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Evaluation of Products and Educational Perspectives of Middle School Students Trained at the STEM Artificial Intelligence Center

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ABSTRACT

This study aims to evaluate the products using product evaluation form resulting from activities conducted by 5th-grade middle school students trained at the STEM Artificial Intelligence Center and to determine the students' perspectives on this education. The research, which uses the case study method, a qualitative research design, was conducted with 5th-grade students. Product Evaluation Form and Student Opinion Form were used in the evaluation of the data. The data were analyzed using the descriptive analysis method. According to the research findings, the products created by the students at the end of a term of STEM activities were determined to be original, adequate, diverse, and made using the materials provided. It was observed that in the material creation process, students collaborated in groups to produce a product; during the scientific research process, students answered open-ended questions by discussing among themselves and produced solutions to given real-life problems; and in the process of integrating what they learned from different subjects, students gained new knowledge from this group work and left happily. Considering the advantages, it can be said that it is important to increase the number of students trained at the STEM artificial intelligence center and the frequency of these trainings.

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1. Introduction

In the rapidly advancing information age characterized by technological developments, students are faced with new and complex problems. The skills required to solve these problems, which arise in daily life, extend beyond mere knowledge accumulation to include dynamic abilities (Scott, 2020). To address these problems, students need to develop 21st-century skills such as critical thinking, problem-solving, communication, and collaboration (English, 2021; OECD, 2021). Education systems must adopt innovative approaches to impart these skills and prepare students for the dynamic nature of the information age (Bybee, 2010; Wagner, 2008; Windschitl, 2009). This can be achieved through certain classroom practices. Indeed, this education can be provided through a system comprising science, technology, engineering, and mathematics, known as the STEM approach (Bybee, 2010). Countries such as the USA, China, Germany, Japan, and the United Kingdom, which lead changes in engineering and technology, argue that the interaction between different disciplines such as science, technology, engineering, and mathematics is as important as scientific literacy (Carnevale et al., 2011; Heinze and Kuhlmann, 2008; Huang, 2017; Li and Schoenfeld, 2019; Macdonald and Williams, 2009; Marginson and Wende, 2007; Oba and Shibayama, 2009; Olson and Riordan, 2012; Smith and Gorard, 2011; Wissema, 2009). This model, formed by integrating these four disciplines, holds a significant place in today's educational systems (Gonzalez and Kuenzi, 2012).

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STEM provides an integrated perspective by combining different disciplines, allowing students to approach complex problems from a broader context (Baran et al., 2016). STEM education, aimed at training individuals capable of solving the complex problems of the information age, focuses on enabling students to relate the theoretical knowledge acquired in school to real-life applications and to produce rational solutions to everyday problems through this knowledge (Şahin et al., 2014). According to Gardner (2004, 2013), future generations need to translate theoretical knowledge from sciences such as mathematics and science into technology and engineering. Currently implemented educational models often teach science, technology, engineering, and mathematics as separate disciplines. However, the complex problems of the modern world require these disciplines to be addressed interactively (Honey et al., 2014). In this interdisciplinary teaching approach, concepts and skills are emphasized while combining common learnings and content from the disciplines (Drake and Burns, 2004). In this interdisciplinary approach, connected, sequential, intertwined, shared, and integrated models come to the forefront (Wang, 2012). These concepts are also frequently used in definitions of the STEM education model (Gencer et al., 2019).

A review of the literature shows that STEM is represented in various ways. These models range from a single discipline STEM to integrated STEM. For instance, Bybee (2013) defined nine models of STEM education for policymakers, educators, and researchers: Single Discipline Example, STEM as a Reference for Science and Mathematics, Separate Disciplines, Science and Mathematics Connected with Technology or Engineering Programs, Interdisciplinary Coordination, Integration of Two or Three Disciplines, Integrated Disciplines, STEM as a Transdisciplinary Course or Program, noting that these models can be used together and none is superior to the others. Breiner et al. (2012) described STEM as a curriculum that integrates the concepts of science, technology, engineering, and mathematics in a way that reflects the practices of professionals working in the STEM field, while Bryan et al. (2015) described it as an integrated curriculum where students participate in an engineering design competition. Studies conducted in various disciplines have shown that students in an integrated model perform better than those in the current instructional model, which includes separate disciplines (Czerniak et al., 1999; Hinde, 2005). Additionally, the use of an integrated model has been found to improve non-cognitive learning outcomes such as interest in STEM (Mustafa et al., 2016; Riskowski et al., 2009) and motivation towards STEM learning (Wang et al., 2011; Thibaut et al., 2018).

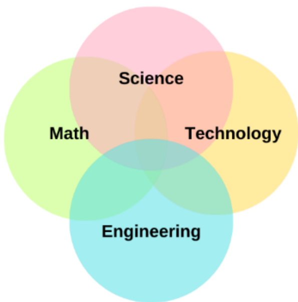


Figure 1. Integrated STEM Education

In this study, Bybee’s (2013) Integrated Disciplines model (Figure 1) was used. This model is an effective educational framework that facilitates the development of students' knowledge and skills in the fields of science, technology, engineering, and mathematics (STEM) (Beers, 2011). This educational model encourages students to understand the connections between these disciplines and to integrate this knowledge to enhance their problem-solving abilities (Hmelo-Silver, 2004; MEB, 2016). Mathematics education holds critical importance in the face of the opportunities and challenges presented by the information age. Despite the prevalent bias and perception of difficulty towards mathematics in our country (Çetin, 2020), the accepted mathematics curricula aim to change this perception.

This study evaluates the education received by students involved in STEM education and the products they created during the educational process. In integrated STEM education, it is expected that students design products and, in this process, develop their creativity, inquiry, critical thinking skills, and technological literacy, either consciously or unconsciously (Fan and Ritz, 2014; Fortus et al., 2005; Morrison, 2006). The products resulting from STEM activities are important for evaluating students' problem-solving and decision-making processes, and they also allow for commentary on the quality of the implemented STEM activity (Doğan, 2020; Okulu, 2019).

This study distinguishes itself from other studies in literature by observing the work of student groups at the STEM Artificial Intelligence Center, an institution focused solely on achieving educational program outcomes through integrated STEM education, and by comprehensively evaluating their products. The aim of this study is to evaluate the products that emerged as a result of the activities carried out by 5th grade students who received education at the STEM Artificial Intelligence Center from a multidimensional perspective, to analyze the skills, cooperation and problem solving approaches that students developed in this process, and to discuss the necessity of expanding such education in the light of scientific data by revealing the effect of STEM-based artificial intelligence education on students' scientific process skills, creativity and critical thinking competencies.

2. Conceptual Framework

2.1. Design Process and Student Participation

In STEM education, the design process is a critical stage that enables students to develop skills such as creative thinking, problem solving and teamwork (Banilower et al., 2013). In this process, students should use all materials while creating their designs and should be able to request new materials when necessary (Dasgupta, 2019). Once they have created their designs, they engage in group discussions to share and develop their thoughts (De Vries, 2018). Drawing sketches and making prototypes allows students to concretize their ideas and develop critical thinking skills in the process (Bybee, 2014). At the end of this process, students are expected to produce functional and original products (National Research, 2009). Collaborative group work both enables students to learn from each other and makes them active participants (Kennedy and Odell, 2014). Research shows that group work improves students' social skills and increases their motivation to learn (Cunningham and Lachapelle, 2014).

2.2. Scientific Research Process and Inquiry

The scientific inquiry process aims to develop students' skills such as inquiry, hypothesis development, data collection, and generating solutions in STEM education (Cohen and Waite-Stupiansky, 2019). In this process, by answering open-ended questions, students not only focus on reaching the correct answer, but also think about developing solutions and problem-solving strategies (Cunningham, 2009). The projects enable students to actively use their scientific thinking skills (MacIsaac, 2019). Moreover, this process should be supported by visual materials used during students' learning; these visuals help students to better comprehend the topic and concretize the design they think about (Li et al., 2019). Students have the opportunity to reflect on their projects through discussions throughout the learning process, which reinforces their inquiry skills (Sweller et al., 2019).

2.3. Integrating Learning from Different Subjects

STEM education helps students develop the ability to combine what they learn from different fields (T. R. Kelley and Knowles, 2016). Group work is of great importance at this point (Johansson-Sköldberg et al., 2013). While working on projects, students share each other's knowledge and integrate what they have learned in different fields (Strimel et al., 2019). This process helps them develop their interdisciplinary thinking skills (Dym and Brown, 2012). Moreover, group interactions strengthen students' social skills and communication abilities (Ahmed et al., 2003). Students who act together learn new information more effectively and reinforce this knowledge by sharing their products with other group members (Razzouk and Shute, 2012). At the same time, the corrections made on their products enable students to develop their critical thinking skills (Wrigley and Straker, 2017).

