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Evaluation of a STEM-Based Activity in a Science Course on STEM Attitudes

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Abstract

This study investigated the effect of the STEM activity developed for the 7th grade "Pure Substances and Mixtures" topic on students' attitudes towards STEM. By the research, the simple experimental research method was used as a model. The sample consisted of 63 seventh-grade students in a middle school in the Denizli province. The second author administered the activity developed for this study for six hours. Data were gathered using the *Attitude Scale Towards STEM* developed by Friday Institute for Educational Innovation (2012), adapted for Turkish by Ozcan and Koca (2018), and analyzed using the SPSS 25.0 program. The data obtained within the scope of the research were evaluated and discussed according to sub-dimensions and total scale scores. It was concluded that the newly developed STEM activity has improved in five sub-dimensions -mathematics, science, engineering and technology, and 21st-century skills- and total attitudes toward STEM.

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Introduction

In the rapidly developing and changing world, the scientific, technological, and economic transformations occurring at the international level are also reflected in the characteristics of the trained manpower needed (Sevim, 2012; Sevim & Ayvaci, 2020). In this context, students growing up in this century are expected to have the skills to understand the value of science and technology and their relationship with society, solve the problems they encounter in daily life, and contribute to society's needs. However, the education system in the 21st century aims to raise information, media, and technology literate individuals who can keep up with scientific and technological developments and use appropriate technologies in researching, evaluating, transferring, and sharing information (Ayas et al., 2002; Ayvaci et al., 2018; Sevim & Ayvaci, 2012). As the education world explores strategies to equip students with the knowledge and skills needed to be successful innovators in the 21st-century workforce, there is increasing emphasis on Science, Technology, Engineering, and Mathematics [STEM].

STEM is an abbreviation for science, technology, engineering, and mathematics. These four areas emphasize innovation, problem-solving, and critical thinking. It also refers to the stage within the academic system that focuses on teaching skills and subjects in a way that resembles real life. Through STEM education, students gain knowledge and skills that can be applied to solve real-world problems. Imagination is critical in this process. Einstein said that "imagination is more important than knowledge." Focusing on one-sided education (mathematics, science, etc.) in the child's development may lead to momentary success, but it may also create irreparable deficiencies in the future (Sevim, 2013, 2020). Therefore, it is crucial to apply an interdisciplinary teaching approach for individuals. With STEM education, efforts are made to provide students with interdisciplinary science, technology, engineering, and mathematics skills. Because of this feature, many experts state that STEM education should start early. There are many reasons why individuals should begin STEM education as early as possible. These are in summary;

STEM subjects are essential in preparing children for the challenges of the future. Technology is rapidly changing, and the demand for highly qualified professionals is increasing. Learning STEM early helps children develop the knowledge and skills they need to meet these future challenges and succeed in these expanding fields.

STEM becomes much more fun and exciting when introduced at an early age. Children are naturally curious and have a remarkable ability to learn. It is also essential to introduce these topics in a creative and stimulating way. For example, with the help of games and experiments, children can learn the basic concepts of these subjects in a fun and exciting way.

Early exposure to STEM helps children develop problem-solving, critical thinking, and creativity skills (Cilengir-Gultekin & Akar-Vural, 2019). These skills intersect and can be applied in many situations, regardless of children's career path.

For these reasons, students in STEM education programs will acquire critical qualifications in future business fields, such as problem-solving, creativity, analysis, teamwork, independent thinking, entrepreneurship, communication, and digital literacy. In this context, even a short STEM education has the potential to impact children's STEM attitudes. Determining attitudes towards STEM will contribute to determining the workforce potential countries will need in the future and making the necessary arrangements to increase the workforce (Kennedy et al., 2016). STEM attitudes will also affect interest in STEM professions (Ayvaci et al., 2023). The middle school age is the most critical period for students who will form the workforce trained in STEM infrastructure (Knezek et al., 2013). STEM activities to be implemented for students during this period can help them develop positive attitudes towards STEM fields and begin to be willing to plan a career in them (Christensen, 2015).

