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Investigating the Impact of Toy Design on 6th Grade Students' Analogical Reasoning, Problem-Solving, and Engineering Design Skills: The Case of Support and Movement Systems

Oyuncak Tasarımlarının 6. Sınıf Öğrencilerinin Analojik Akıl Yürütme, Problem Çözme ve Mühendislik Tasarım Becerileri Üzerine Etkisinin İncelenmesi: Destek ve Hareket Sistemi

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ABSTRACT
Toys are commonly used as educational tools for children. Beyond supporting their pedagogical development, children also explore and make sense of their environment through play and toys. The use of toys in education has become increasingly widespread over time, as they help foster skills such as exploration, inquiry, collaboration, and understanding cause-and-effect relationships. Activities like toy-making further contribute to the development of engineering-related skills in children, which are integral to the widely adopted STEM (Science, Technology, Engineering, and Mathematics) approach. The purpose of this study is to examine the impact of a STEM-based instructional approach supported by toy design on 6th-grade students' analogical reasoning, problem-solving, and engineering design skills within the context of support and movement systems. The study group consisted of 28 6th-grade middle school students. The topic was selected based on the 2018 Turkish Science Curriculum. A mixed-methods research design was employed. The quantitative phase utilized a one-group pre-test/post-test experimental design, while the qualitative phase involved content analysis of students' design products. Data were collected using the Analogical Reasoning Test, the Problem-Solving Skills Questionnaire, and the Engineering Design Rubric. Both quantitative and qualitative data analysis methods were applied. The findings showed that toy design activities related to support and movement systems significantly improved students' analogical reasoning, problem-solving abilities, and engineering design skills.
Keywords: STEM, Analogical Reasoning Skills, Problem Solving Skills, Engineering Design Skills

ÖZ
Oyuncaklar, çocuklar için bir öğrenme aracı olarak kullanılmaktadır. Pedagojik gelişimlerinin yanı sıra, çocuklar oyun ve oyuncaklar aracılığıyla çevrelerini keşfederler. Eğitimde oyuncak kullanımının geçmişten günümüze giderek daha yaygın hale gelmesi, oyuncakların çocukların keşif, sorgulama, işbirliği yapma ve neden-sonuç ilişkilerini anlama gibi becerilerini geliştirmelerine yardımcı olduğunu göstermektedir. Oyuncak yapımı gibi etkinlikler de çocuklarda mühendislik becerilerinin gelişimine katkı sağlamaktadır. Mühendislik becerileri, günümüzde yaygın olarak benimsenmiş STEM (Bilim, Teknoloji, Mühendislik ve Matematik) yaklaşımının bir parçasıdır. Bu çalışmanın amacı, oyuncak tasarımı destekli STEM uygulamalarının 6. sınıf öğrencilerinin destek ve hareket sistemleri konusundaki analojik akıl yürütme, problem çözme ve mühendislik tasarımı becerileri üzerindeki etkisini incelemektir. Çalışma grubunu 6. sınıf 28 ortaokul öğrencisi oluşturmuştur. Çalışmanın konusunun belirlenmesinde Türk eğitim müfredatının 2018 yılı fen bilgisi öğretim programı dikkate alınmıştır. Çalışmada araştırma yöntem ve tekniklerinden karma yöntem kullanılmıştır. Karma desenin nicel boyutu tek grup ön-test son-test deneysel tasarım yöntemiyle gerçekleştirilmiştir. Araştırmanın nitel boyutunda öğrenci tasarım ürünleri içerik analizi ile değerlendirilmiştir. Veri toplamak için Analojik Akıl Yürütme Testi, Problem Çözme Becerileri Anketi ve Mühendislik Tasarımı Rubriği kullanılmıştır. Veriler, nicel ve nitel analiz yöntemleriyle incelenmiştir. Araştırmanın sonuçları, destek ve hareket sistemleri ile ilgili oyuncak tasarımı etkinliklerinin 6. sınıf öğrencilerinin analojik akıl yürütme, problem çözme becerileri ve mühendislik tasarımı becerilerini olumlu bir şekilde geliştirdiğini göstermiştir.
Anahtar kelimeler: STEM, Analojik Akıl Yürütme Becerileri, Problem Çözme Becerileri, Mühendislik Tasarım Becerileri