Examining STEM practices, it is evident that the engineering design process is frequently utilized (Eren and Dökme, 2022). The engineering design process has become the most commonly used approach in STEM because it is deemed suitable for identifying and solving real-world problems through STEM applications (Carberry and McKenna, 2014; Eren and Dökme, 2022). The use of the engineering design process in STEM education is a highly effective method for imparting complex problem-solving skills and promoting interdisciplinary learning (Brewer and Clark, 2012; Farrell et al., 2012). This process systematically teaches students the stages of identifying a problem, conducting research, developing solutions, creating prototypes, testing, and refining (Dym et al., 2005). The engineering design process implemented during the activities of this study is illustrated in Figure 2.

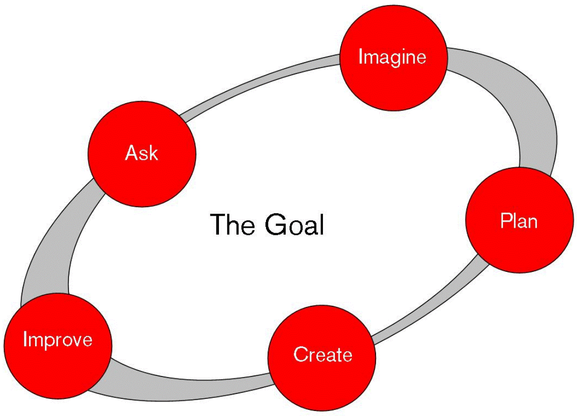


Figure 2. Engineering Design Process (Engineering is Elementary [EiE], 2018).

As seen in Figure 2, the engineering design process includes the stages of asking, imagining, planning, designing, and improving (Engineering is Elementary [EiE], 2018). A well-prepared real-life problem should be the starting point for these steps (Elmas, 2020). Students can return to previous steps and restart the process when they think they have made mistakes. This design process allows students to produce solutions to real-world problems (Elmas, 2020) and learn from mistakes through an iterative approach (Bodner and Elmas, 2020). Additionally, students develop STEM skills such as teamwork, peer learning, and critical thinking while generating various solutions and improving their designs (Bodner and Elmas, 2020). This way, students learn to approach problems with a holistic perspective by integrating scientific knowledge, technological skills, engineering practices, and mathematical analyses (Wang et al., 2011).

3. Method

3.1. Research Model

In this study, the education and the products created by students at the STEM Artificial Intelligence Center in our country were evaluated. Therefore, a qualitative research design was adopted, specifically the case study method. This approach aims to comprehensively understand the effects of variables on the case and how they are affected by the case. This study aimed to conduct a detailed examination by gathering student opinions about the education provided and evaluating the products they created during the instructional process.

3.2. Participants

The participants of the application were students who voluntarily applied to the STEM Artificial Intelligence Center and were admitted through a pre-prepared STEM entrance exam during the 2023-2024 academic year. The STEM entrance exam is prepared by teachers who are experts in the STEM field. This entrance exam is conducted before the start of the academic year, and all students who apply for the exam can take it. The STEM entrance exam measures students' creativity, visual memory, logical reasoning, analytical thinking, and problem-solving skills. The participants were selected using purposeful sampling. This study evaluated the education received by 5th-grade students and the products they created during the instructional process. Studies involving 5th-grade students are essential for evaluating the impact of learning and teaching methods, as this grade level is a critical period for cognitive and academic development (Piaget, 1977; Eccles, 1999; Wigfield and Eccles, 2000). Sixty 5th-grade students were divided into four groups of 15 students each, forming four groups of four students. The participants included 16 5th-grade students, nine girls and seven boys, who scored the highest on the entrance exam.

3.3. Data Collection Process and Tools

Data were collected through observation and document analysis. The Product Evaluation Form was used for observation, and the data obtained from the Student Opinion Forms were analyzed through document analysis. STEM activities developed by the researcher were applied to the students, and the products created by the students were evaluated using the Product Evaluation Form.

3.4. Product Evaluation Form

The form used to evaluate students' products includes three sections: Design Creation Process, Scientific Research Process, and Integrating Learning from Different Subjects (İzmir Provincial Directorate of National Education, 2018) (Look at Table 2). In the Design Creation Process, students' designs are evaluated based on originality and appropriateness to the purpose. In this process, students' learning through inquiry was facilitated. They discussed their projects with each other, answered open-ended questions, and produced solutions in line with GYP. The visuals used during the lesson were sufficient for the designed product. In the Integrating Learning from Different Subjects process, students' competencies before the activity are evaluated. In the Integrating Learning from Different Subjects process, the focus is on what students learned during the activity after the activity. This form was developed by the researcher, and expert opinions were obtained from a mathematics educator specializing in mathematics education and a mathematics teacher at the STEM Artificial Intelligence Center to ensure the validity and reliability of the form. Based on the expert opinions, necessary adjustments were made to the items in the form. After the corrections, the 19-item product evaluation form consisting of three processes was applied to 16 5th-grade middle school students. If the expected situation was not met by the students, it was scored as 0; if partially met, it was scored as 1; and if fully met, it was scored as 2, and the total scores were calculated.

3.5. Student Opinion Form

The implemented STEM activities were evaluated using the Student Feedback Form developed by researchers. The prepared form was refined based on expert opinions. The form includes questions such as *"STEM education is similar to... because... Please complete the blanks," "If you compare the activities you did with other class activities, what benefits might they have provided you?", and "If you were to describe the key features of STEM education in three words, which words would you choose? Why?"* Students were given one class period to answer these questions, and they were encouraged to answer the questions voluntarily and independently of each other.

3.6. STEM Activities

STEM, which integrates disciplines of science, technology, engineering, and mathematics, aims to solve real-life problems and motivate students with engaging experiences. This educational approach focuses not only on product outcomes but also on process and skill development. This approach facilitates the understanding of real-life problems and enhances students' problem-solving abilities (Akarsu et al., 2020). The activities in this research were developed considering 5th grade achievements, achievements related to other STEM disciplines, interdisciplinary relationships, everyday life problems, waste/economic materials, and student level. The activities were developed based on the Engineering Design Process (Engineering is Elementary [EiE], 2018). In the initial stage, questions that students could ask in these activities were considered, ensuring that these questions are achievement-oriented. Subsequently, a narrative was constructed where students could imagine and design their designs. Finally, environments were created to encourage students to develop their designs, and activities were developed accordingly. The views of two faculty members specializing in mathematics education were consulted regarding the developed activities. The experts are also individuals who work in STEM education, problem-solving, and construction areas. Experts evaluated the activities based on their suitability for mathematical content, their mathematical nature, being a STEM problem involving different disciplines, solvability, context, language, complexity, and suitability for student level. Necessary adjustments were made based on these evaluations, and the activities were finalized for use in this application. The activities prepared for use in this implementation are presented in Table 3.1 as follows:

Table 1. Statistical results

Activity No	Weeks	Activity Titles	Sub-learning Areas
Activity 1	Weeks 3 and 4	Designing and creating a mining product for space exploration	Natural numbers and operations with natural numbers
Activity 2	Weeks 5 and 6	Designing and creating a system for easy transportation from the river	Natural numbers and operations with natural numbers
Activity 3	Weeks 7 and 8	Designing and creating durable and economical pavement stones	Natural numbers and operations with natural numbers
Activity 4	Weeks 9 and 10	Designing and creating a Ferris wheel	Fractions and operations with fractions
Activity 5	Weeks 11 and 12	Designing and creating a place for a phone to stand while charging	Fractions and operations with fractions
Activity 6	Weeks 13 and 14	Designing and creating a product for people sensitive to hot items	Decimal representation

