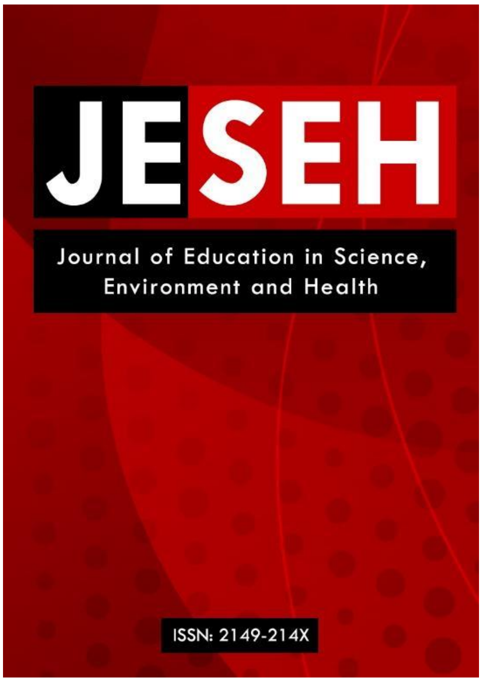


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# Investigation of STEM Supported Engineering and Design Experiences of Students Participating in Design and Innovation Workshop in the Context of Situational Interest Theory

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# Investigation of STEM Supported Engineering and Design Experiences of Students Participating in "Design and Innovation Workshop" in the Context of Situational Interest Theory

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## Abstract

This study aims to examine the engineering and design-supported STEM (Science, Technology, Engineering, and Mathematics) experiences of students who participated in the "Design and Innovation Workshop" organized at the Science and Art Center (SAC) during the semester break. The experiences and perceptions of 17 students (10 males and 7 females) were analyzed in depth in this study, which was conducted using a phenomenology design from qualitative research methods. Semi-structured interview form, student diaries, field notes and STEM product drawing form were used as data collection tools. The research findings showed that students' participation in design and engineering-based STEM activities enhanced their problem-solving skills, creativity and teamwork. The theory accompanying the research suggests that these activities increase students' interest and motivation in STEM disciplines. The research results suggest that design and innovation workshops can positively influence students' attitudes and skills towards STEM fields.

## Introduction

STEM (science, technology, engineering, and mathematics) education occupies a core position in education systems owing to its capacity to equip the youth with the skills that are relevant in the modern world (McDonald, 2016). Engineering and Design enhances the problem-solving abilities and imaginations of the learners (Daly et al., 2014). These disciplines offer students the opportunity to think critically and generate innovative solutions in the process of transforming theoretical knowledge into practice (Kelley & Knowles, 2016). In Turkey, Science and Art Centers (BİLSEM) play an important role in providing special educational opportunities for gifted children. In terms of physical resources and equipment, it is more favorable than other institutions. Science and Art Centers (BİLSEM) are also significant institutions providing special education programs that help gifted students maximize their potential. In 2022, the Ministry of National Education (MoNE) made an amendment, which brought in other students to be trained in these centers. The aim of the program is to blend scientific thinking and behaviors with aesthetic values through the education provided to students through workshops, and to enable them to develop as individuals who produce solutions, are productive and self-knowledgeable. Also, these trainings aim to help students discover their talents and creative potential early on use these talents at the highest level and acquire new skills (MoNE, 2022). In line with this goal, summer school workshops offer students hands-on learning experiences through engineering and design projects, and their academic and personal development has not yet been sufficiently examined in the literature. In the context of this study, the experiences and perceptions of students participating in design and innovation workshops in summer school workshops towards engineering and design-supported STEM practices were examined.

### Literature Review

### STEM Education

The importance of STEM education has increased worldwide with specific focus on intervariance and multifaceted approaches to development (Zhan et al., 2022). In STEM education, students practice the skills of the 21st century, in particular, complex problem solving, communicating, and working in collaboration (Wu & Anderson, 2015). Integration of STEM in the school curriculum has been beneficial to the knowledge and skills of the students (Robinson et al., 2014). Students are given projects that deal with engineering and design, which makes it easier for them to put theory into practice. This approach makes the learning process more efficient and worthwhile. The implementation of the new information technology when teaching or learning STEM subjects, such as online communication technologies cause a better performance and attitude towards STEM subjects among students. (Fang et al., 2021). Literature supports the claim that the practice of doing STEM in relevant studies enhances learning outcomes of the students and it also provides solutions to other problems within the disciplines in question (Wahono et al., 2020). The need for integrated STEM education is primarily to develop the need for a STEM identity and also the ability of the teachers to deliver stimulating STEM content and curriculum in elementary school classrooms (Galanti & Holincheck, 2022). Collaboration within STEM in the activities and environments focuses on the design of their outcome to solve a problem and the glue that holds these components together (Juškevičienė et al., 2020). STEM education is positioned as a key driver in the development of critical thinking, creativity, communication skills, and leadership abilities to overcome complex practical challenges. There are various applications of STEM education in the literature. However, most researchers have argued that the engineering-oriented design process is one of the most useful practices for conducting STEM programs (Roberts & Cantu, 2012; Ting, 2016; Forawi, 2018).

## Engineering and Design Supported STEM

Engineering and design-enhanced STEM education is an approach that combines design and engineering principles to enable students to explore science, technology, engineering, and mathematics topics. The engineering design process (EDP) can be effectively used to enhance K-12 STEM courses and make STEM concepts more relatable and exciting for students by solving authentic problems through a student-centered approach (Billiar et al., 2014). When engineering design is integrated within STEM education, learners are faced with real-world problems and hence get to know how scientific and mathematical principles are used in practice (Uzun & Şen, 2023). In particular, integrative STEM approaches that have technology and teamwork components have been reported to enhance learning performance in engineering design practices and foster conceptual understanding and higher order thinking skills among learners (Fan & Yu, 2017). In the context of primary schooling, real-life engineering challenges are capable of greatly improving the ability of learners to implement the core principles of STEM. A task involving optical engineering, for example, went much beyond theoretical learning and allowed fifth-grade students to grasp the very practical application of designing, building and redesigning STEM concepts (King & English, 2016).