This study investigated the effect of the STEM activity developed for the "Pure Substances and Mixtures" topic on students' attitudes toward STEM.

Method

Research Model

By the scope of this research, a simple experimental research method was preferred as a model. This research model follows the development of a method, approach, or technique applied to students in the same group, and the research is conducted on a single sample group (Creswel, 2023). The aspect that distinguishes the simple experimental method from the experimental method is that it includes the basic steps but does not include a control group (Kucuk & Sevim, 2022; Trochim, 2001).

The Sample

The sample includes 63 7th-grade students studying in two different classes in a middle school in the Pamukkale district of Denizli province. Thirty-four men's and twenty-nine women's mid-term academic success scores in the science course changed between 64 and 96 points. The average score of male students is 75, while that of female students is 74. It can be said that the students of different genders in the research group started the teaching process with similar qualifications. The second researcher also reported that these children had no experience with the stem approach before this research intervention.

Data Collection

Attitude Towards STEM Scale, developed by Friday Institute for Educational Innovation (2012) and adapted by Ozcan and Koca (2018), was used as a data collection tool in the study. The scale consists of four sub-dimensions and 37 items in a five-point Likert type. These sub-dimensions are mathematics, science, engineering and technology, and 21st-century skills. A maximum of 185 and a minimum of 37 points can be obtained from the scale. Here are some example statements for each sub-dimension. The mathematics sub-dimension is "*mathematics has been my worst subject*," the science sub-dimension is "*I am confident when dealing with science*", the engineering and technology sub-dimension is "*If I learn to engineer, I can develop things that people use every day.*" and the 21st-century skills subscale is "*I am confident that I can encourage others to do everything they can.*" is in the form. When the Cronbach Alpha internal consistency coefficients for the scale are examined, they are .91 for the entire scale, .90 for the mathematics sub-dimension, .89 for the science subscale, and .90 for the engineering and technology subscale. It was calculated as .92 for the 21st-century skills subscale. This shows that the scale is reliable in terms of usability.

Data Analysis

Data were analyzed through the SPSS 25.0 program. The primary purpose of the data analysis process is to test whether the data has a normal distribution. To determine the normality of the relevant data, skewness, and kurtosis values were considered, and the relevant values are presented in Table 1.

Table 1
Normality Distribution of the Results (Skewness and Kurtosis)

Sub-Dimension / Total Scale	Pre or Post test	Skewness	Kurtosis
Mathematics	Pretest	,430	-,510
	Posttest	,769	,295
Science	Pretest	,532	-,479
	Posttest	,289	-,912
Engineering and Technology	Pretest	,368	-,964
	Posttest	,603	,422
21st Century Skills	Pretest	,585	-,476
	Posttest	,559	-,551
Total Attitude Scale	Pretest	-,124	-,698
	Posttest	,565	1,256

Table 1 shows that the skewness and kurtosis values of the research group vary between +1.256 and -.912. Tabachnick and Fidell (2013) explained that skewness and kurtosis values must be within ±1.5 to perform parametric analysis. The analysis was carried out with the help of the related samples t-test, one of the parametric tests.

The STEM Activity Development Process

We used a well-known activity development process for the intervention. Figure 1 shows the development process of STEM activities in five basic steps. The first step is to conduct a literature review and examine the activities developed within this scope, and the second step is to obtain the opinions of four teachers regarding the implementation of the activities in the classroom environment. The third step is to determine the achievements; the fourth step is to develop STEM activities, and the fifth step is to pilot the developed STEM activities with nine participants and implement them. It was determined to identify and eliminate the deficiencies in the implementation process and finalize the activities.