Table 1's first activity is related to the sub-learning area of natural numbers and operations with natural numbers. This activity provides students with a concrete example from real life about distant distances using nine-digit or fewer numbers encountered in mathematics class. Additionally, they see the mathematical representation of distances between Earth, Sun, and planets seen in science class, occasionally converting this into miles, a variable distance. In this process, they will also experience division and multiplication shortcuts. By completing the required work step by step, they will use technology, work collaboratively as a team, and progress according to a specific plan, thereby achieving engineering outcomes. The second activity also encompasses the same sub-learning area as the first activity, but here students will design a product by performing mathematical operations using nine-digit or fewer numbers learned in math class and calculating the cost of the product. While calculating product costs in Team Drafts, they will also learn the connection and conversion between cents and lira. Engineering gains will be provided when designing a bridge and experimenting to understand the logic of friction force seen in science class. The third activity also addresses the topic of the same sub-learning area. In this activity, students will design a new model based on pavement stones seen in almost every road and sidewalk today. Students will be asked questions about the functions of pavement stones and where they are found. The expected answer here is that pavement stones are used in places where grass is not to be stepped on. Students will be reminded that pavement stones are made so that living beings are not harmed in such environments, thereby acquiring knowledge about living organisms in science. With the model they design, the importance and usability of creating a new product will be questioned. Additionally, by making mathematical calculations and creating financial statements, they will gain insight into how operations with natural numbers can be used in daily life. The fourth activity is related to the sub-learning area of fractions and operations with fractions. Students will utilize fractions to design a Ferris wheel, observe the motor operation system and the rotational speed of the motor with a single battery, and comprehend the conversion of electrical energy to kinetic energy and vice versa. They will be curious about the necessity of mathematics in engineering by placing a product with the materials provided and making mathematical calculations. The fifth activity is also related to the sub-learning area of fractions and operations with fractions. In this activity, students will use the operation feature of fractions to calculate costs, learn the representation of fractions as decimal numbers, and gain knowledge about their use in daily life. By using the materials provided to create a product, they will learn about conductive materials that they will study in sixth-grade science classes and gain engineering outcomes to find solutions to the problems given using technology. The final activity, the sixth activity, is related to the sub-learning area of decimal representation. While designing a product for individuals with temperature sensitivity, students will perform operations related to decimal numbers. The focus will be on the decimals in coins. Ideas will be generated regarding the use of decimal numbers. In addition, topics such as heat, temperature, and heat exchange, which are science gains, will be mentioned. Students will learn about the hydraulic system and its usage objectives as engineering gain, design a product to be used in daily life, and facilitate their work.

In addition to all these objectives, with effective group work, each student will see themselves as part of a team and will achieve social gains by fulfilling the necessary responsibilities.

3.7. Implementation Process

In STEM education, the steps followed in the learning environment are Design, Implementation, and Evaluation. In the Design phase, STEM activities were created within the framework of 21st-century skills. In the Implementation phase, students were informed about how STEM activities would proceed, exercises were conducted to show students how the process would work. In the Evaluation phase, the products presented were evaluated. A more detailed explanation of the steps followed in this implementation is provided in Figure 3.

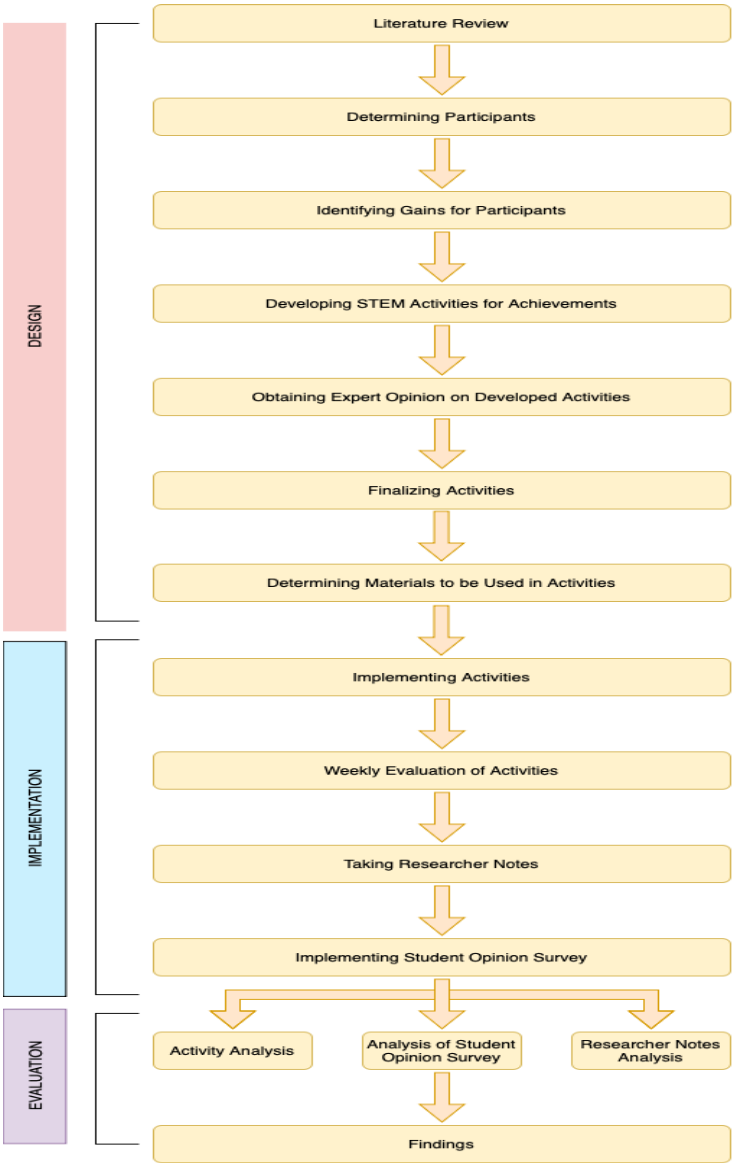


Figure 3. Implementation Process

As seen in Figure 3, the initial stage of the design process involved conducting a literature review to examine previous studies related to STEM. Subsequently, participants were identified in the following phase of the application process. After determining the learning outcomes for the participants, activities were developed accordingly. In the next stage, materials to be used throughout the activities were specified. These materials, such as paper, cardboard, and pipettes, are cost-effective resources necessary for students to create products at the activity level. During the application process, activities were assigned to students, and evaluations of these activities were conducted weekly. The researcher made observations during the implementation of activities, taking notes as part of the process. Following the completion of all activities, a Student Perception Survey was administered to gather feedback from the students.

The implementation of activities took place at the STEM Artificial Intelligence Center in a city in southern Turkey. This center includes classes such as robotic coding, mathematical modeling, mind games, scientific inquiry, and early STEM education. Education is provided five days a week at this center, with each student attending one designated day per week. On this designated day, students attend Mathematical Modeling, Robotic Coding, and Scientific Inquiry classes for three hours after school. Students attend these three classes in groups every day, with lessons structured as 50-minute sessions followed by a 10-minute break. These sessions integrate activities that encompass Science, Mathematics, Technology, and Engineering skills.

Education at this STEM center is student-centered. The application was planned and implemented for a duration of 14 weeks during the autumn semester of the 2022-2023 academic year. During the initial two weeks in this learning environment, students were introduced to how STEM education functions and engaged in exercises. Following these introductory weeks, six activities, each spanning two weeks, were implemented.

Throughout the application process of activities, students were grouped into teams of four, considering heterogeneous distributions in terms of achievement and gender. Activities were applied to students in accordance with the sequence of topics taught at their school. Each activity took two weeks to complete. In the first week, an activity sheet was provided, comprising sections such as Team Name, Team Slogan, Team Logo, Problems Related to Achievements, Materials List, and Product Draft. These sections were designed by researchers to enhance students' creativity. The Problems Related to Achievements section included two or three problems aimed at improving students' procedural skills, while the Materials List section facilitated cost-effective decision-making and determined materials to be provided to students the following week. Finally, the Product Draft section allowed students to sketch prototype designs for the products they would develop the following week. After completing these sections, students engaged in an exercise that reminded them of the decisions they had made to find solutions to the problems provided and were asked to prepare a Team Draft that showed which materials they would choose. Subsequently, they were expected to create prototypes of each product in their team draft using graphic tablets, share their drawings with their group members, develop a prototype as a team, and select materials for their team drafts. Throughout this process, each material had a specified cost, and groups were given a material limit per week. In the second week, students were provided only with the materials they had selected in their team drafts and were instructed to create products suitable for the prototype.

After completing all activities, students were given a Student Perception Form containing thirteen questions related to STEM, aiming to uncover their thoughts on the education they received at the STEM center.

3.8. Data Analysis

In this study, data including student products were analyzed using descriptive analysis, while student perceptions were analyzed using content analysis. Data from the product evaluation form were evaluated based on the observation form in Table 2.

Table 2. Product Evaluation Form

Evaluated Scenarios	Process
Design Creation Process	Implementation of designs was achieved. All materials were utilized in the design. A student requested additional materials for the design. Students discussed among themselves to realize an idea in the design. A draft version was sketched. The created product was tested. An original product emerged at the end of the lesson. The design creation process took place as a group collaboration.
Scientific Research Process	Inquiry-based learning was facilitated for the students. Students discussed among themselves regarding their upcoming projects. Open-ended questions were answered. A solution compliant with RLP (Real-Life Problem) was produced. The visuals used in the lesson related to the designed product were adequate.
Integrating Learning from Different Subjects	Group work pleased the students. They collaborated together. At the end of the lesson, students acquired new information. They shared their products with other group members. They made corrections for any parts lacking in their products.