Studies have revealed that the engineering design process enhances the teaching and learning of STEM subjects tremendously. Schemes of engineering design process allow students to actively participate in activities, interact with each other, and find ways of resolving issues in a creative and systematic manner. This approach aids in deeper appreciation of STEM concepts and inculcates important capabilities like communication, teamwork and hardiness (Sudrajat et al., 2022). Also, the rationale for STEM education has been cited as the incorporation of engineering design into the pedagogical process as a means of enhancing student motivation and performance. Shahali et al. (2016) report that following an extensive integrated STEM education program, middle school students showed a marked increase in the interest for STEM subjects and careers. In the same vein, Fan and Yu (2017), found that students in high school who were taught a STEM engineering module did better in conceptual understanding, reasoning, and performance in engineering design projects than their education technology counterparts. Carr et al. (2012) made a case for the inclusion of engineering components within primary curricular learning standards while Carlson and Sullivan (2004) addressed the issue of design as a factor in interest building towards engineering within the K-12 engineering curriculum. This is why, as Winarno (2020) explains, this method boosts students' interest in STEM disciplines and equips them for the kind of careers which are multidisciplinary and creative in nature. Therefore, the following studies review and present research evidence about the benefits of infusing engineering design throughout the education system to the students' motivation and even performance.

## Theoretical Framework

"Situational Interest Theory" explains how individuals' interest in a particular topic or activity is shaped by current circumstances and interactions. "Situational Interest Theory," developed by Hidi and Renninger (2006), explains how situational interest triggered by certain conditions or activities can lead to the maintenance of individual interest in a topic. The Situational Interest Theory identifies four stages of learner interest development, which includes "triggered situational interest", "sustained situational interest", "emerging individual interest" and "well-developed individual interest" (Hidi & Renninger, 2006). In this theory, it is argued that situational interest plays a role of enhancing the mood of the learner which further enhances their learning processes and learning outcomes (Kron et al. 2022). Additionally, it has been demonstrated that clarity affects situational interest, although its role in the growth of personal interest over time is still being researched (Tröbst et al., 2016). Related to the situational condition of interest, there are studies which argue that an activity's interest is not based solely on the activity, but also on the environment that surrounds the activity (Higgins et al., 2010).

In addition, another finding by Lo (2015) suggests that situational interest can play an important role in influencing students' learning and future behavior, pointing to the importance of situational factors in educational settings. Another study underlines the link between the quality of motivation in learning situations and the development of stable individual interest in a particular domain (Seidel et al., 2005). Conclusions endorse that, the educational environment, or situational factors, can also play a role in affecting an individual's level of interest and motivation in learning. According to Rotgans and Schmidt (2014), posit that a situation becomes interesting when there is a feeling of lacking adequate knowledge, and that level of interest can also go down when the problem becomes overly familiar. This study presents an opportunity to explore some implications of Situational Interest Theory with respect to explaining students' interest in the STEM fields. More specifically, workshops aim to change participants' motivation and interest in STEM areas by providing new and meaningful, interactive ways of learning. In this respect, it can suggest important ways how those involved in education and designing the curriculum by addressing questions of design and innovation workshops guided by Situational Relevance Theory can further enhance the motivation of the students.

### Innovation and Contribution of the Research

The objective of the Design and Innovation Workshop Summer School Program is to facilitate students with knowledge and skills necessary in the field of design and issues of innovation. In everyday practices, the basic approach of the program combines many different methods of teaching, while addressing the individual differences and the developmental levels of the students. This approach is meant to facilitate active engagement of students, where the reluctance to embrace innovation and design processes is averted (MoNE, 2022). The organization of the program involves informing the students about the project cycle process, designing as well as manufacturing any technological or innovative products. It aims to provide students with the skills to use innovation processes, to gain experience in three-dimensional solid modeling and design development, and to transform the ideas obtained through innovative thinking into practical applications. Through practical activities such as modeling exercises and the use of electronic components, the program enables students to increase their technological literacy while gaining experience in solid modeling and additive manufacturing techniques. The importance of this program lies in the fact that it guides students towards innovative thinking, creativity and problem-solving skills in parallel with the ever-evolving and changing technology in today's world. Giving students these skills at an early age increases their capacity to cope with the challenges they will face in the future and raises them as active and productive individuals of the information society. The Design and Innovation Workshop Summer School Program has the potential to contribute to both the academic and personal development of students, enabling them to take their place as active and respected individuals in the world of the future (MoNE, 2022). This research aims to fill the gaps in existing studies by examining the effects of design and innovation workshops on student experiences and perceptions, especially in special education centers such as BİLSEM. The research provides valuable findings for educators and policy makers by offering new perspectives on how such workshops affect students' interest and motivation in STEM fields. This study will contribute to the development of educational practices for students and help identify strategies to support their academic and personal development.

### Aim

The aim of this study is to examine the engineering and design-supported STEM experiences of the students who participated in the design and innovation workshop in the support and training course implemented in the Science and Art Center (BİLSEM) during the semester break. In line with this purpose, the following sub-questions were sought to be answered:

1. What are the students' experiences of engineering and design-supported STEM applications?
2. What are the students' perceptions of engineering and design-supported STEM practices?
3. How can students' perceptions and experiences towards engineering and design supported STEM implementation be evaluated in the context of Situational Interest Theory?

## Method

### Research Design

A phenomenological, qualitative research methodology was employed to determine students' views on a phenomenon. Phenomenology is used to illuminate phenomena that we are aware of but do not have an in-depth and detailed understanding (Yıldırım & Şimşek, 2013). Phenomenology is a research method that reveals the common meaning of a group of people's personal experiences about a particular phenomenon, fact or concept (Creswell, 2013). A phenomenological methodological approach enables data to be collected to explain the main features and significance of the experience (Merriam, 2013). In this study, students' perceptions and experiences regarding the phenomenon of engineering and design supported STEM application were examined.