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INTRODUCTION

1.1. Engineering Design in Science Education

While scientists strive to understand the natural world through scientific process and inquiry, engineers focus on solving problems in the man-made world and addressing the needs of individuals. Although these two fields may seem distinct, they complement each other (King& English, 2016). In science education, the engineering design process is important as it demonstrates how real engineers approach and think about problems (Arık & Topçu, 2020; Ercan & Şahin, 2015). Through engineering design-based science education, students learn to acquire knowledge, solve everyday problems, and develop scientific and technological literacy through scientific inquiry and design-based activities (Topalsan, 2018). The engineering design process presents real-life problems within scenarios that help students to identify problems, generate solutions, discuss the significance of these solutions, and collaborate with peers by reading and analyzing these scenarios. As students transfer and test their solutions through designs, they must assess whether prototypes are suitable for solving the problem (Akarsu et al., 2020). The aim of engineering design is to create a functional model based on a repeatable approach involving testing and redesign, rather than a single correct method (King & English, 2016). The engineering design process involves developing the most appropriate solution to a problem by creating repeatable prototypes related to STEM fields (Akarsu et al., 2020). The engineering design process is represented in figure 1 below. As indicated in figure 1, the engineering design process involves asking questions, imagining, planning, creating and improving the design that is created (Cunningham, 2009).

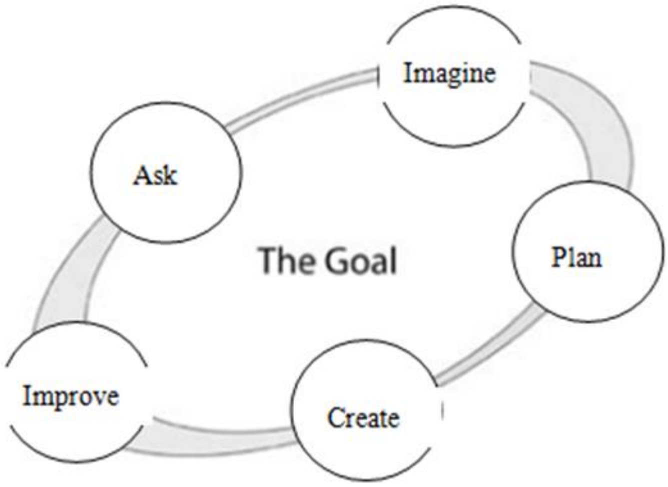

Figure 1. *The EiE Engineering Design Process* (Cunningham, 2009)

Engineering design activities in classrooms promote an interdisciplinary approach that brings together knowledge from science, mathematics, and technology (Brophy et al., 2008; Thornburg, 2009), while also fostering skills such as problem solving, creative thinking, and effective communication (NRC, 2009; Lewis, 2006; Roth, 2001; Thornburg, 2009). Studies have shown that integrating engineering design into science instruction can enhance students' understanding of scientific concepts (Cantrell et al., 2006; NRC, 2009). Therefore, considering the significance of teaching engineering design in schools, the need to expand pathways into the engineering field, and the strongly supported benefits of connecting STEM disciplines for student learning, it is essential to provide students with opportunities to explore engineering and engage in design processes through formal, informal, or non-formal educational settings (Shahali, et al., 2016). Drawing from previous studies where students were asked to create drawings on topics such as photosynthesis, evaporation, plants, the human body, and the internal structures of animals, King and English (2016) included drawing as one of the engineering design applications in their research. The engineering design process offers ideal STEM learning opportunities for students. In this process, STEM knowledge is shaped within the framework of conceptual understanding and the content of the involved steps (Arslanhan & İnaltekin, 2020). For example, Bilen et al (2021) studies preschool children as they design a parachute. The aim of the activity was to help children gain an understanding of each STEM field. Concepts such as force, gravity, motion, and friction were introduced in the science domain, while time and sequencing were used in mathematics. For technology, children were encouraged to select the most suitable materials for the activity, and in engineering, they created sketches of their models and built them. In their study, students were actively engaged in 21st-century skills such as problem-solving, collaboration, communication, and creative thinking during the activity. Similar to the activities that are done as STEM applications in classes, scientific process skills and methods of scientific inquiry are utilized in the engineering design process (Bartholomew & Strimel, 2017). In the context of model design, the design process typically involves several key stages: identifying a need, generating ideas, exploring potential solutions, constructing and testing prototypes, and refining the final solution. For instance, the design of a robotic model serves as a tangible representation through which students can explore, test, and communicate the features of a biological system. Consequently, the ideas, solutions, and prototypes developed throughout the design process are validated by comparing them to the characteristics of the biological system uncovered through scientific inquiry (Cuperman &Verner, 2019). Engineering design is a pedagogical strategy that integrates science and mathematics concepts in the context of solving open-ended problems, developing creative thinking skills, generating solutions, making decisions, and evaluating alternative solutions (Samsudin et al., 2007; Wang et al., 2011; Yasin et al., 2012). Engineering involves the use of scientific and mathematical concepts to address open-ended problems encountered in the real world (Sheppard et al., 2009). By using engineering design as a context for open-ended problems and conducting research on their solutions through STEM integration, students' learning can be enhanced. Utilizing engineering topics as contexts where students can develop models that represent the real world can aid in the understanding of related scientific and mathematical concepts by facilitating the use of multiple representations (concrete models, images, language, and symbols) and the connections between them (Moore et al., 2013).