In this context, for the assessment-oriented scoring system, 0 points were assigned for not meeting the expected criteria, 1 point for partial completion, and 2 points for complete fulfillment.

Content analysis (Yıldırım and Şimşek, 2018) was employed in the analysis of student perception forms to identify codes in the obtained data and explore relationships among these codes. Similar data were organized within specific coding frameworks for this purpose. The data analysis involved two different researchers reading and coding the student perception forms.

4.Findings

Students engaged in 6 different activities over a period of 14 weeks, although only one activity and its process are exemplified here.

Example Activity: "With government support, we are preparing trees in a specific region for paper production raw materials. There is a river beyond our work site, and we transport materials across the river using boats. Recently, there has been heavy rainfall, increasing the water flow of the river. Along with the wind, the current speed has also intensified. We can no longer use the river as effectively as before. Due to the current, we need to exert more effort and use more paddles to reach our desired destination. This physically strains us. Together with our friends, we have decided that we cannot continue transporting materials like this anymore. How can we find a solution? Produce the most cost-effective solution using the provided materials."

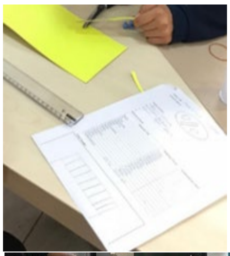
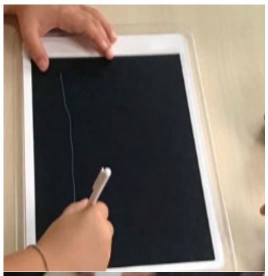
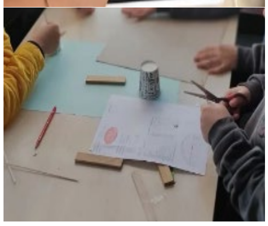
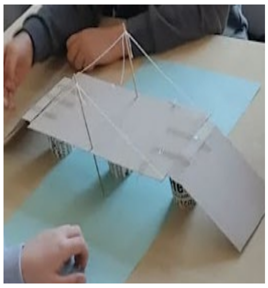
Materials:

Materials (Quantity)	Prices	Products (Quantity)	Prices	Products (Quantity)	Prices
- Cups	75 krş	- Pipette	190 krş	- Rubber band	130 krş
- Rope	175 krş	- Tape	120 krş	- Foam plate	75 krş
- Divider	250 krş	- Plastic cup	850 krş	- Glue	50 krş
- Wooden sticks	150 krş	- Lid	120 krş	- Ruler	60 krş
- Cardboard	280 krş	- Trash bottle	80 krş	- Scissors	270 krş

In the first week of the application process, the teacher checked the distribution of students into groups and asked them questions related to mathematics, science, and engineering achievements upon entry. Subsequently, the teacher evaluated each material and asked questions about them, providing examples. Following this, Team Drafts were distributed to students. The groups were instructed to complete their Team Drafts comprehensively and select the necessary materials for the design. Students determined the materials and calculated their costs. Then, students sketched the draft of the product they would create. During this time, groups were asked to create a log each to test the product they would make the following week, thereby learning to create cylinders. Once the design and calculations were completed, students were asked to submit the logs they created and their team drafts for the following week, and were instructed to think about the design and the product they would create until the application day next week.

In the second week, the teacher drew a river of 30 cm for each group and determined the length of the river according to the length of the tables. Students were given their team drafts and logs from the previous week along with the materials they had selected, and after deciding on their products, they exchanged ideas with each other about their desired outcomes. Following these discussions, students used the materials to build either a bridge or a cable car. Visuals related to the design process and the products are included in Table 3.

Table 3. Implementation Process

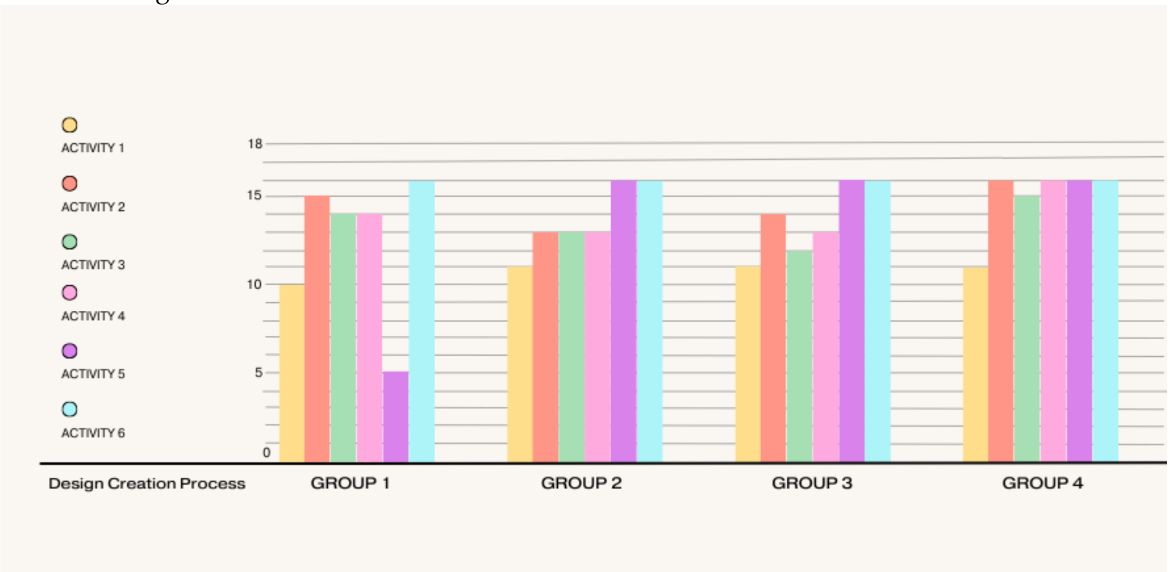
	Group 1	Group 2	Group 3	Group 4
Design Process	 	 	 	 
Product				

Upon examining the design and product processes of the groups, it was observed that all groups collaborated and produced a product. Each student in the groups contributed to the process and supported their groupmates. Utilizing graphic tablets, students merged their ideas and thoroughly completed their team drafts. The groups created unique designs. Group 1 considered securing their bridge using plastic bottles, ensuring minimal damage even if the current increased. Group 2 anchored their bridge into the river with supports but did not secure the ends to the ground, considering access for people passing through. Group 3 used plastic bottles to anchor the bridge to the river without securing them to the bridge itself. Group 4 anchored their bridge to the river using cups and secured the ends to the ground, reinforcing it with string and plastic bottles.

Throughout the term, students' activities culminated in the creation of original, sufficiently diverse products using the provided materials, demonstrating effective teamwork among peers.

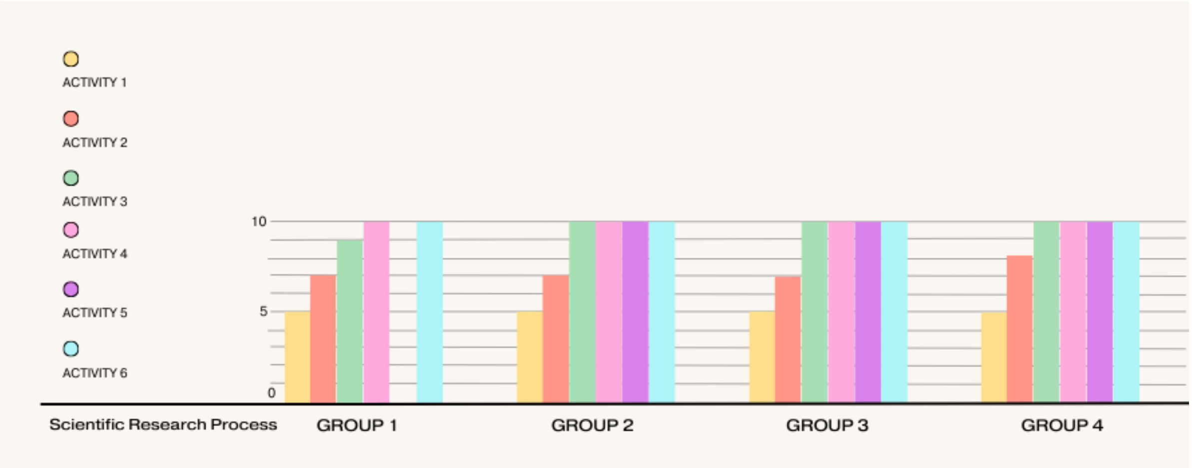
During this process, students learned to create cylinders and devised solutions for transporting logs across the river. Subsequently, they developed a system to easily transport logs, showcasing their performance and products evaluated under the categories of material design, scientific research process, and integration of learning from various subjects (Look at Appendix 1).

