics.

Only S-6 stated that he did not fulfill the task assigned to him. He stated that he had a conflict with the team leader and did not complete the task. The opinion of S-6 about this situation is as follows.

S-6. Since the team leader always tried to do what he wanted and gave me tasks that I did not want, I left the task given to me halfway. Finally, another friend completed the task that I had left unfinished.

When the codes belonging to the theme of Risk-taking are examined, it is seen that most students do not prefer to take risks, and a team ta kes risks by trying quick, practical solutions to use time well. S-2 expressed his opinion about this situation as follows.

S-2. In order to complete the project on time, we cut something that we should normally measure and cut it with a ruler without measuring it at all to make it faster. We would never have finished our project if we had cut it wrong. However, by taking a risk, we used the time well.

When the codes belonging to the theme of innovation were examined, the students stated that they made original designs related to their projects, could produce more than one solution to the subject, and could use a product for different purposes. Related to this, T-8 expressed his opinion as follows.

S-8. We found many solutions for our project, but among these solutions, we tried to find the one that had never been done before and chose it. We made our design in the most interesting and unprecedented way.

When we look at the positive codes of the time management theme, there are codes for using time well, working in a planned manner, and delivering the project on time, while the negative code is the failure to deliver the project on time. When the teams formed during the implementation process were evaluated in terms of time management, three of the four teams did not have any problems with time management and delivered their projects on time. Only one team did not use time well and could not deliver their projects on time. Students who used time well stated that they made plans and followed the plan. In this sense, planning will positively affect using time management correctly. T-7 expressed his opinion about this situation as follows.

S-7. We had problems such as being unable to use the time well because we did not plan. In the next study, we used the time better by planning and determining what everyone would do in advance.

At the end of the application process, each team prepared a promotional poster of the project, and in this poster, the presentation of the product, cost calculation, estimated sales amount, and the profit to be obtained from the product were stated. In this sense, the codes related to marketing were obtained by the students in the process of preparing the poster at the end of the process. When the codes belonging to the marketing theme were examined, the students stated that they made product promotions related to the projects they prepared, and, in this context, they determined the cost calculation, estimated sales amount, and profit to be obtained from the product. The students stated that they should advertise the product on platforms such as TV and social media, have a slogan to make the product memorable, and have an exciting advertisement text to increase interest. In this situation, S-3 expressed their opinions as follows:

S-3. We prepared posters to promote our projects. We told what needed to be done for everyone to hear about our project. For example, we chose to advertise on Instagram. We created a slogan for our project and prepared the advertisement's text. After preparing our team poster, we presented all these to our friends and teacher.

The opinions S-20 about calculating the cost of the marketing theme and the estimated sales amount and profit are as follows.

S-20. We researched the price of the parts of the product we developed on the internet and determined how much it would cost. Then, we calculated how much we should sell this product, how many we would sell, and how much we would earn.

It was concluded that Arduino-based E-STEM education increased students' entrepreneurial skills (Table 5). The results obtained in this study are in parallel with the results obtained in the studies of Meral and Yalçın (2022), Kalik and Kırındı (2022), Zokowski, Geramita, Ashdown, Brooks, and Thompkins (2016), Akrami (2022), Ahmad and Siew (2021), Olawale et al. (2020), Shahin, Ilic, Gonsalvez, and Whittle (2021). Likewise, it was found that Arduino-based E-STEM education positively affected students' attitudes toward STEM (Table 6). The results obtained in this study overlap with those of Çetin and Kahyaoğlu (2018), Jin et al. (2015), and Irak (2019).

When the qualitative data on STEM attitudes were evaluated, students stated that their interest in engineering and technology professions increased in their career choices. In addition, students stated that they were able to establish the relationship between science lessons and daily life and that they were able to use the information they learned in science lessons during the project preparation process. She also stated that students learned what engineering professions do in different fields and used engineering design processes in project preparation. Similarly, students stated that they actively used mathematics in the project preparation process, developed a positive attitude towards mathematics, realized the relationship between coding and mathematics, and were able to establish the relationship between mathematics and daily life. These results align with the study conducted by Coşkun (2022). Students stated in their opinions that they understood how many technological products they encountered in daily life work, expressed ideas about how technological tools can be used for the benefit of society, and learned new technological applications. This result coincides with the study conducted by Karakaya (2017).

When the qualitative data on entrepreneurial skills are evaluated in general, students stated that they worked in harmony, cooperation, and solidarity with the team and that individuals contributed to the team by taking responsibility. This result is similar to Pekbay (2017) and Yıldırım (2016). Most students stated that they could communicate positively during this application process, respect different ideas within the team, and resolve conflicts using the correct communication language. In parallel with these results, Yasak (2017) supports each other with the results obtained by Yıldırım (2016).

In this process, the students stated that they completed the task assigned to them in the team, realized what they could do, and felt a sense of achievement from contributing to the team with their work. In addition, students stated that they did not prefer to take risks. Students stated that they made original designs related to their projects, were able to produce more than one solution to the subject, and were able to use a product for different purposes. The students stated that they were successful in time management and marketing. The students stated that they promoted the product related to the projects they prepared, and, in this context, they determined the cost calculation, estimated sales amount, and the profit to be obtained from the product. These results align with Charney and Libecap (2000); Şirin (2020). As a result, it was seen that the qualitative results and quantitative results

**Table 6** Wilcoxon test results for STEM attitude scale pre-post test scores

| | Post Test-Pre-test | N | Ranking Average | Ranking Total | Z | p |
|---|---|---|---|---|---|---|
| STEM Attitude Scale | Positive Sequence | 15 | 13.00 | 195.00 | -3.360 | .001 |
| | Negative Sequence | 5 | 3.00 | 15.00 | | |
| | Equal | 0 | | | | |
| | Total | 20 | | | | |

**Table 5** Wilcoxon test results for science-based entrepreneurship scale pre-post test scores

| | Post Test- Pre-test | N | Ranking Average | Ranking Total | Z | p |
|---|---|---|---|---|---|---|
| Science-based Entrepreneurship Scale | Positive Sequence | 14 | 10.21 | 143.00 | -2.507 | .012 |
| | Negative Sequence | 4 | 7.00 | 28.00 | | |
| | Equal | 2 | | | | |
| | Total | 20 | | | | |

obtained in this study support each other. In this sense, it can be said that Arduino-based E-STEM activities have positive effects on students' attitudes toward STEM disciplines and entrepreneurship skills.

## 4. CONCLUSION

Arduino-based E-STEM education was determined to increase students' entrepreneurial skills and positively affect their attitudes toward STEM. The students stated that their interest in engineering and technology professions has increased; what the engineering profession does, they use engineering design processes in the project preparation process, they work in harmony, cooperation, and solidarity with the team, they contribute to the team by taking responsibility, and they feel the sense of success that contributes to the team. Recommendations of this research;

In this study, the scientific and social domains serve as the foundation for the content of E-STEM applications. However, similar studies can be carried out using data from other disciplines, including mathematics.

This study showed that students disliked taking chances in E-STEM applications. The development of this talent can be aided in this situation by experimental research that fosters conditions where students can take chances when using STEM applications.

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