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The Impact of Engineering Design-Based STEM Education on Students' Attitudes Toward STEM and Problem-Solving Skills

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ABSTRACT The impact of engineering design-based STEM education on 9th-grade high school students' attitudes toward STEM and their problem-solving skills was examined in this study. The subject of factors affecting the heat conduction rate in solids was taught using STEM education. In an experimental design with one group pre-test and post-test, students completed a STEM attitude scale and problem-solving inventory before and after the treatment. According to the paired samples t-test findings, students' attitudes toward mathematics, engineering, and 21st-century skills increased significantly, whereas their attitudes toward science and problem-solving did not change. The eta-squared effect size suggests a high level of change for other dependent variables but only a moderate change for problem-solving skills. In light of the findings, several recommendations about incorporating engineering design-based STEM education have been suggested.

Keywords Engineering design process, STEM education, Attitude toward STEM, Problem-solving skills, High school students.

1. INTRODUCTION

The need for people with science, technology, engineering, and mathematics education is rising in the modern world. Therefore, more functional programs are necessary for teaching these disciplines, and at the moment, STEM education is the solution to this problem (Gencer, Doğan, Bilen & Bilge, 2019). STEM education is a process-oriented approach besides focusing on the product while blending science, mathematics, engineering, and technology disciplines to solve problems of everyday life and empower students with motivating experiences (Akarsu, Akçay & Elmas, 2020).

Moreover, STEM education provides the skills necessary for today's workforce (Yamak, Bulut & Dündar, 2014). These skills are problem-solving, using information, creativity, analyzing, adaptability, entrepreneurship, communication, and digital literacy. These skills taught to students through STEM education are anticipated to propel them academically (Pekbay, 2017). In this context, STEM education is a necessary strategy that countries must adopt to attract qualified individuals and safeguard and advance their economic interests. As a result, countries strive to develop technology-literate people who can keep up with innovations and changes and boost the number of competent people who have obtained STEM education and their employment rate in the industry (Wang, 2012). Applying information rather than just knowing it and putting theoretical knowledge into practice while solving problems are what matter in our current era. For this, it is necessary to integrate more than one discipline. Here, STEM education is an interdisciplinary approach that aids students in developing 21st-century skills (Çorlu, Capraro & Capraro, 2014). The engineering design process is widely employed in STEM education in the USA to address today's problems (Moore, Stohlmann et al., 2014). Even though there are several versions of the engineering design process, they always strive to combine numerous disciplines to tackle problems. It is anticipated that combining these disciplines properly would help people develop their 21st-century skills. 21st-century skills can be expressed as using knowledge and equipment to solve an existing problem. Hence, individuals must gain 21st-century skills as early as possible (Sayın & Seferoğlu, 2016).

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The early introduction of students to STEM activities enables them to cultivate a positive attitude toward STEM (Bybee & Fuchs, 2016). Curriculum changes and research are carried out with the aim of the acquisition of 21st-century skills for students. The goal is to develop problem solvers who have mastered 21st-century skills through STEM education (Beers, 2013). Problem-solving is the ability to deal with difficulties using the knowledge and equipment at your disposal (Özsoy, 2017).

The engineering curriculum was integrated with the science curriculum to develop STEM education in the USA (Kuenzi, Matthews & Mangan, 2008; Moore et al., 2013). Moreover, a national report promoting STEM education's integration of other disciplines and engineering disciplines has been published in the United States (NAE & NRC, 2009). In Turkey, *engineering and design skills* were included in the grades 3 to 8 science curriculum as one of the field-specific skills to be developed for students (Ministry of National Education [MoNE], 2018a). In addition, a *technology and design course* was added to the educational program for 7th and 8th grades (MoNE, 2018b). The 9th-grade physics curriculum aims to relate application areas of physics with other disciplines such as biology, chemistry, mathematics, and engineering (MoNE, 2018c). The present study aimed to investigate the effects of STEM education, which utilized the engineering design process regarding the factors affecting the heat conduction rate solids in physics courses on 9th-grade students' attitudes toward STEM and problem-solving skills.