Table 4. Design Creation Process



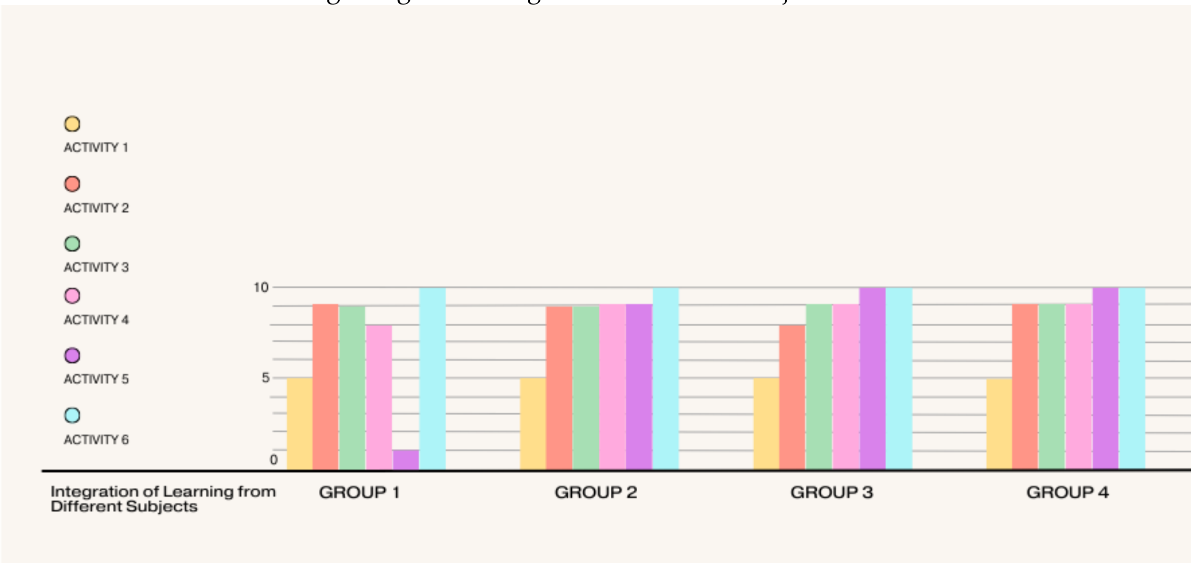
As seen in Table 4, an increase in scores is observed when comparing the points received by students in the initial activity and the final activity during the Design Creation Process. The 1st Group was unable to produce a product in the 5th Activity due to internal disagreements, resulting in lower scores for the design creation process because they did not collaborate as a group. This highlights the importance of communication skills in group work (Eroğlu and Bektaş, 2016).

Table 5. Scientific Research Process



As seen in Table 5, students increased their scores in the Scientific Research Process from the first activity. The 1st Group did not receive any points in the 5th Activity because they did not engage in group work. This indicates the importance of collaboration skills in group work (Uğraş and Genç, 2018).

Table 6. The Process of Integrating Knowledge from Different Subjects



As seen in Table 6, there is an observed increase in the scores from the first to the last activity in the Process of Integrating Knowledge from Different Subjects. In the 5th Activity, the students in the 1st Group received low scores because they did not exchange information among themselves, even though they learned new information from other groups by the end of the lesson. The disagreement within the group did not affect the following week's activity, and the group received high scores in the next week's activity.

Reviewing the categories, it was observed that in the material creation section, students collaborated within their groups to produce a product. While creating the prototype in the first week, students did not request additional materials beyond those selected the previous week. In the scientific research process, students answered open-ended questions through discussions and produced solutions according to the given RLP. In the process of integrating knowledge from different subjects, it was observed that students learned new information from this group work and left the sessions happy.

It can be said that the products created by students throughout the semester were original, of sufficient quality, diverse, and made using the provided materials, while students worked harmoniously with their group members.

Students compared STEM education to various contexts, such as school (n=7), course (n=2), entertainment venue (n=2), invention place (n=2), game (n=1), experiment (n=1), and teaching a fish to fly (n=1) (Figure 4.1). Contrary to the majority, one student who compared STEM to a course said, "I compare STEM to a course rather than a school because we learn new information different from school, but we also do activities and experiments." Another student explained that STEM makes the impossible possible by saying, "We learn everything we didn't know, and the information we learn is very useful in our daily lives." A word cloud related to these statements is provided below.

Figure 4. Metaphors Regarding STEM Education

Students emphasized the advantages of STEM education more than its disadvantages. Numerous advantages were identified, including: acquiring new/different knowledge (n=14), learning computers and coding (n=9), having fun (n=11), deep learning (n=4), supporting daily life (n=2), learning by doing (n=2), gaining different perspectives (n=2), creativity (n=2), group work (n=2), and other benefits (responsibility, respect development, play).

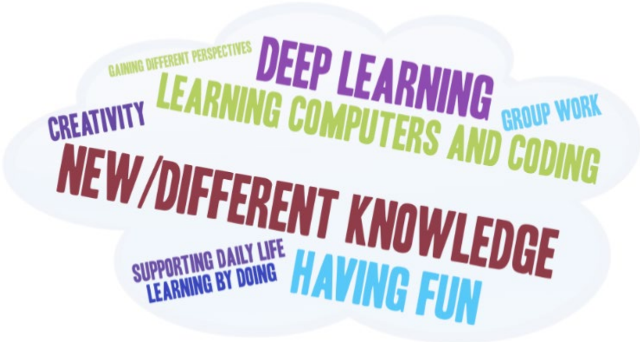


Figure 5. Advantages of STEM Education

Students generally expressed satisfaction with STEM education, noting the absence of disadvantages (n=6). However, some students mentioned a few drawbacks, such as insufficient time allocated (n=2), time loss (n=2), the presence of group work (n=1), and other issues (early rising, punishment, lack of classroom space) (n=5) (Figure 4.3).

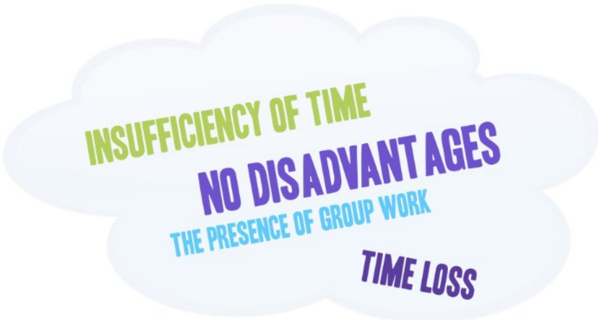


Figure 6. Disadvantages of STEM Education

When asked about the feelings STEM education evoked in students, the majority responded with happiness (n=10), while others expressed positive emotions such as excitement (n=3), love (n=1), and pride (n=1). Only two students mentioned feelings of unhappiness and sadness (Figure 4.4). The reason for unhappiness was attributed to a lack of friends.

Figure 7. Emotions Evoked by STEM Education in Individuals

Lastly, students were asked about what they were curious about regarding STEM, with the majority expressing curiosity about how these schools were established and why they were founded. Another question of interest was how the school's resources were provided.

5. Conclusion, Discussion, And Recommendations

This study evaluated the education received by 16 fifth-grade students at the STEM Artificial Intelligence Center and assessed the products they developed during the educational process. The study was conducted over a fourteen-week period, during which students' products were evaluated, and their opinions regarding this education were gathered.

In conclusion, according to the findings obtained from the observation forum, a positive increase was observed between the products produced by the students in the first week and the products produced in the last week in terms of design creation, scientific research process and integration of learning from different subjects. Students working in groups improved their collaboration and communication skills. When a cooperative learning model consisting of heterogeneous groups in terms of ability, gender and achievement, which has an important place in active learning strategies, is applied, a supportive learning environment is created in which students are encouraged to explore, their motivation increases and they can express their ideas freely (Christison, 1990; Cooper, Prescott, Cook, Smith, Mueck and Cuseo, 1984). In such an environment, students' learning levels increase, their critical thinking and problem solving skills improve, they exhibit more positive attitudes towards their peers and themselves, and they gain the ability to work in harmony (Leikin and Zaslavsky, 1997; Nelson-Legall, 1992). In addition, it has been observed that students' oral communication skills are strengthened, and they participate more actively in the learning process (Doymuş, Karaçöp and Şimşek, 2010; Genç and Şahin, 2015; Koç, 2014; Önder and Sılay, 2015; Şimşek, 2007; Webb, Sydney and Farivor, 2002). Similarly, Karahan, Canbazoğlu-Bilici, and Ünal (2015) found that STEM activities improved students' collaboration and communication skills.