Engineering design consists of several key elements, including system thinking, understanding constraints, predictive analysis, and optimization (Arslanhan & İnaltekin, 2020). Identifying the most effective solution to a specific problem, designing a prototype model, testing the prototype, analyzing its results, and making redesigns through optimization are also part of engineering process skills. The engineering design process, which focuses on creating prototypes and generating solutions, is argued to contribute to students' problem-solving skills while enhancing their creative and critical thinking abilities (Hynes Portsmore et al., 2011; Siew et al., 2016).

1.2. Analogical Reasoning in Engineering Designs

Through designs, students experience making connections between real-world situations and modeled scenarios. Therefore, models and designs are important tools for enhancing students' analogical reasoning skills (Gray, 2021). STEM education includes associative learning, which can be explained through analogical reasoning (Kesercioğlu et al. 2004). The use of analogies in presenting STEM topics to children facilitates the establishment of parallels between the subjects. In this way, teachers have the opportunity to introduce students to different STEM fields by not only focusing on the direct examination of a single topic but also leveraging the interdisciplinary nature of STEM subjects. Working with analogies means making connections and establishing relationships between the concepts that are learnt (Ben-Horin & Rosenberg, 2016). The use of familiar real-world experiences, color coding, visual presentations, videos, models, and designs as analogy sources in lessons enhances students' motivation and facilitates the easier establishment of connections between the topic taught in class and the child's mind (Gray, 2021). Analogical reasoning is considered a cornerstone of design thinking, as design is a cognitive activity, and the analogy process is fundamental to cognition (Goel & Shu, 2015; Christensen & Schunn, 2007). The importance of analogical reasoning in the development of engineering design skills lies in its ability to help students establish cause-and-effect relationships and generate solutions to problems they encounter by drawing connections between real-world objects and the knowledge they have acquired (Ergül, 2023). Researchers emphasize that analogical reasoning is a key cognitive tool for solving design problems (Daugherty & Mentzer, 2008; Verhaegen et al., 2011). As seen in biomimicry, designing a car inspired by an insect or an arch bridge based on natural cave formations highlights relational and structural similarities (Hey et al., 2008).

1.3. The Relationship between STEM, Engineering Design, and Analogical Reasoning

Morrison (2006) argued that STEM education should enable students to perform as (1) problem solvers, (2) innovators, (3) inventors, and (4) logical thinkers, while also helping them to understand and develop the skills necessary for (5) self-confidence and (6) technological literacy. STEM has two main focal points: problem-solving and inquiry (Clark & Ernst, 2006; Felix & Harris, 2010; Yasar et al., 2006). Therefore, STEM education should not only focus on content knowledge but also incorporate problem-solving skills and inquiry-based learning. Sanders (2009) emphasized that the core focuses of STEM education include applying knowledge of mathematics, science, and engineering, designing and conducting experiments, analyzing and interpreting data, and communicating and collaborating with interdisciplinary teams. The STEM curriculum utilizes the engineering design process as a context for teaching students scientific concepts (Anwar et al., 2022; Cunningham et al., 2020). Engineering design is the process engineers use to solve problems and develop products, and it also represents the essence of the engineering profession. Analogical reasoning serves as the cognitive foundation of engineering design processes. Therefore, teaching students analogical reasoning is crucial for high-quality STEM education and design-based instruction (Richland, 2014). Analogical reasoning has been proposed as a powerful tool to foster conceptual understanding and transfer across STEM domains. By highlighting the causal-relational structure of STEM concepts, analogical reasoning facilitates inferences from a known source to a newly learned target (Gray & Holyoak, 2021). Figure 2 below represents the role of toy design within engineering design process, as well as the incorporation of analogical reasoning in engineering design process.