### Participants

The participants of the study consisted of students who chose the "Design and Innovation Workshop" within the scope of the support and training course during the semester break at a Science and Art Center located in the east of Turkey in the 2022-2023 academic year. The study group was selected with the "easily accessible case sampling" method, which is one of the purposeful sampling methods. With this method, the researcher gains speed and practicality to the research because the researcher chooses a situation that is close and easy to access (Yıldırım & Şimşek, 2013). The study group consisted of a total of 17 students, 10 boys and 7 girls, attending different primary schools in the province. The ages of the participants ranged between 8 and 10 years old.

### Data Collection Tools

*Semi-structured Interview Form*

Semi-structured interview forms, especially in STEM education, allow researchers to delve deeply into the views of teachers, students or other stakeholders about STEM practices, pedagogical approaches or challenges in education. This method provides researchers with an important tool to understand participants' perspectives and gain the knowledge needed to improve educational practices (Kelley & Knowles, 2016). At the end of the implementation, semi-structured interviews were conducted with the students in the study group.

*Student Diaries*

Student diaries are used as an important tool in STEM education. Diaries enable students to reflect their experiences, personal observations and learning processes from classroom activities (Aktan & Budak, 2020). At the end of each activity, the students in the study group were asked to write their feelings and thoughts about the application in the form of a diary and the diaries were collected the next day.

*Field Notes*

Field notes are very important in STEM education and provide valuable information about the implementation of activities and the perspectives of teachers and students (Altan et al., 2018). Field notes play an important role in enriching special activities such as STEM camps and evaluating studies to improve students' STEM skills (Okulu et al., 2022). In this study, which was conducted according to the phenomenological design, the researcher/teacher acted as a participant observer, watched the groups as they carried out their work, established relationships with them, and took notes of an important event in the order of occurrence as soon as the practice was over.

*Document Analysis (STEM Product Drawing Form)*

Drawing in science education has been shown to have multiple benefits for children's learning and development. Research shows that drawing can increase memory retention, help to structure memories in stages and sequences, and provide guidance for recalling and articulating experiences (Bonilla-Sánchez et al., 2022). Drawing can also help children reveal their thinking on abstract or challenging topics, making it a valuable tool for understanding children's perspectives on complex issues (Brechet et al., 2022). Examining students' drawings of STEM fields (Benek & Akçay, 2018) and employees in STEM fields (Dönmez, 2023) has been used in previous studies. This form was prepared to reveal what kind of tool/invention/product creation ideas students have in their minds for the future. In the form; "Can you draw a tool/invention/product that you want to make in your future life? Can you write the name of this product and what it does?". After the application was completed, the students were asked to fill in the form.

**Research Process**

This study, which examines students' design and engineering-based STEM experiences and perceptions, was conducted during the semester break of the 2022-2023 academic year. The study was conducted within the scope of the Design and Innovation workshop opened within the scope of the support and training course opened within BİLSEMs. The study was conducted with students who participated in the Design and Innovation workshop during the semester break at a Science and Art Center in Van city center. In this context, the application was carried out for a total of 16 hours, eight hours in the first week and 8 hours in the second week.

Three separate design and engineering-based STEM activities were conducted during the implementation. The researcher/teacher informed the students about the activities before the actual implementation. In the first class hour, an introductory activity was conducted with the students and student groups were formed. In the second class hour, the groups were given information about the engineering design process. In the third and fourth class hours, a pilot application was carried out with a sample activity. In the light of the data obtained in the pilot application, it was decided that four class hours would be appropriate for each activity. The process followed in the study is presented in detail in the table below.

Table 1. Activities and date/time of realization

| Events | Date | Hours |
|---|---|---|
| Pilot Application | 26.01.2023 | 4 |
| Energy Activity with Triangular Prism | 27.01.2023 | 4 |
| I Design My Seismograph Activity | 02.02.2023 | 4 |
| Mini Saw Making Activity | 03.02.2023 | 4 |

During the implementation, three different STEM activities were carried out: "Energy with Triangular Prism", "I Design My Seismograph" and "Mini Saw Making". The activities were carried out by taking into account the outcomes of the Support Education Program (DEP) and Science Curriculum of BİLSEMs. The outcomes related to the activities are given in Table 2.

Table 2. Activities and related outcomes

| Activities | Outcomes | Resource |
|---|---|---|
| Energy Activity with Triangular Prism | -Explains the concept of energy.<br>-Understands that potential energy turns into kinetic energy. | -Science and Art Centers Science and Technology Supplementary Course Material<br>-Support Education Program (SEP) Science Area Framework Plan |
| I Design My Seismograph Activity | -Explains the destructive natural events caused by natural processes. | -Science Curriculum (Grade 5) |
| Mini Saw Making Activity | -Makes his/her own design using an electric motor.<br>-Creates his/her own design using the electric motor details the products.<br>-Recognizes the circuit elements that make up the simple electrical circuit with their functions.<br>-Battery, light bulb, cable and switch are introduced as circuit elements.<br>-Establishes a working electrical circuit. | -Support Education Program (SEP) Science Area Framework Plan<br>-Science Curriculum (Grade 4) |

The activities were carried out following the "engineering design process" proposed by Cunningham (2009). The activities related to the design process are described below:

**Activities in the Engineering Design Process**

*Ask:* In the first stage of engineering design, the problem situation was identified and students were encouraged to conduct research individually or in groups by searching various sources related to the problem. The groups determined the purpose of their work and planned what they would do for the solution. At the same time, they set criteria and limitations for the product they would make. In other words, they were provided to define the successful operation of the product to be developed and the obstacles in designing the product.

*Imagine:* At this stage, students brainstormed in groups and developed alternative solutions for the product. At the same time, it was ensured that they first made individual drawings about the design and then decided on a common drawing by bringing their individual drawings together. They chose the best solution among the alternative solutions they developed.