In addition to these findings, Mildenhall et al. (2019), who designed and conducted a STEM activity showing that students successfully completed a technological design process using solutions appropriate for real-life problems, drawing from Mathematics and Sciences, and were able to explain these products to their peers. Similarly, Dabney et al. (2012) demonstrated in their study that extracurricular activities promote students' interest and engagement in STEM areas such as science and mathematics. Uğraş (2020) also concluded in his study that STEM activities positively impact students' scientific creativity. Similarly, Cho and Lee (2013) highlighted in their studies that middle school students' creativity improved with STEM-based lessons. Lou et al. (2011) emphasized that integrating STEM with real-life problems could enhance students' problem-solving skills, technical literacy, mechanical application, and mathematical calculation abilities. In a Problem-Based STEM education, students are expected to integrate theory with practice, thereby developing problem-solving skills and higher-level thinking abilities (Lou et al., 2011).

Similar to these findings, Karışan and Yurdakul (2017) concluded in their study that STEM activities enabling interdisciplinary approaches in STEM fields positively influence students' attitudes towards these fields. STEM encompasses the content, skills, and thinking styles of each discipline, as well as the understanding of interactions between disciplines and how they support and complement each other (Moore et al., 2014). This research underscores the importance of interdisciplinary approaches in STEM education, suggesting that such activities can effectively enhance students' interest and motivation in STEM fields (Karışan and Yurdakul, 2017).

In general, students have a positive attitude towards STEM education and find it both necessary and enjoyable. In addition to these findings, Yıldırım (2016) found that STEM applications and whole learning approach integrated into the 7th grade science course positively affected students' attitudes towards STEM. Karahan et al. emphasized that STEM activities offer a fun and enjoyable learning experience for students. Damar, Durmaz, and Önder (2017) also found that STEM applications were found interesting, and Gazibeyoğlu (2018) stated that lessons supported by these applications were more fun and motivating. Şentürk (2017) reported that students expressed positive opinions about STEM activities.

It is believed in this study that effective group communication and collaboration in STEM activities have a significant role in the product development process. Similarly, Karakaya et al. (2019) emphasized the importance of teamwork in STEM activities in their study. Choi and Hong (2013) and Kim et al. (2014) emphasized that communication and collaboration among students during STEM activities to realize creative ideas and experience the process are essential in creating a sense of accomplishment in students. Shengquan and Xiang (2015) highlighted that acquiring knowledge and skills such as group work and collaboration in STEM areas could help students learn about real-world applications of scientists and engineers and encourage them to think about problem-solving.

This study focused on evaluating the products of 16 fifth-grade students based on STEM-based education and their views. Future research could provide different educational experiences for different middle school classes. In addition, middle school teachers can integrate STEM activities into their own classrooms, new activities can be developed for the achievements of the classes to be studied. The number of activities and the application process in the study can be regulated and the effect of STEM-based activity applications on academic success in mathematics course can be researched. Such STEM centers can be made accessible throughout the country to popularize STEM education.

References

Ahmed, S., Wallace, K. M., & Blessing, L. T. (2003). Understanding the differences between how novice and experienced designers approach design tasks. *Research in Engineering Design, 14*(1), 1-11. https://doi.org/10.1007/s00163-002-0023-z

Akarsu, M., Akçay, N. O., & Elmas, R. (2020). STEM eğitimi yaklaşımının özellikleri ve değerlendirilmesi. *Boğaziçi Üniversitesi Eğitim Dergisi, 37*, 155-175.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). Report of the 2012 national survey of science and mathematics education. *Horizon Research, Inc.(NJ1).*

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education, 32*(3), 347-364. https://doi.org/10.1007/BF00138871

Bodner, G. & Elmas, R. (2020). The impact of inquiry-based, group-work approaches to instruction on both students and their peer leaders. European Journal of Science and Mathematics Education, 8(1),51-66.

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. School Science and Mathematics, 112 (1), 3–11.

Brewer, D. B., & Clark, F. B. (2012). Engineering design thinking: A powerful framework for developing STEM literacy. In J. Krajcik & R. Byas (Eds.), *Designing and implementing STEM education and programs* (pp. 27-46).

Bryan, L. A., Moore, T. J., Johnson, C. C., & Roehrig, G. H. (2015). Integrated STEM education. In C. C. Johnson, T. J. Moore, & E. E. Peters-Burton (Eds.), STEM roadmap: A framework for integrated STEM education (pp. 23–37). New York, NY: Routledge.

Burkhardt, H., & Schoenfeld, A. H. (2003). Improving educational research: Toward a more useful, more influential, and better-funded enterprise. *Educational Researcher, 32*(9), 3-14. https://doi.org/10.3102/0013189X032009003

Byas, R., & Krajcik, F. (2000). Establishing effective experiential STEM education. National Academies Press.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*(1), 30.

Bybee, R. W. (2013). A case for STEM education. Arlington, VA: NSTA Press.

Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education, 25*(2), 211-221. https://doi.org/10.1007/s10972-014-9381-4

Carberry, A,R. & McKenna, A, F (2014). Exploring student conceptions of modeling and modeling uses in engineering desing. Journal of Engineering Education, 103(1), 77-79.

Carnevale, A. P., Smith, N., & Melton, M. (2011). STEM: *Science technology engineering mathematics*. Georgetown University Center on Education and the Workforce.

Chen, C. W. J., & Lo, K. M. J. (2019). From Teacher-Designer to Student-Researcher: a Study of Attitude Change Regarding Creativity in STEAM Education by Using Makey Makey as a Platform for Human-Centred Design Instrument. *Journal for STEM Education Research, 2*(1), 75-91. https://doi.org/10.1007/s41979-018-0010-6

Cho, B., & Lee, J. (2013). The Effects of Creativity and Flow on Learning through the STEAM Education on Elementary School Contexts. Paper presented at the International Conference of Educational Technology, Sejong University, South Korea.

Choi, Y. ve Hong, S.H. (2013). The Development and application effects of steam program about 'world of small organisms' unit in elementary science. Elementary Science Education, 32(3), 361-377.

Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9-13. https://doi.org/10.3102/0013189X032001009

Cohen, L., & Waite-Stupiansky, S. (2019). STEM in Early Childhood Education: How Science, Technology, Engineering, and Mathematics Strengthen Learning. *Routledge*. https://doi.org/10.4324/9780429453755

Cunningham, C. M. (2009). Engineering is elementary. *The Bridge, 30*(3), 11-17. http://irhe.sciedupress.comInternational Research in Higher Education Vol. 5, No. 1; 2020

Cunningham, C. M., & Lachapelle, C. P. (2014). Designing engineering experiences to engage all students. *Engineering in pre-college settings: Synthesizing research, policy, and practices*, 117-142. https://doi.org/10.2307/j.ctt6wq7bh.10

Cunningham, J. F., French, B. S., & Layton, R. I. (2007). Engineering in K-12 education: Building a strong foundation. National Academies Press.

Czerniak, C. M., Weber, W. B., Sandmann, Jr., A. and Ahern, J. (1999). Literature review of science and mathematics integration. *School Science and Mathematics*, 99(8), 421–430. https://doi.org/10.1111/j.1949-8594.1999.tb17504.x

Çetin, İ. (2020). Ortaöğretim öğrencilerinin matematik umutsuzluğunu yordayan değişkenler: Matematik kaygısı, matematiğe yönelik motivasyonel inançlar, matematik başarısı (köşk ilçesi örneği) (Doktora Tezi). Aydın Adnan Menderes Üniversitesi Sosyal Bilimler Enstitüsü.

Dabney, K. W., Miller, F. R., & Karnes, M. (2012). Afterschool STEM (science, technology, engineering, and mathematics) programs: A comprehensive review of the literature. Review of educational research, 82(1), 269-309.

Dasgupta, C. (2019). Improvable models as scaffolds for promoting productive disciplinary engagement in an engineering design activity. *Journal of Engineering Education, 108*(3), 394-417. https://doi.org/10.1002/jee.20282

De Vries, M. J. (2018). Handbook of technology education. *Springer*. https://doi.org/10.1007/978-3-319-44687-5

Doğan, H. (2020). Beşinci sınıf fen bilimleri dersi ünitelerinin bütünleşik STEM eğitimi yaklaşımı ile tasarlanması, uygulanması ve değerlendirilmesi.