1.1 Engineering Design Process (EDP)

The Engineering Design Process (EDP) is a theoretical framework employed during the STEM education approach (Moore, Glancy et al., 2014). The engineering design process is an iterative process that starts with defining the problem and continues with learning, planning, prototyping, testing, and decision-making (Moore et al., 2013; Moore, Glancy et al., 2014). Yılmaz Bilir (2021) added the preparation phase at the very beginning of the process to introduce students to engineering design, Engineering Notebook (EN), and forming groups (See Figure 1). In the defining the problem stage, students are given examples of a problem scenario from everyday life as they define the problem at hand. Students must assess the problem scenario and establish criteria and limitations to find a solution. Following the constructivist approach, the learning step entails the student's acquisition of the information required for problem resolution. In the planning phase, each student must develop a plan for solving the problem based on the information acquired in the preceding step. Students must present their design plans to their groups while presenting their evidence. Group members debate the advantages and disadvantages of the suggested designs before settling on an agreed-upon design plan. Then, students move to the prototyping step and create their prototypes following their mutual plan. Students who complete their prototypes proceed to test, the fifth step. This step evaluates how well the built prototypes adhere to the previously established criteria and constraints. During the final stage, the decision-making process, students evaluate the suitability of their design for problem-solving purposes by considering the criteria and restrictions established in the testing stage. Subsequently, they share their designs with other groups in the classroom. Throughout this process, students are encouraged to revisit the engineering design stages repeatedly and, if necessary, return to the beginning to arrive at a better solution. EDP represents an iterative procedure that allows re-transition between phases rather than being linear (Akarsu, Akçay & Elmas, 2020; Moore et al., 2013; Moore, Glancy et al., 2014).

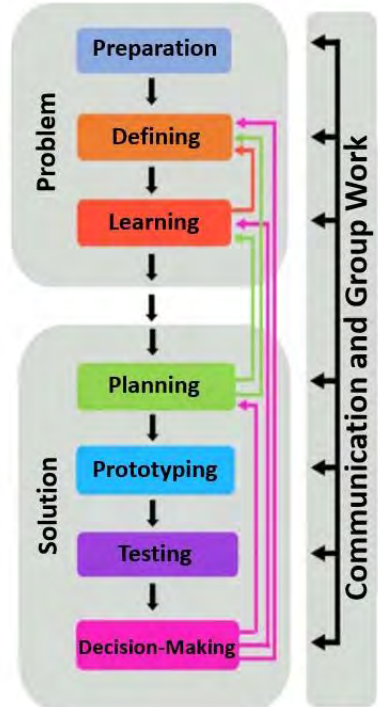

Figure 1 Engineering design process (Yılmaz Bilir, 2021, p. 45)

Note: The Engineering Design Process proposed by Moore et al. (2013) was updated with the addition of a preparation step by Yılmaz Bilir (2021).

1.2 Effects of STEM education approach

Several studies (e.g., Bircan & Çalışıcı, 2022; Erden & Yalçın, 2021; Yıldırım & Altun, 2015) examining the effects of the STEM education approach on students in grades ranging from kindergarten to university have been conducted. For instance, in his research with children in kindergarten, Akçay (2019) sought to determine the impact of STEM activities on children's problem-solving skills. And the study showed a permanent increase in the participants' problem-solving skills. In a separate study, Erden & Yalçın (2021) used a problem-based learning approach to implement STEM activities with preschoolers. They tried to determine the effect of these activities on children's problem-solving skills. Consequently, their study indicated that the problem-solving skills of these children were increased.