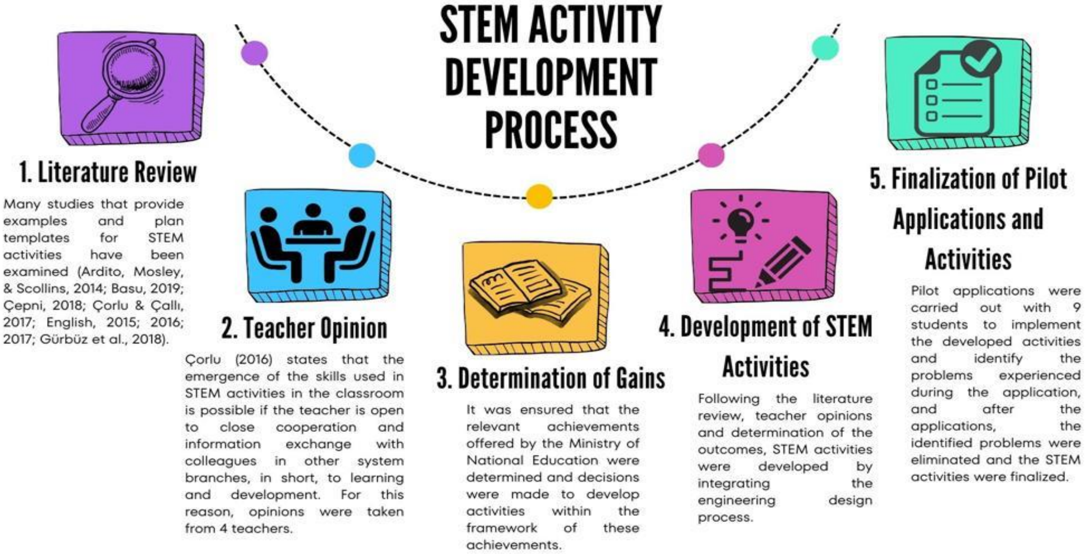

Figure 1. STEM Activity Development Process

There are many models for implementing the STEM education approach. One of these is known as the engineering design process steps. This model aims to teach the student the problem, how the research process will take place, what solutions can be provided to the problem, how to determine the most appropriate solution, and how to develop a design. There are many steps suggested by different researchers and/or institutions (Hynes et al., 2011; MDOE, 2010; NASA, 2015; Wendell et al., 2019; Winarno et al., 2020). A seven-step model was used in this study (see appendix for the activity). The researchers designed an activity worksheet with this model, where students studied pure substances and a mixture of science education subjects. It was implemented for six hours and two weeks. This activity was personally implemented by the second researcher, the science teacher of both classes. The teaching process was recorded and submitted to the first researcher for approval. In this way, it has been confirmed that the teaching is carried out by the seven-stage engineering design process. In this context, it was decided that it would be appropriate to reflect a possible change in stem attitude measured by the intervention program as the outcome of a short-term stem activity.

Results

We divided the results into subheadings, including the sub-dimension data and the total attitude scale scores.

Mathematics Sub-Dimension Results

Table 2

The Results of Mathematics Sub-Dimension

Measurement	N	X	s	sd	t	p
Pretest	63	27,58	3,19	62	-8,23	**,00**
Posttest		29,25	3,29			

Table 2 shows that there is a significant increase in the mathematics sub-dimension of the attitudes of the students in the research group towards STEM [t (62) = -8.235, p <.05] after the intervention.

Science Sub-Dimension Results

Table 3

The Results of Science Sub-Dimension

Measurement	N	X	s	sd	t	p
Pretest	63	30,68	2,87	62	-12,74	**,00**
Posttest		34,26	3,08			

Table 3 shows that there is a significant increase in the science sub-dimension of the attitudes of the students in the research group towards STEM [t(62) = -12.749, p <.05] after the intervention.

Engineering and Technology Sub-Dimension Results

Table 4

Results of Engineering and Technology Sub-Dimension

Measurement	N	X	s	sd	t	p
Pretest	63	31,80	3,11	62	-8,584	**,00**
Posttest		33,34	3,08			

Table 4 shows that there is a significant increase in the engineering and technology sub-dimension of the attitudes of the students in the research group towards STEM [t(62) = -8.58, p <.05] after the intervention.