Drake, S. M., & Burns, R. C. (2004). Meeting standards through integrated curriculum. ASCD.

Dym, C. L., & Brown, D. C. (2012). Engineering design: representation and reasoning. *Cambridge University Press*. https://doi.org/10.1017/CBO9781139031813

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1), 103-120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Dym, C. L., Agogino, E., Eris, O., Frey, M. D., & Leifer, L. J. (2005). Engineering design thinking. Cambridge University Press.

Early Childhood, S. W. G. (2017). Early STEM matters: Providing high-quality STEM experiences for all young learners. *Chicago (IL): UChicago STEM Education and Erikson Institute.*

Elmas, R. (2020). Bağlamın anlamı ve nitelikleri ve öğrencilerin fen eğitiminde bağlam tercihleri. Türkiye Kimya Derneği Dergisi Kısım C: Kimya Eğitimi, 5(1), 53-70.

English, L. D. (2019). Learning while designing in a fourth-grade integrated STEM problem. *International Journal of Technology and Design Education, 29*(5), 1011-1032. https://doi.org/10.1007/s10798-018-9482-z

English, L. D. (2021). Advancing STEM education for the 21st century. International Journal of Science and Mathematics Education, 19(2), 285-298.

English, L. D., & King, D. T. (2015). STEM learning through engineering design: fourth-grade students' investigations in aerospace. *International Journal of STEM Education, 2*(1), 14. https://doi.org/10.1186/s40594-015-0027-7

Eren, E. & Dökme, İ. (2022). Fen eğitiminde kullanılan STEM uygulamalarının değerlendirilmesi. Muğla Sıtkı Koçman Üniversitesi Eğitim Fakültesi, 9(2), 669-681. DOI: 10.21666/muefd.1080617

Eroğlu, S. ve Bektaş, O. (2016). STEM eğitimi almış fen bilimleri öğretmenlerinin STEM temelli ders etkinlikleri hakkındaki görüşleri. Eğitimde Nitel Araştırmalar Dergisi, 4(3), 43-67.

Fan, S.-C., & Yu, K.-C. (2017). How an integrative STEM curriculum can benefit students in engineering design practices. *International Journal of Technology and Design Education, 27*(1), 107-129. https://doi.org/10.1007/s10798-015-9328-x

Fan, S., ve Ritz, J. (2014). International views of STEM education. In PATT-28 Research into Technological and Engineering Literacy Core Connections (pp. 7-14). Orlando: International Technology and Engineering Educators Association.

Fortus, D.,Krajcikb, J., Dershimerb, R.C., Marxc, R.W. ve Naaman R. (2005). Design-based science and real-world problem-solving, International Journal of ScienceEducation, 27(7), 855–879.

Farrell, S., Pearson, G., & Shafer, M. (2012). The role of engineering design in K-12 STEM education. In J. Krajcik & R. Byas (Eds.), *Designing and implementing STEM education and programs* (pp. 105-122).

Gardner, Howard (2004). Zihin Çerçeveleri: Çoklu Zeka Kuramı. İstanbul: Optimist Yayınları.

Gardner, Howard (2013). Çoklu Zeka: Yeni Ufuklar. İstanbul: Optimist Yayınları.

Heinze, T., & Kuhlmann, S. (2008). *Across institutional boundaries? Research collaboration in German public sector nanoscience*. Research Policy, 37(5), 888-899. https://doi.org/10.1016/j.respol.2008.01.009

Hinde, E. T. (2005). Revisiting curriculum integration: A fresh look at an old idea. *The Social Studies*, 96(3), 105-111. https://doi.org/10.3200/TSSS.96.3.105-111

Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM integration in K-12 education: Status, prospects, and an agenda for research. Washington, DC: National Academies Press.

Hu, Y., Du, X., Bryan-Kinns, N., & Guo, Y. (2019). Identifying divergent design thinking through the observable behavior of service design novices. *International Journal of Technology and Design Education, 29*(5), 1179-1191. https://doi.org/10.1007/s10798-018-9479-7

Huang, F. (2017). *Graduate employment and higher education in Japan*. In Higher education in East Asia (pp. 117-137). Springer, Singapore.

İzmir İl Milli Eğitim Müdürlüğü. (2018). *STEM AKADEMİZMİR Okul Öncesi Çalışmaları Kitapçığı*. İzmir: Milli Eğitim Müdürlüğü

Johansson-Sköldberg, U., Woodilla, J., & Çetinkaya, M. (2013). Design thinking: past, present and possible futures. *Creativity and Innovation Management, 22*(2), 121-146. https://doi.org/10.1111/caim.12023

Karakaya, F., Yantırı, H., Yılmaz, G. ve Yılmaz M. (2019). İlkokul öğrencilerinin STEM etkinlikleri hakkında görüşlerinin belirlenmesi: 4. sınıf örneği. Uluslararası Türk Eğitim Bilimleri Dergisi, 7 (13), 1-14.

Karataş, İ., & Güven, B. (2003). Problem çözme davranışlarının değerlendirilmesinde kullanılan yöntemler: Klinik mülakatın potansiyeli. *Elementary Education Online, 2*(2).

Karışan, D. ve Yurdakul, Y. (2017). The effects of microprocessors based science technology engineering ve mathematics (STEM) investigations on 6th grade students' attitudes towards these subject areas. *Adnan Menderes University Education Faculty Journal of Educational Sciences,* 8(1), 37-52.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(1), 11. https://doi.org/10.1186/s40594-016-0046-z

Kelley, T., & Sung, E. (2017). Examining Elementary School Students' Transfer of Learning through Engineering Design Using Think-Aloud Protocol Analysis. *Journal of Technology Education, 28*(2), 83-108. https://doi.org/10.21061/jte.v28i2.a.5

Kelly, G. J., & Cunningham, C. M. (2019). Epistemic tools in engineering design for K-12 education. *Science Education, 103*(4), 1080-1111. https://doi.org/10.1002/sce.21513

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International, 25*(3), 246-258.

Kim, D.H., Ko, D.G., ve Han, M.J. (2014). The Effects of science lessons applying steam education program on the creativity and interest levels of elementary students. Journal of the Korean Association for Science Education, 34(1), 43-54.

Koehler, C., Binns, I. C., & Bloom, M. A. (2015). The emergence of STEM. In C. C. Johnson, E. E. PetersBurton, T. J. Moore, C. C. Johnson, E. E. Peters-Burton, & T. J. Moore (Eds.), STEM Road Map: A framework for integrated STEM education (pp. 13–22). New York, NY: Routledge.

Kretzschmar, A. (2003). The economic effects of design. *Danish national agency for enterprise and housing*. In.

Lesseig, K., Holmlund Nelson, T., Slavit, D., & Siedel, R. (2016). Supporting middle school teachers' implementation of STEM design challenges. School Science and Mathematics, 116(4), 177–188.

Li, Q., & Schoenfeld, A. H. (2019). *Practices and impacts of policies for STEM education in China*. International Journal of STEM Education, 6(1), 1-12. https://doi.org/10.1186/s40594-019-0196-1

Li, Y., Schoenfeld, A. H., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2019). Design and design thinking in STEM education. *Springer*. https://doi.org/10.1007/s41979-019-00020-z

Lou, S. J., Shih, R. C., Ray Diez, C., & Tseng, K. H. (2011). The impact of problem-based learning strategies on STEM knowledge integration and attitudes: an exploratory study among female

Taiwanese senior high school students. *International Journal of Technology and Design Education*, *21*, 195-215.

Macdonald, A., & Williams, J. (2009). *STEM education in the UK: The roles of policy and science parks in fostering innovation and entrepreneurship*. Technology Analysis & Strategic Management, 21(6), 805-816. https://doi.org/10.1080/09537320903124055

MacIsaac, D. (2019). US government releases Charting a Course for Success: America's Strategy for STEM Education, report guiding federal agencies that offer STEM funding opportunities. *The Physics Teacher, 57*(2), 126-126. https://doi.org/10.1119/1.5088484

Marginson, S., & Wende, M. C. V. D. (2007). *Globalisation and higher education*. OECD Education Working Papers, No. 8, OECD Publishing. http://dx.doi.org/10.1787/173831738240

McFadden, J., & Roehrig, G. (2019). Engineering design in the elementary science classroom: supporting student discourse during an engineering design challenge. *International Journal of Technology and Design Education, 29*(2), 231-262. https://doi.org/10.1007/s10798-018-9444-5

Mildenhall, P., Cowie, B., & Sherriff, B. (2019). A STEM extended learning project to raise awareness of social justice in a Year 3 primary classroom. *International Journal of Science Education*, *41*(4), 471-489.