Similar studies with primary school children show the benefits of the STEM approach. To illustrate, in another study that was executed with 4th-grade students (Bircan & Çalışıcı, 2022), the effects of STEM activities on mathematics achievement, 21st-century skills, and attitude toward STEM were tested. At the end of this study, it was discovered that participating in STEM activities did not influence the participants' mathematics achievement; yet, students formed a favorable attitude toward STEM activities, and their 21st-century skills were improved. Again, a study with students from primary schools (Kavak, 2019) looked into the impact of STEM practices on 4th-grade students' attitudes toward science, problem-solving, and scientific process knowledge. According to the study, students were able to come up with suitable answers to the issues they ran into when using STEM activities. Besides that, it was found that students' scientific process abilities, problem-solving skills, and positive attitudes toward science all improved.

As another example, the influence of microprocessor STEM activities on the 6th-grade students' attitudes toward STEM was examined in a study (Karışan & Yurdakul, 2017). The study's findings showed that students' attitudes toward STEM subjects improved after participating in STEM activities. In their study, Kayahan, Mısır, Küpeli & Fırat (2018) explored whether STEM activities affect the problem-solving skills and academic achievement of 4th grade students. Henceforth, their study indicated that STEM activities improved students' academic achievement and problem-solving skills. While another study with high school students indicated that STEM education utilizing the 5E model and engineering design processes in physics courses boosted students' academic achievement in the electricity topic in the 10th grade, it did not affect STEM and physics attitudes (Yılmaz, 2019). The present study aims to investigate how high school students' attitudes toward STEM and their problem-solving skills are affected by STEM education that uses the engineering design process.

2. METHOD

The study was conducted via one group pre-test and post-test experimental design without a control group. Activities affecting the heat conduction rate in solid materials among the 9th-grade physics course subjects were executed for 11 class hours. Data collecting tools were used on the students to gather data before and after the treatment. Participation was voluntary, and the study's Ethics Committee approval was obtained.

2.1 Participants

The 17 students who participated in the research were all in the 9th grade at a public high school in a district of one of the largest provinces in eastern Turkey. The sample was selected by convenience sampling method. Of these participants, 7 are boys and 10 are girls, and their ages vary between 14 and 15.

2.2 Data Collection Tools

The demographic information form, which included questions on the students' ages and genders, the STEM Attitude Scale, and the Problem-Solving Inventory, were used to collect the study's data.

STEM Attitude Scale

Faber et al. (2012) created the STEM Attitude Scale. The scale was adapted to Turkish by Yıldırım & Selvi (2015), who conducted validity and reliability analyses for the Turkish version of the scale. In the exploratory factor analysis conducted for this adaptation, it was found that the scale consisted of four dimensions, and the Cronbach Alpha coefficients of the factors ranged between .86 and .89. Confirmatory factor analysis (RMSEA= .06, SRMR= 0.05, NFI= 0.95, CFI= 0.96, IFI= 0.96) also supported the four-dimensional structure (Yıldırım & Selvi, 2015). Table 1 contains the Cronbach's Alpha reliability coefficients derived from the pre-test and post-test conducted for the present study. Additionally, the table presents a sample item for each sub-dimension of the scale. The scale items are answered in a 5-point Likert-type questionnaire (1= = strongly disagree, 5= = strongly agree).

Problem-Solving Inventory

The Problem-Solving Inventory was developed by Heppner & Peterson (1982), and Sahin, Sahin & Heppner (1993) evaluated the validity and reliability of the Turkish version. Cronbach Alpha reliability coefficient of the entire scale was determined as .88 (Sahin, Sahin & Heppner,

Table 1 STEM attitude scale sub-dimensions and reliability coefficients

	Number of items	Sample item	Pre-test Cronbach's Alpha	Post-test Cronbach's Alpha
Attitude toward mathematics	8	I am a student who can succeed in mathematics.	.94	.77
Attitude toward science	9	I may consider building a career in science.	.90	.87
Attitude toward engineering	9	Designing products or structures will be crucial for my future work.	.80	.81
21st-century skills	11	I am sure that I will consider other people's opinions when making decisions	.71	.77

1993). The 6-point Likert-type scale (1= Strongly disagree, 6= Strongly agree) consists of 35 items, and three items of those were dismissed during the analysis. These items include the behaviors and approaches to real-world problems (For instance, "When confronted with a complex problem, I do not take the time to formulate a strategy for gathering information that will help me determine the root cause of the problem.") In this study, the Cronbach Alpha coefficient calculated for the problem-solving inventory was .91 in the pre-test while it was determined as .88 in the post-test.