21st Century Skills Sub-Dimension Results

Table 5

Results of the 21st Century Skills Sub-Dimension

Measurement	N	X	s	sd	t	p
Pretest	63	36,33	3,56	62	-63,04	**,00**
Posttest		42,19	4,18			

Table 5 showed that there is a significant increase in the engineering and 21st-century skills sub-dimension of the attitudes of the students in the research group towards STEM [t(62)=-63.04, p<.05] after the intervention.

Total Attitude Scale Towards STEM Results

Table 6

Results of Total Attitude Scales Towards STEM

Measurement	N	X	s	sd	t	p
Pretest	63	126,41	8,80	62	-29,13	**,00**
Posttest		139,06	9,88			

Table 6 showed that there is a significant increase in the attitudes of the students in the research group towards STEM [t (62) = -29.13, p <.05] after the intervention.

Conclusion and Discussion

The results show that the newly developed STEM activity has improved in both five sub-dimensions and total attitudes toward STEM. It was also concluded that the increase was meaningful. Some results support this research. For example, Knezek et al. (2013) concluded that the perceptions of secondary school students who took courses in educational environments where STEM activities were used improved positively regarding mathematics. In another study conducted by Naizer et al. (2014) on STEM applications with secondary school students, they found that students' interest in mathematics, science, and technology increased. Freeman et al. (2008) explained that STEM education positively improved undergraduate students' attitudes towards science and mathematics. Wendell and Roger (2013) evaluated the effect of the engineering design program, which is included in STEM activities, on the attitudes of primary school students toward science. They concluded that there was a slightly significant difference between the control and experimental groups, which is in parallel with the results obtained regarding the science sub-dimension of the current study. In another study, Yamak et al. (2014) concluded that STEM activities for secondary school students positively increased their attitudes towards science. Ricks (2006) stated a significant increase in the attitudes of students who received training that included STEM-related activities toward science.

STEM education is an essential interdisciplinary approach from pre-school to higher education (MNE, 2016). However, when it comes to STEM education, the first disciplines that come to mind are science and mathematics. The importance of engineering and technology fields needs to be emphasized, and students' attitudes towards these fields need to be positively increased. Therefore, increasing student attitudes towards the engineering and technology sub-dimension is a significant result. Bagiati and Evangelou (2015) stated that STEM develops positive attitudes toward engineering and technology, teaching students to activate many senses, encouraging the use of more materials, and creating a combined mathematics and science application area. Tseng et al. (2013) found that project-based activities implemented with STEM integration positively affect attitudes toward the engineering dimension of STEM, supporting the current study.

When the STEM activity was applied in the current study, a significant difference was observed in the 21st-century skills sub-dimension towards STEM. It has been concluded that it has a significant effect on increasing 21st-century skills. Hamarat (2019) explained that 21st-century skills are skill sets in a continuous development process and are expected to be possessed by individuals to be equipped and actively participate in our information age. They include both knowledge and skills (Dede, 2010). These skills emerge from their integration (Umut, 2022). Thus, they are skills required to cope with the difficulties encountered in all areas of life, including business life. The importance of these skills in STEM activities is excellent.

The fact that there was a significant increase in the total attitudes of the students towards STEM after the intervention coincides with the research in the literature (Gulhan & Sahin, 2016; Sahin et al., 2014). In addition, Guzey et al. (2014) compared the attitudes of schools where STEM education activities are implemented and non-STEM-focused schools towards the STEM field. They observed a significant difference in attitude in favor of the students studying in schools where STEM education activities are implemented. In a study with fourth-grade students, Rehmat (2015) concluded that STEM activities are essential for developing positive attitudes. In this context, it is essential to implement STEM-based activities to improve attitudes towards STEM. This study revealed that the attitudes of students with no prior experience with STEM changed even after a short-term activity. For this reason, it was concluded that children subjected to long-term stem training can quickly achieve the goals of the stem approach.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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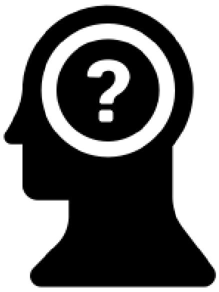
Appendix.