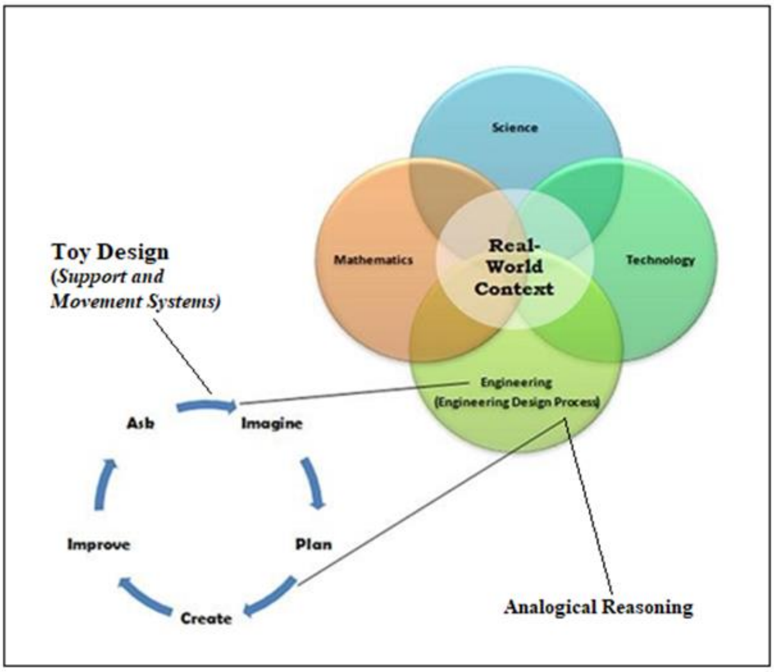

Figure 2.*The Relationship between STEM and Engineering Design* (Adapted from Shahali et al., 2016)

1.4. Toy Design in Science Education

Toys are defined as any tools that regulate children's actions during their developmental processes, contribute to their mental, physical, and psychosocial development, and also enhance their imagination (Pehlivan, 2016). Additionally, toys can be meaningfully utilized in classrooms for both students and teachers. Many teachers use toys, such as stress balls, balloons, retractable and releaseable toy cars, and spinning tops, in science lessons to establish connections between concepts and everyday life (Jarrett et al., 2020). Toys help children observe and understand scientific events in the surrounding environment (Kaçan, 2015; Egwutvongsa, 2020). The toys used in classrooms are familiar to students from their daily lives. As a result, they can explain how these toys are related to specific scientific concepts or bring them to class to share with others. In this way, students can establish a connection between science and their daily lives and engage in questioning the events happening around them (Stein & Miller, 1997). In the book Toys of Science, STEM-based toy design activities encourage children to play with toys while learning about measurement, scientific design, and engineering principles (Jarrett et al., 2020). Therefore, incorporating toy design activities into classrooms positively contributes to children's engineering design skills and creativity (Gök & Sürmeli, 2022). Bilen, Ergün, and Şimşek (2021) used the "Parachute Design" activity to teach concepts such as force, gravity, motion, and friction. Çeken (2010) designed the "Balloon Car" activity to help students meaningfully understand scientific concepts. These types of activities encourage critical thinking and provide students with the experience of working like a scientist. In the literature, there are studies on the use of play and toys as teaching materials in science lessons, the integration of STEM-based activities in classrooms, and activity designs to introduce students to the engineering design process. However, there is limited research on the integration of play, toys, and STEM, and how these elements are related to analogical reasoning. In this context, this study is expected to contribute to the field. Moreover, STEM and toys have mostly been researched in the context of physics topics. This study is intended to provide teachers with examples by focusing on toy-based designs related to a biology subject that is support and motion systems stated in the 6th grade curriculum of MEB (2018).

The purpose of this study is to investigate the impact of toy-making supported STEM applications on 6th-grade students' problem-solving skills, analogical reasoning, and engineering design abilities related to the topic of the movement system. The research problem statement is as follows: "Does toy design-supported STEM implementation have an effect on the analogical reasoning, problem-solving, and engineering design skills of 6th-grade students regarding the support and movement system?"