2.3 Treatment Process

The actions taken in the activities followed the engineering design process (EDP) steps. Groups were created in the first class, which was the preparation step. There were 5 or 6 students in each group. The teacher explained EDP to the class and instructed them to utilize the Engineering Notebook (EN) for this procedure. The teacher has asked the students to affix the *Introduction to Engineering Profession* worksheet, which includes questions such as "Who is an engineer?", "How do engineers solve problems?" and "How do engineers know if their designs are successful?" to their ENs and write down the answers. Each group's students shared their answers to these questions with the whole class, and the instructor provided the appropriate explanations when the responses appeared inadequate. To establish a connection between the examples from the students' lives and the engineering profession, the teacher asked students to consider a problem from their daily lives and collect their answers to possible solutions. After that, the teacher told the students that they were assigned to an engineering project, and they would work like an engineer.

During the second class, students proceeded to define the problem. Ms. Umay's e-mail requesting assistance with a project was circulated to the students who would serve as engineers in this project (See Figure 2).

> Hello,
> I'm Umay, a businessperson. I want to build animal shelters to provide the fundamental requirements of street animals, such as shelter and food, in order to combat the harsh winter conditions in Erzurum. Animal shelters must have thermal insulation in order to reduce their heating costs. Follow the concept of being economical while planning the thermal insulation of shelters. I'm looking forward to seeing your designs on how to create thermal insulation in shelters. The group that executes their design in the most qualified manner will get a free week of vacation from me.
> Would you like to help us with this project?
> Businessperson Umay...

Figure 2 Ms. Umay's first e-mail

The students examined the problem independently, then discussed it in groups and defined it. In this process, they could contact Ms. Umay via e-mail and ask her questions to solve the problem. Students asked questions such as where thermal insulation should be applied (walls, roof, floor), whether there is a time limit and budget, and what it means to be economical. The students wrote the questions they would ask Ms. Umay in their EN; these questions were then read aloud to the class, allowing the students to recognize the variety of questions. The students conveyed their questions to Ms. Umay via their teacher. The teacher assumed the role of the inquirer and shared the answers with the class. The second e-mail from Ms. Umay is given in Figure 3.

> Hello Dear Engineers,
> Thank you all for your questions. I sent your teacher the answers to your questions. There are essential factors to consider when designing thermal insulation for shelters. These are:
> - According to veterinarians I spoke with who are experts in their professions, the optimum width, height and height dimensions of the shelters should be 2.5m x 2.5m x 2.5m or minimum 2m x 2m x 2m.
> - For your work on the insulation of shelters, I'd like you to construct 1/10-scale models of the dimensions of the shelters listed above.
> - I will send you styrofoam, glass wool, and xps insulation materials for your designs, along with 5cm and 10cm thicknesses of each material.
> - I would like you to create appropriate and cost-effective thermal insulation using a material that you will determine through your cooperation while adhering to the requirements listed above.
>
> After the design process is over, I kindly ask you to send me the 4 documents I stated below.
> - Drawing of the model of your design, as well as the model itself that you've prepared according to the drawing
> - The list of materials you will use for your design
> - An image of the prototype you created
> - The test results of the prototype you created
>
> Thank you.

Figure 3 Ms. Umay's second e-mail

After receiving the second e-mail, the students determined the necessary criteria and constraints for the problem's solution and began work by documenting them in their ENs. With the third class, the learning stage started. In this class, students learned Ratio and Proportion, one of the mathematics course topics they will use to address problems about the animal shelter model they will design through an activity. With the activity of creating an airdock for the Turbulence Airline company, the students understood the concept of proportion and discovered how to find the unknown value. This knowledge will be beneficial in the size reduction process that students will perform when designing animal shelter models.