Millî Eğitim Bakanlığı, Talim ve Terbiye Kurulu Başkanlığı. (2018). *İlkokul ve ortaokul matematik dersi öğretim programı*. Ankara: MEB.

Milli Eğitim Bakanlığı. (2016). *STEM Eğitim Raporu*. Erişim tarihi: 28 Mart 2024, http://yegitek.meb.gov.tr/STEM_Egitimi_Raporu.pdf

Moore,T., Tank,K, Glancy, A., Kersten,J.,Smith,K., Stohlmann, M.(2014). A frameworkfor implementing engineering standards in k-12. Pre-College Engineering Education Research, 4(1), 1-College Eng

Morrison, J. (2006). Attributes of STEM education: The student, the school, the classroom. *TIES (Teaching Institute for Excellence in STEM)*, *20*(2), 7.

Mustafa, N., Ismail, Z., Tasir, Z., Said, M. and Haruzuan, M. N. (2016). A meta-analysis on effective strategies for integrated STEM education. *Advanced Science Letters*, 22(12), 4225-4228. https://doi.org/10.1166/asl.2016.8111

National Council of Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Research, C. (2009). Engineering in K-12 education: Understanding the status and improving the prospects. *National Academies Press.*

Oba, J., & Shibayama, S. (2009). *Turning point of Japanese university governance and management: Hybridization of new and old*. In Higher Education Forum (No. 6, pp. 27-45).

OECD. (2021). PISA 2021 Results: Creative problem solving: Students' skills in tackling real-life problems (Volume V). PISA, OECD Publishing.

Okulu, H. Z. (2019). STEM eğitimi kapsamında astronomi etkinliklerinin geliştirilmesi ve değerlendirilmesi.

Olson, S., & Riordan, D. G. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Report to the President. Executive Office of the President.

Orona, C., Carter, V., & Kindall, H. (2017). Understanding standard units of measure. *Teaching Children Mathematics, 23*(8), 500-503. https://doi.org/10.5951/teacchilmath.23.8.0500

Partnership for 21st Century Skills (2013). Framework for 21st century learning.

Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important?. *Review of Educational Research, 82*(3), 330-348. https://doi.org/10.3102/0034654312457429

Riskowski, J. L., Todd, C. D., Wee, B., Dark, M. and Harbor, J. (2009). Exploring the effectiveness of aninterdisciplinary water resources engineering module in an eighth grade science course. *International Journal ofEngineering Education*, 25(1), 181–195.

Scott, C. L. (2020). The futures of learning 2: What kind of learning for the 21st century? UNESCO Education Research and Foresight, Paris. ERF Working Papers Series, No. 14.

Simon, H. A. (2019). The sciences of the artificial. *MIT Press.* https://doi.org/10.7551/mitpress/12107.001.0001

Smith, E., & Gorard, S. (2011). *Is there a shortage of scientists? A re-analysis of supply for the UK*. British Journal of Educational Studies, 59(2), 159-177. https://doi.org/10.1080/00071005.2011.578567

Soylu, Y., & Soylu, C. (2006). Matematik derslerinde başariya giden yolda problem çözmenin rolü. *İnönü Üniversitesi Eğitim Fakültesi Dergisi, 7*(11), 97-111.

Strimel, G. J., Kim, E., Grubbs, M. E., & Huffman, T. J. (2019). A meta-synthesis of primary and secondary student design cognition research. *International Journal of Technology and Design Education*, 1-32.

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, 1-32. https://doi.org/10.1007/s10798-019-09505-9

Şahin, A., Ayar, M. C., & Adıgüzel, T. (2014). Fen, teknoloji, mühendislik ve matematik içerikli okul sonrası etkinlikler ve öğrenciler üzerindeki etkileri. *Kuram ve Uygulamada Eğitim Bilimleri, 14*(1), 1-26.

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., ... & Depaepe, F. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education*, *3*(1), 2.

Uğraş, M. (2020). The effects of STEM activities on STEM attitudes, scientific creativity and motivation beliefs of the students and their views on STEM education. *International Online Journal of Educational Sciences*, *10*(5), 165-182.

Uğraş, M. ve Genç, Z. (2018). Pre-School teacher candidates' views about STEM education. Bartın Üniversitesi Eğitim Fakültesi Dergisi, 7(2), 724-744.

Wagner, T. (2008). *The global achievement gap: Why even our best schools don't teach our kids what they need to know*. New York: Basic Books.

Wang, H. (2012). A new era of science education: Science teachers' perceptions and classroom practices of science, technology, engineering, and mathematics (STEM) integration. Unpublished doctoral dissertation, Minnesota University.

Wendell, K. B., Wright, C. G., & Paugh, P. (2017). Reflective decision-making in elementary students' engineering design. *Journal of Engineering Education, 106*(3), 356-397. https://doi.org/10.1007/s10648-019-09465-5

Windschitl, M. (2009, February). Cultivating 21st century skills in science learners: How systems of teacher preparation and professional development will have to evolve. Presentation given at the National Academies of Science Workshop on 21st Century Skills, Washington, DC (Vol. 15).

Wissema, J. G. (2009). *Towards the third generation university: Managing the university in transition*. Edward Elgar Publishing.

Wright, N., & Wrigley, C. (2019). Broadening design-led education horizons: Conceptual insights and future research directions. *International Journal of Technology and Design Education, 29*(1), 1-23. https://doi.org/10.1007/s10798-017-9429-9

Wrigley, C., & Straker, K. (2017). Design thinking pedagogy: The educational design ladder. *Innovations in Education and Teaching International, 54*(4), 374-385. https://doi.org/10.1080/14703297.2015.1108214

Yıldırım, A. & Şimşek, H., 2018. Sosyal Bilimlerde Nitel Araştırma Yöntemleri, Seçkin Yayıncılık, Ankara.

Yıldırım, N., & Akdeniz, M. (2017). Bağımsız STEM Eğitim Merkezlerinin Öğrenci Başarısına Etkisi Üzerine Bir Araştırma. *Eğitim ve Bilim Dergisi*, 42(162), 315-326.

Appendix 1: Product Evaluation Form of Groups

Evaluated Scenarios	Process	Group 1						Group 2						Group 3						Group 4					
		Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6
Design Creation Process	Implementation of designs was achieved.	1	2	2	2	0	2	1	2	1	2	2	2	1	2	1	2	2	2	1	2	2	2	2	2
	All materials were utilized in the design.	1	2	2	1	1	2	1	1	1	1	2	2	1	1	1	2	2	2	1	2	2	2	2	2
	A student requested additional materials for the design.	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
	Students discussed among themselves to realize an idea in the design.	1	2	2	2	0	2	1	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	2	2
	A draft version was sketched.	1	2	2	1	1	2	1	2	2	1	2	2	1	2	1	1	2	2	1	2	1	2	2	2
	The created product was tested.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	An original product emerged at the end of the lesson.	0	1	0	2	1	2	1	0	1	1	2	2	1	1	1	0	2	2	1	2	2	2	2	2
	The design creation process took place as a group collaboration.	1	2	2	2	0	2	1	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	2	2
	Implementation of designs was achieved.	1	2	2	2	0	2	1	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	2	2
Scientific Research Process	Inquiry-based learning was facilitated for the students.	1	2	2	2	0	2	1	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	2	2
	Students discussed among themselves regarding their upcoming projects.	1	1	2	2	0	2	1	1	2	2	2	2	1	1	2	2	2	2	1	1	2	2	2	2
	Open-ended questions were answered.	1	1	2	2	0	2	1	1	2	2	2	2	1	1	2	2	2	2	1	1	2	2	2	2
	A solution compliant with RLP (Real-Life Problem) was produced.	1	2	1	2	0	2	1	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	2	2
	The visuals used in the lesson related to the designed product were adequate.	1	1	2	2	0	2	1	1	2	2	2	2	1	1	2	2	2	2	1	2	2	2	2	2
Integrating Learning from Different Subjects	Group work pleased the students.	1	2	2	1	0	2	1	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	2	2
	They collaborated together.	1	2	2	2	0	2	1	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	2	2
	At the end of the lesson, students acquired new information.	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	They shared their products with other group members. They made corrections for any parts lacking in their products.	1	2	2	2	0	2	1	2	2	2	2	2	1	1	2	2	2	2	1	2	2	2	2	2
	Group work pleased the students.	0	1	1	1	0	2	0	1	1	1	1	2	0	1	1	1	2	2	0	1	1	1	2	2
Total		20	31	32	32	6	36	21	29	32	32	35	36	21	29	31	32	36	36	21	33	34	35	36	36