Sub-Problems:

1.Does toy design-supported STEM implementation have an effect on the analogical reasoning skills of 6th-grade students regarding the support and movement system?

2.Does toy design-supported STEM implementation have an effect on the problem-solving skills of 6th-grade students regarding the support and movement system?

3.Does toy design-supported STEM implementation have an effect on the engineering design skills of 6th-grade students regarding the support and movement system?

4.What is the effect of toy design-supported STEM implementation on the development of the engineering design skills of 6th-grade students regarding the support and movement system?

RESEARCH DESIGN

This study employs a mixed research design. The mixed research method refers to the process by which a researcher collects both quantitative (closed-ended) and qualitative (open-ended) data to understand the problems in a particular research area, synthesizes the collected data into a cohesive whole, and utilizes the benefits gained from combining both data sets to derive conclusions (Creswell, 2021). The reason for choosing the mixed research approach is to enhance the research problem by combining statistical data (quantitative) and the experiences and narratives of individuals involved in the research process (qualitative) (Creswell & Plano Clark, 2011). In this study, a mixed embedded design, with a balance of both quantitative and qualitative methods, is employed. In the quantitative section of the research, a one-group pretest-posttest model is applied using a weak experimental design, while the qualitative section employs a case study approach. In case studies, the 'case' refers to the phenomenon observed at a specific point in time or at a particular stage of a process (Gerring, 2007). The aspect of this study that is considered a case focuses on highlighting a class of 6th grade students' STEM- based engineering design products. To analyze these products, content analysis was preferred in the qualitative section of the case study. The main objective of content analysis is to identify concepts and relationships that can explain the collected data. The fundamental process in content analysis involves grouping similar data within specific concepts and themes and interpreting them in an organized manner that is understandable to the reader (Yıldırım & Şimşek, 2006). In this study, the concepts and relationships in student designs have been evaluated through content analysis

Study Group

The study group of this research consists of 28 students (16 male, 12 female) from a 6th-grade class at a public school located in the Hendek district of Sakarya, a province of Turkey during the 2022-2023 academic year. The convenience sampling method was used in selecting the study group. In convenience sampling, the elements that are already available and easily accessible are selected (Patton, 2005). The reason for choosing a convenience sample in this study was the ease of implementation for the researcher. The researcher was able to conduct the study smoothly in the selected public school in Sakarya province. When selecting the study group, the one class was randomly chosen from among the seven sections in the school.

Data Collection Tools

The quantitative data of the research were obtained through the Problem-Solving Skills Questionnaire (PSSQ), the Engineering Design Skills Rubric (EDSR), and the Analogical Reasoning Skills Questionnaire (ARSQ), while the qualitative data were derived from a content analysis of the toy design models created by the students.

Quantitative Data Collection Tools

1. Problem-Solving Skills Questionnaire

The "Problem-Solving Skills Questionnaire" used in the study was developed by Ge (2001) and translated into Turkish by Coşkun (2004). This questionnaire is a Likert-type scale consisting of four sections and 20 items. In the questionnaire, students are asked to select one of the following options based on how much the statements apply to them: "Always (5 points), Often (4 points), sometimes (3 points), rarely (2 points), and Never (1 point)." The reliability test of the questionnaire was conducted, and the Cronbach's alpha value was found to be 0.76. In this study, the Cronbach's alpha value of the questionnaire was calculated as 0.80.Some of the items on the questionnaire is shown below.

Table 1. *Examples of Problem Solving Skills Questionnaire*

Problem Solving Skills Questionnaire	Always	Often	Sometimes	Slightly	Never
I think about whether I have fully understood what the problem is asking of me.					
I think about the information I will need to solve the problem.					
I draw or visualize a figure, either in my head or on paper to better understand the problem.					

2. Engineering Design Skills Rubric

The "Engineering Design Rubric," developed by the researcher, consists of 12 questions. The questions are rated on a 5-point scale, ranging from "Does not reflect me at all (1)" to "Completely reflects me (5)." To ensure the reliability of the rubric, expert opinions were sought. Specifically, one faculty member from the field of science education and three science teachers were consulted. Based on their suggestions, revisions were made, and the rubric was finalized. Some of the items on the rubric are shown below.