In the fourth class, an activity was done concerning the heat conduction-type of matter relationship with the objective of "analyzing the factors affecting the heat conduction rate in solids" in the heat and temperature unit. In this activity, the teacher instructed students to compare the burn times of honey candles affixed to various metals at equal distances from the heat source using an experimental setup. Before the activity, the students wrote their hypotheses in their ENs. Afterward, they filled out the sections regarding whether the heat conduction rate in the solids depends on the matter type. With the assistance of activity, the students learned about the connection between the rate of heat conduction and the surface area of a material in the fifth class; in the sixth class, they learned about the connection between the rate of heat conduction and the thickness of the matter; and in the seventh class, they learned about the connection between the rate of heat conduction and the temperature difference. Before beginning each activity, the students were instructed to formulate their hypotheses and, based on the findings obtained at the end of the activity, write their interpretations to the ENs.

In the eighth class, the planning step has been started. Students created a design plan to address the animal shelter's heat insulation issue utilizing the information they learned about the factors affecting heat conduction rate in solids and the ratio-proportion subject in the previous classes. Each student in the groups drew individual design plans in their ENs. Then, the group evaluated these designs, and the most suitable design was chosen as the group's plan. They drew the chosen design plan in their ENs. They had to explain the insulating material they would use and the sizes in which they would construct the shelter while creating the design plan.

In the ninth class, the prototype creation step has been started. The students created the prototype following the group design plan they selected during the planning step. The supplies, such as XPS thermal insulation material, styrofoam, a small model house, a prop, and a stopwatch required to make their prototypes, were provided to the students. There was also a mini refrigerator they could use in the laboratory. In the tenth class, EDP's testing and decision-making steps were applied. At this point, the students determined how to test how their prototype met the problem's criteria and constraints. They tested the prototypes they created by measuring their temperature at room temperature and then putting them in the mini refrigerator. They evaluated the data gathered from the test and concluded the problem's solution. The groups requested feedback from the class after presenting their prototypes.

In the eleventh and last class, the redesign step of EDP was applied. The unsuccessful group initiated the redesign process due to the tests they performed in the preceding class. The groups analyzed the feedback that was put forward about their prototypes by other groups in the class and discussed what was wrong with their prototypes. They identified which step of the EDP caused these errors and wrote what they would do for it to their ENs. To put it more explicitly, the group who used styrofoam and recorded more heat loss concluded that the error was due to the material they used. As a solution, they decided to use XPS thermal insulation material. After their efforts, they redeveloped their designs. They put their prototypes through a series of tests and documented the results in their ENs to be considered throughout the decision-making process. After going through the test results, there was further discussion over whether or not the prototype satisfied the requirements and constraints. After it was determined that an adequate solution had been found, the second e-mail that Ms. Umay had written was reread, and the documents that she asked for were prepared and sent to her.

2.4 Data Analysis

A paired (dependent) sample t-test comparing pre-and post-test scores was performed using the SPSS 20 package to examine whether the treatment affected students' attitudes toward STEM and problem-solving skills. Before performing the analyses, the assumptions of the t-test for paired samples the normal distribution of the difference scores, was examined (Green & Salkind, 2005, p. 162). Pre-test scores were deducted from post-test scores for each dependent variable to produce different scores, and the Shapiro-Wilk test was employed to evaluate the normality assumption since the sample size was small (n= 17) (Büyüköztürk, 2002). Results of the Shapiro-Wilk test revealed that all of the study's variables' difference scores had a normal distribution (p= .60 for the difference score of attitude toward mathematics, p= .16 for the difference score of attitude toward science, p= .64 for the difference score of engineering, p= .84 for the 21st-century skills difference score, and p= .70 for the problem-solving skills difference score) In other words, since the difference scores according to the Shapiro-Wilk test results verify the assumption of normal distribution ($p > .05$) paired samples t-test was performed.