*Plan:* At this stage, students made plans about the design they were planning to make. They were made to clearly determine which materials they would use in the design process, where, why and how they would use the materials, and the reasons for choosing the materials. They also determined the conditions under which they would work and the sequence they would follow. As a result of the planning, the researcher/teacher gave the necessary materials to each group.

*Create:* After the planning, the groups created their products by following the necessary steps. They were told that they should pay attention to the predetermined criteria and limitations while creating their products. The products created by the groups were tested in front of the class and it was determined whether they met the criteria and limitations.

*Develop:* In the last stage, the groups further developed their products as a result of the tests. The products that did not meet the predetermined criteria and limitations were revised and retested after revision.
Students used knowledge and skills from the fields of science, mathematics, engineering and technology. The association of the activities carried out by the students with STEM fields is given in Table 3.

Table 3. Association of activities with STEM fields

| Activities | STEM Fields | Activities carried out |
|---|---|---|
| Energy Activity with Triangular Prism | Science | - Learning the definition of the concept of energy, the meaning of potential energy and kinetic energy, the transformation of potential energy into kinetic energy. |
| | Mathematics | - Learning the definition and properties of an equilateral triangular prism.<br>- Creating a model of an equilateral triangular prism using angle and length measurements with the help of a ruler.<br>- Making distance measurements of thrown balls. |
| | Engineering | - Creating a product by following the stages of engineering design. |
| | Technology | - Creating an audiovisual advertisement for the product they created using phones, tablets, computers, etc. |
| Designing My Seismograph Activity | Science | - Learning the negative effects of natural disasters and determining which precautions should be taken against natural disasters.<br>- Learning what a seismograph is, where and for what purpose it is used and its working principles. |
| | Mathematics | - Creating the graph of straight and zigzag lines on the seismograph paper.<br>- Interpreting the graph created. |
| | Engineering | - Creating a product by following the engineering design stages. |
| | Technology | - Producing audio-visual advertisements about the product they created using phones, tablets, computers, etc. |
| Mini Saw Making Activity | Science | - Identifying simple circuit components, knowing their functions, and using them to set up a simple electrical circuit. |
| | Mathematics | - Calculating the number of rotations and the speed of the saw.<br>- Establishing the proportion between the number of teeth on the saw and the amount cut. |
| | Engineering | - Creating a product by following the engineering design stages. |
| | Technology | - Creating visual-audio advertisements related to the product they created using phones, tablets, computers, etc. |

### Data Analysis

In the analysis of data, content analysis methodology was employed in a manner consistent with the nature of qualitative research methods. Initially, interview recordings, diaries, and field notes were transferred to digital format and readings were made from these. After the readings, coding was done, and related codes were grouped under certain themes. In the coding process, two independent researchers produced separate lists of codes, the obtained codes were compared, and consensus was reached by discussing the diverging parts of the coding. In the data analysis conducted by the researchers, coder reliability was calculated using the reliability calculation formula of Miles and Huberman (1994) and the reliability among coders was found to be 93%.

### Validity, Reliability and Ethics

In qualitative research methods, validity and reliability are ensured through methods such as credibility, transferability, dependability, and confirmability (Merriam, 2013). In this context, to enhance credibility in our study, expert opinion was sought in the preparation of the interview form, diversity was provided in data collection with the triangulation method, student opinions were given directly in data analysis, and participants' confirmation was sought for the data obtained. For transferability, detailed description was made, the obtained data were detailed, and direct quotations were included. Furthermore, purposeful sampling method was used in this context (Yıldırım & Şimşek, 2013).

To increase dependability; similar processes were followed in data collection, it was checked whether the obtained results were consistent with the collected data, and different experts were actively involved in coding. For confirmability in the research, the reached conclusions were continuously confirmed with the collected data. In this context, all data were transferred to a computer environment, and these data were revisited when necessary. Moreover, ethical principles were considered in the research. The study group was informed about the purpose of the research and how the data obtained in the research would be used. They were told that participation was voluntary. In addition, real names of the participants were not used in the study; instead, codes like Participant-1 (P1), Participant-2 (P2) … Participant-17 (P17) were used.

## Findings

In this section, the findings of the research are discussed under the themes created in relation to the purpose of the study. As a result of the analysis of the data of the research, themes such as “benefit,” “emotions,” “learning new information,” “activities,” and “design making skill” were formed. Benefit based on interviews with students, students' diaries, and the teacher's field notes, the application was determined to be beneficial for students. The codes formed under this theme are provided as a word cloud in Figure 1.


Figure 1. Word cloud for the theme of benefit

As shown in Figure 1, based on the responses received from the participants in the study, seven (7) different codes have been created for the "benefit" theme. Under this theme, seven (7) students (P3, P4, P5, P6, P8, P10, P11) mentioned that the application helped them learn new information, three (3) students (P2, P6, P11) noticed an improvement in their design skills, three (3) students (P7, P8, P10) developed innovative ideas/thoughts, two (2) students (P2, P4) felt an enhancement in their intelligence, one (1) student (P1) used their hands and fingers better, one (1) student (P1) observed an increase in their attention level, and one (1) student (P6) became more socialized. Additionally, eight (8) students (P1, P4, P5, P6, P7, P8, P9, P11) expressed their interest in participating in similar new workshops. Some of the students' opinions related to this theme are as follows:

> *S1: "Thanks to this course, I used my hands and fingers better. I learned to be more careful and meticulous while making a design. I would like to participate again in such activities and courses because I really enjoy designing. I never get bored or tired while engaging in these activities."*
> *S2: "My design skills improved. I realized my intelligence developed."*
> *S3: "I learned new information. For example, I learned what a seismograph is, what it's used for, and where it's used."*
> *S4: "I would like to participate again if this course is organized. Because it developed my intelligence and skills. Also, it was very fun."*
> *S7: "I would like to participate again in this workshop because learning educational and innovative things is very beneficial."*
> *S8: "It helped me develop better thinking for inventing new things. It allowed me to understand and make a design. I would apply and participate again if this workshop is organized because we spend quality time here. Instead of wasting time at home, I learn to invent here."*
> *S11: "I learned new information. I learned how to design. Now, I too can design something like an engineer, an explorer, a scientist."*