Table 2. *Examples of Engineering Design Skills Rubric İtems*

It doesn't reflect me at all (1)				It reflects me completely (5)	
I can design a toy for myself	1	2	3	4	5
If my sibling/friend asks me to design a toy, I can plan a design on the topic they want	1	2	3	4	5

"I can do research about the toy I will design."	1	2	3	4	5
"I wonder how the technological devices at home work."	1	2	3	4	5

3. Analogical Reasoning Skills Questionnaire

The "Analogical Reasoning Skills Questionnaire," developed by the researchers, consists of five open-ended questions. These questions are designed to establish relationships between support and movement systems and analogous characteristics in real life. The questions were created after reviewing analogical reasoning questions in the literature. The reliability of the questionnaire was ensured through the feedback of three experts, including teachers and academics. The Cronbach alpha value of the test is calculated as 0,63. Because the test consists of five questions, the cronbach alpha value can be below 0,70 (Tavakol ve Dennick, 2011).

Table 3. *Reliability Statistics of Analogical Reasoning Skills Questionnaire*

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,636	,638	5

2 of the test items are shown in the below as examples.

18)

a) What does the model in the image below represent?

b) Which arrow represents a bone, and which arrow represents a joint? Write next to the arrows.

c) Write one of the functions of the modeled support and movement system structure below.

19)

a) What type of joint is present in the structure shown in the model below?

b) Briefly explain how arm muscles work

Figure 3. *Examples of the Questions in the Analogical Reasoning Skills Questionnaire*

Collection of Qualitative Data

In the study, qualitative data were obtained through the evaluation of students' design products. The designs created by students during the activities in the implementation process constitute the qualitative data collected in this study. The evaluation and interpretation of these designs provided the qualitative findings. The designs were assessed in terms of originality, relevance to the purpose, and functionality, etc. Detailed information regarding the content analysis of the designs is provided in the findings section of the study.

Validity and Reliability

In this study, various measures were taken by the researchers to minimize or eliminate the factors that threaten or affect validity and reliability (Aydın, 2014; Yıldırım & Şimşek, 2013). These measures are presented in Table 4 below.

Table 4.*Validity and Reliability*

Validity	**Internal Validity**	• Obtaining expert opinion • Participant validation • Prolonged engagement • Direct quotation
	External Validity	• Explanation of the data collection tool and process • Description of the data analysis process • Description of the characteristics of the study group • Explanation of how the study group was selected • Description of the implementation process of the study • Explanation of the rationale for the chosen method • Explanation of the measures taken to ensure validity and reliability
	Internal Reliability	• By ensuring that the activities were enjoyable, efforts were made to eliminate factors such as lack of motivation, fatigue, and unwillingness that might arise among students. • Photographs of the students' products were taken to prevent data loss.

	• Full attendance was achieved in each weekly session.
External Reliability	• Appropriate discussion of the data in the results section • Checking the consistency among the data • The comprehensibility of the questions was checked

Potential threats to internal validity in this study include maturation—such as changes in participants over time due to factors like fatigue or mood swings related to adolescence—changes in the measurement instrument, events occurring outside the scope of the experimental intervention, and participant attrition. To mitigate these threats, the activities included in the intervention were deliberately chosen to be engaging and enjoyable in order to increase students' motivation. Additionally, students actively participated in design tasks during the lessons and frequently collaborated with one another that promoted social interaction. To prevent internal validity threats related to changes in the measurement instrument, the same instruments were used for both the pre-test and post-test without any modification in the questions. The responses to the research questions are influenced by methodological constraints. Due to the use of a weak experimental design in this study, the ability to draw robust causal inferences is restricted. Since the experiment was conducted with a single group, there is no control group available for comparison. Future studies employing quasi-experimental or true experimental designs would allow for such comparisons.

No external events that could threaten internal validity occurred during the study. There were no natural disasters, conflicts, or disputes among students. From the beginning of the intervention, students reported that they are enjoying the activities and participated eagerly and fully in the lessons. Full attendance was achieved in each weekly session throughout the implementation. Also, in the process of developing the scales, expert opinions were obtained, and the questions were prepared based on this feedback to analyze the readability and clarity of the tests. To ensure external validity, the research model, study group, data collection tools, data collection process, data analysis, and how the findings were organized have been described in detail. Additionally, the participants of the study consist of individuals who are suitable and contribute to the purpose of the study.