Let's Evaluate Domestic and Recyclable Wastes

13-year-old Bilgin, unlike his peers, is interested in scientific articles and science-fiction movies. He constantly asks his parents and teachers questions to find answers to the questions that arise in his mind about science and nature and thus tries to shed light on the complexities in his mind. Moreover, he is not satisfied with these, he reads scientific articles and articles in print, visual and social media and takes notes for himself. One day, while reading articles and writings, Bilgin came across an interview with the Green Environment Company on waste and recycling, one of the recent popular topics. In the interview, he could not fully understand the statement of the owner of Green Environment Company "*… We need to focus on recyclable waste and prioritize scientific and technological studies on this subject. This is very important for our country and the world. There is a need for scientists who can design new generation alternative energy sources with scientific competence and equipment to reintroduce domestic and recyclable waste into the system throughout the country …"*.

STEP 1: <u>DETERMINE NEEDS AND CONSTRAINTS</u>



- Based on the case study above, what are the reasons why the owner of the Green Environment Company emphasizes household and recyclable waste? Which of the related problems do you think is the most important? Explain with justification.

- What could be the project designed to solve the problem you identified above?

- What scientific concepts are needed to know for the project to be designed?

- What are the requirements (materials, expert opinion, etc.) and limitations (duration, cost, etc.) of the project to be designed?

- Who is interested in the project to be designed and how? What are your thoughts on its relationship with daily life?

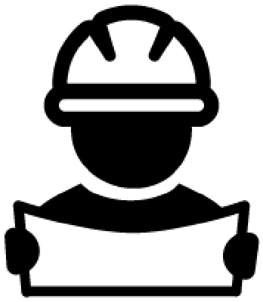
STEP 2: <u>RESEARCH THE PROBLEM</u>

Which institutions/organizations or individuals are dealing with the problem identified above? Do your research.

Which institutions/organizations or individuals are dealing with the problem identified above? Do your research.

STEP 3: **IMAGINATION: DEVELOPING POSSIBLE SOLUTIONS**

- What are the features of the design for domestic and recyclable waste?
- What kind of materials should be used to design domestic and recyclable waste?



- What features should the materials to be preferred in the design of domestic and recyclable waste contain?

STEP 4: **PLANNING: SELECTING THE PROMISING SOLUTION**

- Compare the domestic and recyclable waste design with the designs previously made in the subject area. Do research and seek expert opinion.

STEP 5: **CREATION: PROTOTYPING**

- Draw the design prototype for domestic and recyclable waste in the space below.

DRAWING AREA	**FEATURES OF THE DESIGN**	
	STRENGTHS	**ASPECTS TO BE DEVELOPED**

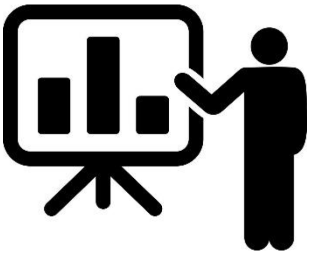
STEP 6: <u>TESTING AND EVALUATING THE PROTOTYPE</u>

- Test whether the prototype developed for domestic and recyclable waste works by discussing whether it meets the need.

- Critically evaluate the technology developed for domestic and recyclable waste.

STEP 7: <u>DEVELOPMENT, PRESENTATION and SHARING</u>

- What would you pay attention to if you were to redesign household and recyclable waste? What would you change or improve? Explain with justification.



- Plan studies to present and promote the design developed for domestic and recyclable waste.