Participants completed diaries on the days of the activities and wrote their thoughts and opinions in their diaries about learning new information, the usefulness of the activities they participated in, spending productive time during the application, and the development of their design skills. Some of the expressions written by students in their diaries are as follows:

> *P8: "Hello diary. My name is P8. I registered for BİLSEM during the semester break and joined the design and innovation workshop. Our teacher said we would be doing designs and activities related to STEM in this workshop. I really had fun today. Because I learned new things and had a good time with our friends. I'm glad I came here. Because we spend our time productively here. For example, today we learned what energy is, and how potential energy and kinetic energy are formed. Our teacher told us about some steps, and we completed our design by sticking to those steps. We used materials like skewers, electric tape, scissors, hard plastic cups, pens, rulers, metal tape, rubber. Our group finished the design nicely and it turned out great." (Date: 27.01.2023)*
> *P13: "A seismograph is a device that measures earthquakes. I learned this today. I think it's a very nice thing. Imagine. There's an earthquake and you can measure its intensity. Our group tested our seismograph. The teacher was shaking the table, and we were slowly pulling the seismograph paper. It was like there was an earthquake. I enjoy learning new and different information like today." (Date: 27.01.2023)*

The usefulness of the activities for students is confirmed by the data obtained from the researcher/teacher's field notes. On 27.01.2023, the researcher/teacher noted: *"The necessary materials were provided to the students for the product to be made, and the students tried to make their designs in groups by following the engineering design stages. Students mentioned that they learned what an equilateral triangle prism is during the process of creating an equilateral triangle with skewers. During the testing of the design, they learned how flexibility, potential energy, and kinetic energy are formed, and found learning this enjoyable."* and on 03.02.2023: *"It was observed that students now design products more professionally using engineering design stages. Students who struggled during the 'Triangle Prism with Energy Activity' on the first day had no difficulty in today's activity. It was noticed that today's application helped students use their psychomotor skills better. In addition, it was found that more innovative and creative ideas emerged during the 'Ask' and 'Imagine' stages."* These field notes are considered under this theme and confirm the codes related to the "beneficial" theme.

**Emotions**

The theme of emotions was formed based on the analysis of the opinions of the students in the study group and the field notes of the teacher. The codes under this theme are provided as a word cloud in Figure 2:


Figure 2. Word cloud for the theme of emotions

As depicted in Figure 2, based on the responses received from participants in the study, five (5) distinct codes have been formed under the "emotions" theme. Upon examining student responses under this theme, eight (8) students (P1, P3, P4, P5, P6, P7, P8, P10) stated they had a lot of fun and found the activities very entertaining during the application process, four (4) students (P3, P6, P9, P10) felt very excited and found the activities exciting, three (3) students (P8, P10, P11) enjoyed their time throughout the activities, one (1) student (P10) mentioned that their curiosity was piqued during this process, and one (1) student (P4) expressed an increased interest in the activities. Some of the students' opinions related to this theme are as follows:

> *P1: "I had a great time. I found the activities very entertaining."*
> *P2: "The activities were very nice. I made new friends during the activities, had good relations with our group members, and we could talk and chat with each other."*
> *P3: "It was very fun. I was especially excited during the saw and energy activities. My excitement doubled in the seismograph activity."*
> *P4: "The activities we did really caught my interest. I loved them. Throughout the process, my group mates and I had a lot of fun."*
> *P9: "We did some activities in groups, and these group activities were exciting."*
> *P10: "The activities we did were fun and exciting. Also, every day at home, I kept asking myself, 'I wonder what activity we will do tomorrow?' because I was very curious about the activity we would do."*

Upon reviewing the participants' diaries, it is observed that the majority wrote about how the application positively affected their emotions. Some of the feelings and thoughts written by students in their diaries are as follows:

> *P3: "Hello diary. Today in the workshop, we designed a seismograph. First, we discussed with our group mates what we would do. Then we asked our teacher for the necessary materials and started making our design. We first cut the middle of the plastic cup to the size of a coin. We passed a felt-tip pen through the cut and fixed it with play-dough. Then we tied it to a shoebox with string. We obtained a long roll using A4 papers, ruler, scissors, and tape given by our teacher. After each group finished their design, they presented their seismograph. Each group tested their seismograph in turn. Ours was good. Zigzags formed on the paper. Those zigzags were the measure of the earthquake. In this process, I gained a lot of knowledge and had enjoyable times with our friends." (Date: 02.02.2023)*
> *P17: "Dear diary, today at the Science and Art Center, we designed a seismograph to measure earthquakes. After nice work, we made our seismograph as a group. It turned out very well because we made it with team spirit and perseverance. The activity we did before was very nice. That's why I was excited about this activity. When I heard we were going to make a seismograph, I felt strange. Because it was the first time I heard this name. It turns out it's a very nice thing. We had a good time with our friends today. It was an enjoyable activity for me." (Date: 02.02.2023)*

The positive contribution of the application to the affective skills of the participant students is also confirmed by the field notes kept by the researcher/teacher. On 02.02.2023, the researcher/teacher noted: *"One of the most notable events today was some students coming to me in the corridor before the class started, asking me what activity we would do today. The students were curious about today's activity since they enjoyed the previous one. Their excitement was observed. Students had fun and spent a good time while designing and testing their seismographs."* This field note supports the codes formed under this theme.