Application Process

Initially, students were administered pre-tests consisting of the Analogical Reasoning Skills Questionnaire (ARSQ), the Problem-Solving Skills Questionnaire (PSSQ), and the Engineering Design Skills Rubric (EDSR). After the pre-tests, students were provided with background information about the study, and work groups were formed. The groups began the implementation phase by starting to create their toys under the guidance of the teacher. The activities in the study were inspired by the toy work shop study conducted by Zhou et al. (2017). In the toy workshop, the toy creation process included stages such as drawing, iteration, problem-solving, model creation, and the development of technology-assisted materials. These activities aimed to engage students in using engineering design processes, such as designing, visualizing ideas, making observations, designing prototypes, drawing, brainstorming, and collaborating. Within the framework of this study, six distinct activities were conducted. These included: drawing, iteration, model creation, reverse engineering, problem-solving, and developing the toy with different materials. During the development of the toys, the goal was to encourage students to actively use engineering design processes, such as working collaboratively in groups, designing, drawing, and applying reverse engineering techniques. The toy design activities were carried out over six weeks, with two lessons each week. The activities were carried out within a total of 80 minutes, with each lesson lasting 40 minutes.

Engineering Design Activities

Below are the student designs from the construction process of the "Hand Model to Carry My Drink," a toy design created in the study. The design process consists of stages such as drawing, iteration, prototype creation, reverse engineering, problem-solving, and model improvement.

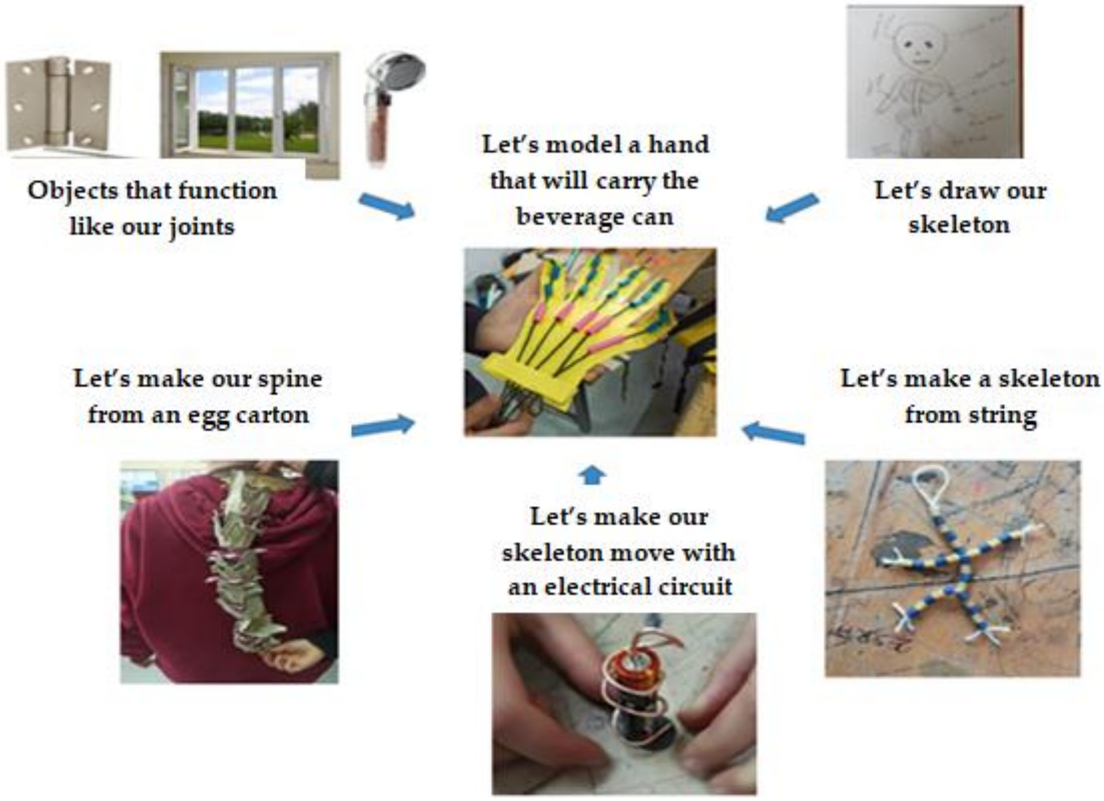

Figure 4. *Examples of Toy Designs Created by the Students*

Figure 4 represents the designs of each activity that were created by students during the application process of this study. As seen in the activities carried out, students also followed the steps of engineering design skills such as prototyping, modeling, sketching, etc.