3. RESULT AND DISCUSSION

Descriptive statistics for the variables of the study are provided in Table 2. The means indicate that all variables' scores improve after the treatment compared to before the treatment. Additionally, it is worth highlighting that among the attitudes toward STEM variables, students' attitudes toward mathematics in the pre-tests ($\bar{X}$ = 2.58, SD = 1.19) had the lowest attitude value and was below the midpoint score of 3 on the 5-point Likert-type response scale. After

Table 2 Descriptive statistics of the variables

Variable	*n*	Pre-test		Post-test	
		$\bar{X}$	*sd*	$\bar{X}$	*sd*
Attitude toward mathematics	17	2.58	1.19	3.43	.87
Attitude toward science	17	3.61	.74	4.01	.64
Attitude toward engineering	17	3.90	.56	4.25	.60
21st-century skills	17	3.80	.50	4.23	.47
Problem-solving skills	17	4.08	.72	4.33	.72

Table 3 Paired sample t-test

Variable	Difference score (Post-test - Pre-test)	*SE*	*t*	*sd*	*p*	η^2
Attitude toward mathematics	.85	.26	3.22	16	.01*	.39
Attitude toward science	.40	.23	1.79	16	.09	.17
Attitude toward engineering	.35	.15	2.41	16	.03*	.27
21st-century skills	.43	.13	3.40	16	.00*	.42
Problem-solving skills	.25	.19	1.32	16	.20	.10

*$p < .05$

the treatment, it was seen that the mean scores for these variables were all higher than the midpoint of the scale, with the attitude toward engineering having the highest mean score ($\bar{X}$ = 4.25, SD= .60). The mean scores of problem-solving skills were higher than the midpoint, which is 3.5 on the 6-point Likert-type scale both in the pre-test ($\bar{X}$ = 4.08, SD = .72) and in the posttest ($\bar{X}$ = 4.33, SD = .72).

The findings obtained concerning the paired sample t-tests performed separately for each dependent variable are presented in Table 3. Analysis results showed that after attending STEM education activities, the scores of students' attitudes toward mathematics ($t_{16} = 3.22, p < .05$), engineering ($t_{16} = 2.41, p < .05$), and 21st-century skills ($t_{16} = 3.40, p < .05$) showed a statistically significant change. On the other hand, there was no change in their attitude toward science ($t_{16} = 1.79, p > .05$) and problem-solving skills ($t_{16} = 1.32, p > .05$).

Besides, the effect size of the difference between the pre-test and post-test scores was calculated with eta squared (η^2). Cohen (1988) categorized the benchmark for eta squared value of .01 as small, .06 as medium, and .14 as large effect size. The effect sizes calculated in this study showed that (see Table 3) the effect sizes of the difference between pre-test and post-test scores are large for attitude toward mathematics, attitude toward science, attitude toward engineering and 21st-century skills, and medium for problem-solving skills.

4. CONCLUSION

This research investigated the impact of engineering design-based STEM education on 9th-grade students' attitudes toward STEM and their problem-solving skills. After attending these STEM activities, there was a statistically significant improvement in students' attitudes toward mathematics and engineering and an increase in their scores on 21st-century skills, with large effect size values. These findings suggest that STEM education built on the engineering design process contributed to students' attitudes toward mathematics, engineering, and 21st-century skills.

In the literature, it is possible to encounter other studies supporting these results. For instance, Bircan & Çalışıcı's (2022) study findings indicated that 4th-grade students developed a positive attitude toward STEM activities, and their 21st-century skills improved after attending STEM activities. In another study with 4th graders, it was found that students' 21st-century skills were improved, and they could come up with acceptable answers to the problems they ran across during STEM activities (Kavak, 2019). Another study investigating the effect of microprocessor STEM activities showed that these activities positively affected the 6th-grade students' attitude toward STEM (Karışan & Yurdakul, 2017). Ceylan & Karahan (2021) found that STEM activities positively influenced high school students' mathematical attitudes and 21st-century skills.