**Learning New Information**

Based on the responses received from the participants, the theme of learning new information has been formed. The codes under this theme are presented as a word cloud in Figure 3:

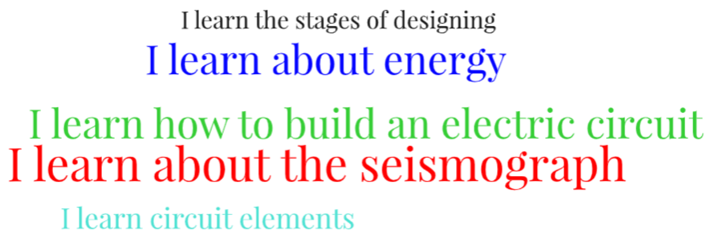


Figure 3. Word cloud for the theme of learning new information

As shown in Figure 3, in line with the participants' opinions in the study, the theme of "learning new information" has been created, and under this theme, five (5) distinct codes have been formed. Upon reviewing student opinions, it was found that all participating students reported learning what a seismograph is and its purpose, how to construct a simple electric circuit, and the properties of kinetic/potential energy. Additionally, six (6) students (P3, P4, P5, P6, P7, P8) mentioned learning the functions of electrical circuit components, and one (1) student (P4) reported learning the stages of making a design. Some responses from the participants are as follows:

> *P1: "In the seismograph activity, I learned that a seismograph is a tool for measuring earthquakes. In the Triangle Prism activity, I learned about kinetic and potential energies. In the saw activity, I learned how to set up an electric circuit."*
> *P2: "Even though it was in a beginner's fashion, thanks to the seismograph we made, I can measure earthquakes. I learned what potential and kinetic energy are. I learned how to set up an electric circuit."*
> *P3: "I learned that a seismograph is a tool that measures earthquakes. Also, I learned the concepts of potential and kinetic energy. I learned the functions of electric circuit components."*
> *P4: "I learned the stages of making a design. I learned all the details of a design. I learned the benefits and harms of the product we made."*
> *P6: "I learned how earthquakes happen and what their effects are. I learned how to measure the magnitude of an earthquake and which instrument is used for it. Also, I learned how to set up an electric circuit using a switch, battery, DC motor, and wires. I learned that moving objects have kinetic energy and objects at height have potential energy."*
> *P8: "I learned how and with which instrument earthquakes are measured. Besides, I learned what potential and kinetic energy are. Also, I learned the functions of electric circuit components and how to set up an electric circuit."*
> *P9: "With the design we made, I learned that flexible objects store potential energy, and when these objects are released, that potential energy turns into kinetic energy. Besides, I learned how earthquakes are measured thanks to the seismograph activity."*

Students also mentioned learning new information in their diaries. Here are some expressions written by students in their diaries:

> *P5: "Today at BİLSEM, we did a new activity. Thanks to this activity, I learned that a seismograph is an earthquake measuring device. Actually, we did some research about seismographs before making the design. As a result, we learned that seismographs have been used for a very long time. I had heard of this device for the first time. I brought the seismograph I made home. My brother was also very interested in it." (Date: 02.02.2023)*
> *P6: "Dear diary, today in the workshop, we learned how potential energy is converted into kinetic energy. We did an application of this. It was a very exciting activity. The teacher gave us materials. First, we made a triangle prism out of skewers. Then we cut the cup and mounted it to our equilateral triangle prism with a rubber band. Then the bell rang, we played. When we came back to class, we started testing our designs. When we pulled back the cup, potential energy was building up, and when released, the ping pong ball gained speed and moved away. Here, kinetic energy was happening. After the class ended, we dispersed and went home." (Date: 27.01.2023)*

### Activities

At the end of the application, students participating in the study were asked to write down their favorite activities during the application, ranking them from 1 to 3.


Figure 4. Word cloud for the theme of activities

As shown in Figure 4, among the "activities" theme, participants in the study expressed enjoying the "mini saw making" activity the most (8 students). This activity was followed by "Energy Activity with Triangular Prism" (3 students) and "Designing My Seismograph" (1 student). The researcher/teacher noted on 03.02.2023, *"I think their favorite activity was the 'mini saw making'. They also liked the other two activities, but their enjoyment of this activity was evident in their eyes. I guess they liked setting up the electrical circuit and making the product work through a correctly assembled circuit."* This field note, upon analysis, confirms the codes within this theme are valid.

### Design Making Skill

Nine participants in the discussion stated that the application improved their design-making skills, positively influenced their desire and thoughts about creating an innovative tool/product/invention, prepared them for making new designs, enhanced their imagination and creativity, built their confidence towards designing a product, and accelerated the idea/thought of making a product. Their responses are as follows:

> *P1: "Through the activities we did, I feel my ability to design a tool has improved. Now, I won't have any trouble doing my activities at home. Actually, I used to make designs at home, but the ones here are more professional. The designs we made here sparked new ideas in my mind. I started thinking about what kind of designs I could make."*
> *P2: "I now have confidence in myself about making a tool, product, or invention. I've learned how a tool is made and which stages to follow. It increased my imagination, my ideas, and thoughts developed. My curiosity to make a discovery has grown. Now, making a new discovery seems more appealing to me."*
> *P3: "Thanks to the activities we did, I think both my ability to create a new tool and my design-making skills have improved. My desire to make an invention has increased. Now, at home, I constantly think about what I can design or develop."*
> *P5: "Now, I feel ready to use my intelligence more to create new things."*
> *P8: "Thanks to what we learned in this workshop, I can think about and immediately design new things. It developed my idea and thought of making a new tool or design. I think most importantly, I can express my new ideas and thoughts more easily, and the person in front of me understands me better."*

The positive impact of the application on students' design-making skills is also evident from the field notes kept by the researcher/teacher. On 03.02.2023, the researcher noted: *"Concerning the saw to be made, students first identified the problem in groups and brainstormed to come up with the best solution. Then they made drawings related to their design and took note of the necessary materials. Afterward, they requested the necessary materials from me and presented their products, adhering to the other stages of engineering design. They fully utilized the engineering design stages they learned in both the pilot study and previous applications. Today, it was observed that the groups proposed different solutions, wrote more options, thought, and made decisions faster."* This note confirms the validity of the "design-making skill" theme.

### Participants' Drawings about a New Product

Participants were asked to make drawings of a tool/product that came to their mind after the application. The drawings made by the participants are as follows:

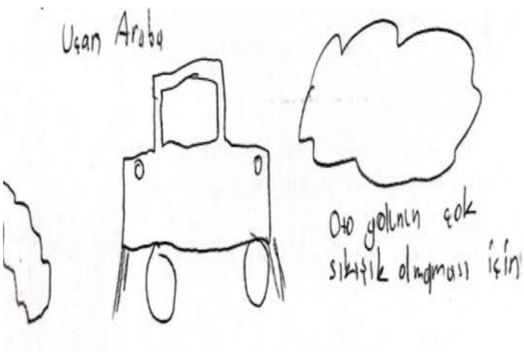


Figure 5. Drawing by P2 (flying car)

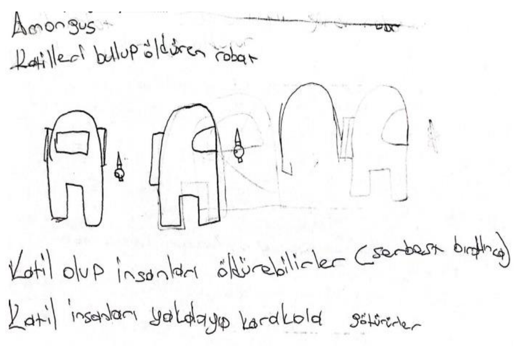


Figure 6. Drawing by P3 (A robot that finds and kills weeds)

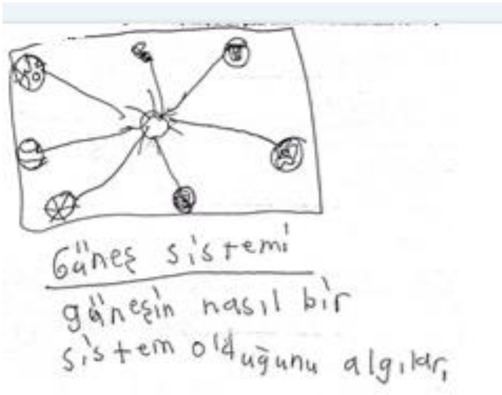


Figure 7. Drawing by P4 (solar system detecting system)


Figure 8. Drawing by P5 (time machine)

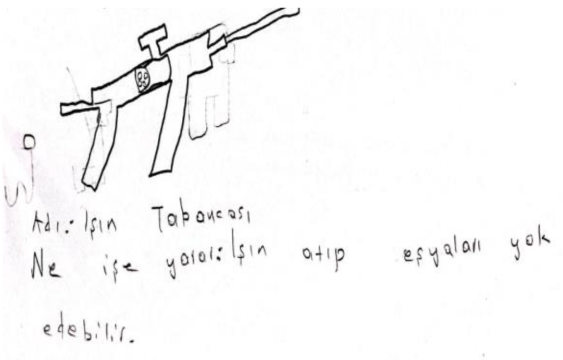


Figure 9. Drawing by P6 (ray gun)

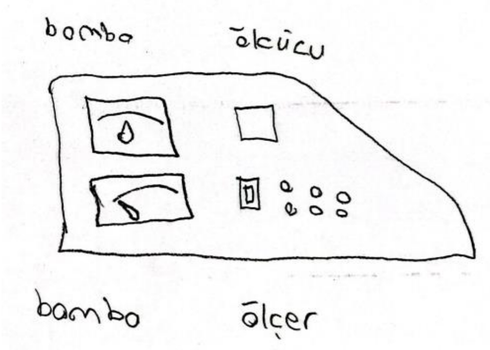


Figure 10. Drawing by P7 (bomb detector)

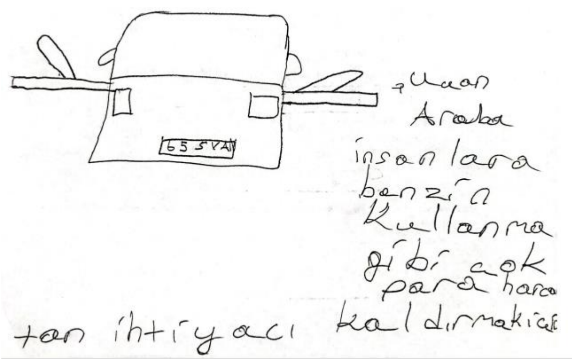


Figure 11. Drawing by P8 (flying car)

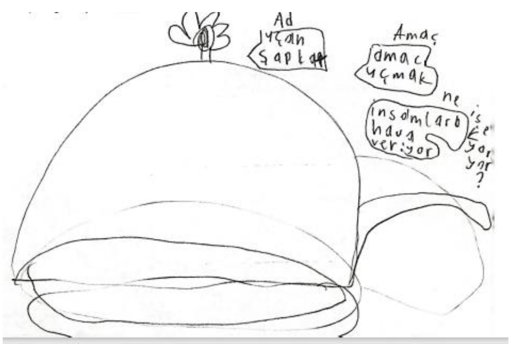


Figure 12. Drawing by P9 (flying hat)

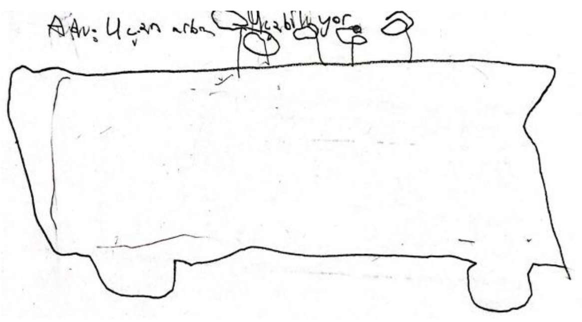

Figure 13. Drawing by P10 (flying car)