Regarding the impact of STEM activities on attitudes toward STEM subjects and problem-solving skills of students, several studies have shown that students' attitudes toward STEM subjects and problem-solving skills are improved as a result of engaging in these activities (e.g., Akçay, 2019; Erden & Yalçın, 2021; Özdoğru, 2013; Sung & Na, 2012; Şahin & Kabasakal, 2018). For instance, Öztürk & Çınar (2022) found that engineering design-based STEM activities improved preschool children's problem-solving skills. Students who participate in STEM activities can produce original solutions to the problems they encounter, and their attention spans increase (Akdağ & Güneş, 2017; Balat & Günşen, 2017; Uğraş, 2017). On the other hand, some studies demonstrated that STEM education did not contribute to the problem-solving skills of preschool children (Asığağan, 2019; Şahin & Şahin, 2020) and attitudes towards physics of 10th-grade high school students (Yılmaz, 2019). The present study also demonstrated no statistically significant change in students' attitudes toward science and their scores for problem-solving skills after attending engineering-based STEM activities. Although the change in students' attitudes toward science and problem-solving skills is not statistically significant, the effect size value was large for attitudes toward science and medium for problem-solving skills. This suggests that the small number of samples may cause the lack of a statistically significant difference. Nevertheless, more studies are needed to clarify the impact of engineering design-based STEM education on attitudes toward science and the problem-solving skills of students with different age groups.

According to the findings, it is thought that offering high school teachers in-service training programs regarding STEM education and engineering activities can be beneficial. Teachers' insufficient knowledge and skills in engineering design-based science teaching discourage teachers from using these activities in their lessons (Akgündüz et al., 2015). In his study, Capobianco (2011) found that besides the positive opinions of teachers about engineering design-based science teaching, they also have concerns. Hsu, Purzer & Cardella (2011) emphasized that although teachers have a positive attitude toward engineering design, the necessary training and equipment should be provided for its effective integration. The fact that these training programs are focused on practical application might be helpful for the activities that teachers will eventually carry out in their classrooms. The activities carried out throughout the present study might be adapted for usage with digital media and made accessible to a greater number of teachers. Thus, teachers can access examples of STEM activities. Concerning the training programs to be offered to teachers, preparation of STEM activities that are less expensive and call for accessible materials can be encouraged. In addition to teachers, pre-service teachers can be assisted in applying the STEM education approach in their future careers by offering them training to improve their STEM approach-related skills and knowledge at teacher education programs. Additionally, when the related literature is examined, it is seen that studies regarding the design based STEM activities mostly focused on students in the preschool period (e.g., Akçay, 2019; Erden & Yalçın, 2021; Erol & Erol, 2022; Güldemir & Çınar, 2021; Öcal, 2018; Öztürk & Çınar, 2022; Yalçın & Çakır, 2022). There is a need to increase the number of similar studies with older age groups.

4.1 Limitations and Recommendations for Future Studies

This study has some limitations that should be mentioned. In the study, one group pre-test and post-test experimental design was applied by working with a previously created class. There are particular risks associated with this scenario for the study's internal validity (Fraenkel & Wallen, 2006). The addition of a control group and random class assignment will strengthen the validity of future results in subsequent studies. Another factor is related to the size of the sample. Working with a small sample (n = 17) may have contributed to the lack of statistically significant differences between the pre-test and post-test scores regarding students' attitudes toward science and problem-solving skills, even if a large effect size was determined as a consequence of the analyses. The sample size influences the test's power, and if it is investigated with small samples, statistically insignificant findings may be produced since the test's power would be insufficient (Stevens, 1996; Cited by: Pallant, 2007). Therefore, the results can be compared with this current study by applying the same STEM education activities with more participants. In this way, the generalizability of the study can also be increased. This study's sample included the 9th-grade high school students. Future STEM education activities using the engineering design process can be carried out with students from different grades. Also, in this study, the activities were performed regarding the physics subjects. In future studies, STEM education activities can be performed about chemistry and biology subjects, which are other branches of science..

Abbreviations

EDP, Engineering Design Process; EN, Engineering Notebook.

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