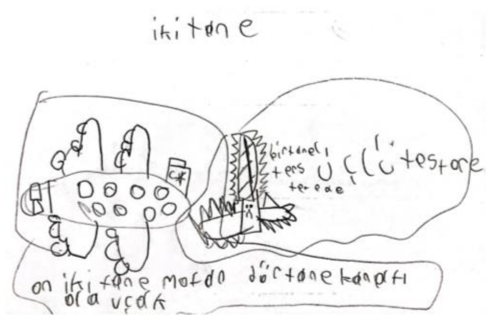


Figure 14. Drawing by P11 (airplane)

When analyzing the drawings made by the students, it was observed that they drew products named "Flying Car" (P2, P8, and P10), "A Robot that Finds and Kills Weeds" (P3), "Time Machine" (P5), "Solar System Detecting System" (P4), "Ray Gun" (P6), "Bomb Detector" (P7), "Flying Hat" (P9), and "Airplane" (P11). P2 suggested the idea of a flying car as a solution to the traffic problems in their area. P3 proposed a concept aiming at the quick apprehension of individuals committing crimes in society. P8, aware of the high economic value of fuels used to power cars, thought of escaping the high cost of fuels with the design of a flying car. P11 aimed at creating a new generation airplane. It's noteworthy that half of the students' drawings related to the concept of "flying". Overall, it can be concluded that students made drawings aimed at solving real-life problems. From this, it can be stated that the application positively influenced the students' creativity, innovation, and skills in solving societal issues.

## Discussion

The implications of the ‘Design and Innovation Workshop’ have been demonstrated in the existing literature on student engagement in engineering and design in STEM education. One of the implications of the study is that students enhance their problem-solving, creativity, and teamwork skills after engaging in engineering and design educational activities. This finding is consistent with earlier studies that support the notion of providing practical learning experiences for the students in the 21st century (Daly et al., 2014; Kelley and Knowles, 2016). Also, the propensity and willingness of participants particularly to engage in STEM subjects raises the need to implement design and innovation workshops in STEM education. This is particularly important in the literature as it proposes students in STEM fields should be given more interesting active forms of learning in order to make them stay in such fields (Wu and Anderson, 2015; Fang et al., 2021).

In a broader overall picture of the research conducted in STEM education, the outcome also indicates that conducting design and innovation workshops is not only meant to teach technical training, but also a way of enhancing the acceptable social behaviors and attitudes in STEM. This supports previous research that encourages the blending of engineering theories as well as design practices in the teaching of STEM subjects so as to increase the effectiveness of the learning (Fan and Yu, 2017; Wahono et al., 2020). The study was the finding that students' social skills and attention spans also improved significantly, workshop sessions were capable of enriching the educational experience towards all-rounded growth. The accounts of students engaged in the "Design and Innovation Workshop" were assessed through the prism of "Situational Interest Theory." The students' high levels of interest and motivation in the course of participation in the workshop activities are in line with the tenets of the theory which further posits that some conditions and interactions may foster individual interest.

The workshops were showcased to initiate, support and further develop the individual interests of the students in STEM fields which turned into a well nurtured personal interest. The Situational Interest Theory considers the development of learner interest to consist of four stages, namely: Triggered Situational Interest, Maintained Situational Interest, Emerging Individual Interest, and Well-Developed Individual Interest. The first stage of “triggered situational interest” was in design, and engineering-based STEM activities, which incited students upon the use of new and interactive design features, hence commencing their learning. The workshop activities enabled students to sustain their interest. While being in one of the “maintained situational interest” stages, the students kept and developed their interest, solving problems in a creative manner, and in a team. More so, during “Emerging Individual Interest” the students experienced an enhanced drive and interest in STEM fields. This could have resulted in students developing a need to delve more into the STEM areas after some time. However, there is no clear evidence on how the research helped students acquire “well-developed individual interest" in the STEM areas of their choice. In addition to this, further studies may seek to investigate students' levels of interest and motivation toward STEM aspects after undertaking design and innovation workshops over time.

## Conclusions

The study on students' interaction with engineering and design-based applications of STEM has shown that students acquired additional knowledge on topics such as energy, electric circuits, seismographs, and the engineering design spiral. This added knowledge helped in the students' comprehension and the growth of the body of knowledge in the areas of science, Technology, engineering, and Mathematics. Among the activities that were carried out, "making mini saws" was highly rated by the learners. The different levels of enjoyment of the activities show the different interest areas and the ability of doing things concrete to encourage students. The applications sharpened students' skills in making designs, developed their imagination and creativity, and made them more self-assured in developing new designs. Real life's problems were the motivating force in students designing solutions. Real life problems were evident in the creative art work of the students. Drawings particularly associated with the idea of "flying" illustrated the diversity and inventiveness of students' minds. The study indicates that STEM education delivered on the backdrop of design and engineering helps in improving the scientific knowledge and skills, creativity, and problem-solving capabilities of the students. Upon students' attitudes' assessment in engineering and design-related tasks, STEM was seen as useful to the students. They learned new things, improved in coming up with designs and in making them, and had new ideas. In addition, such activities promoted students' socialization, enhanced attention and development of intelligence. The students enjoyed, were enthusiastic and had fun in the course of implementation which positive stems for attitude change in STEM education. When analyzing students' perceptions and experiences with the engineering and design-supported STEM application within the context of Situational Interest Theory, it suggests that applying this theory in the educational field within the context of STEM education can design interactive and meaningful learning environments to enhance students' interest and motivation. This provides guidance for educators and curriculum developers on designing learning experiences that will capture and sustain students' interest.

## Limitations and Future Research

The study has various limitations. The study's sample size and the specific context of BİLSEM may interfere with the applicability of the findings. Later on, the research can deal with the issue of sample size and test such interventions in different settings and educational environments. Furthermore, longitudinal studies could investigate the impact of such workshop activities with regard to sight on the students' career options and educational pathways in 'STEM' after the workshops. It can also be studied how the design and innovation workshops can be used in other learning environments and how they can be combined for the students benefit.

## Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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