Drawing (Skeleton)

In this phase, students were asked to draw the toy they planned to create related to the support and movement system. This activity encouraged students to visualize the system and concepts in their minds, promoting analytical thinking and the development of their visual-spatial skills.

Iteration (Skeleton Modeling with Pasta)

These activities are used to ensure that the subsequent stages of engineering skills development are solidly built. In this study, the iteration activity involved students creating a skeleton model using everyday materials, such as pasta.

Model Design Creation

At this stage, students designed models related to the support and movement system using simple materials like cardboard egg cartons.

Reverse Engineering

In this phase, students were introduced to materials in everyday life that function like joints (e.g., window or door hinges, shower heads) to help them recognize and understand joint types. This approach enabled students to establish a connection between science and real-life objects.

Problem Solving (Mechanical Hand Design)

In this stage, students were asked to develop a model to solve a given problem. Example problems included: "Who can carry a box of pencils with their hand?" or "Who can carry classroom objects like pens, chalk, or erasers with their hand?" Students played a game where they used the mechanical hands they designed to move objects around the classroom.

Design Creation with Technology or New Material Support

At this stage, students were asked to enhance their designs made with simple materials by incorporating technological tools to create more advanced designs. For example, they were expected to integrate a simple electrical circuit into their skeleton model to make the skeleton move.

Personal Information Form

The personal information form utilized in this study documents that parental consent was duly obtained to enable student participation. Parents completed the informed consent forms and formally authorized their children's involvement in the research. All students present in the classroom participated in the study in accordance with the permissions granted by their parents. Prior to the commencement of the study, both students and their parents were thoroughly informed regarding the purpose, scope, and procedures of the research.

DATA ANALYSIS

The process of data analysis is explained in this part.

Scoring of the Problem-Solving Skills Questionnaire (PSSQ)

The analysis of the PSSQ was conducted using the SPSS program. The items in the questionnaire were scored as follows: "Always = 5, Often = 4, Sometimes = 3, Rarely = 2, Never = 1." The maximum score obtainable from this questionnaire is 100, while the minimum score is 20.

Analysis of the Engineering Design Skills Questionnaire (EDSQ)

The Engineering Design Skills Questionnaire was scored on a scale from "Completely reflects me (5)" to "Does not reflect me at all (1)." The highest possible score students could achieve was 60, while the lowest possible score was 12. The data were analyzed using the SPSS program.

Scoring of the Analogical Reasoning Skills Questionnaire (ARSQ)

In the Analogical Reasoning Skills Questionnaire, the questions were scored as follows: fully understood = 2 points, partially understood = 1 point, and misunderstood = 0 points.

Fully Correct: Responses where the matches were made correctly and the explanations were clear and accurate.

Partially Correct: Responses where the matching was correct but the explanation was incomplete or inaccurate, or the matching was incorrect but the explanations were accurate. In short-answer questions, answers containing both correct and incorrect elements were considered partially correct.

Incorrect: Responses where the matches were wrong, explanations were incorrect or unrelated, or where the questions were left unanswered.

Analysis of Student Designs

The designs created by the students were evaluated using content analysis. A criteria table was created to evaluate the suitability of the designed toys for the intended purpose, originality, functionality of the design, visual quality of the design, and the compliance of the design with the desired criteria (conditions) in the activity. Content analysis was employed in interpreting the student products through the rubric. In the findings section of the study, under the heading of "Content Analysis of Engineering Designs", detailed explanations of the content analysis process are provided, along with descriptions of how it was conducted for each activity. In the reliability section of the data analysis, the data were analyzed by two independent experts, and the reliability of the results was enhanced by combining the similarity rates between the analysis outcomes. In this regard, the reliability value of the qualitative data analysis was found to be 85%. A coder reliability value above 70% indicates that the results are reliable (Arastaman, Öztürk Fidan, & Fidan, 2018).

Ethics Statements

In order to evaluate the compliance of this study with ethical principles, an application was submitted to the Research and Publication Ethics Committee of the Institute of Educational Sciences at Marmara University. The committee granted ethical approval on January 19, 2023, and confirmed the study's adherence to ethical standards through an official letter dated March 3, 2023, with reference number 492988.

FINDINGS

This study investigates the effects of toy design-based STEM applications on 6th-grade students' problem-solving, engineering design, and analogical reasoning skills in relation to the support and locomotion system. The findings obtained from this research are presented below. In order to assess whether the quantitative data exhibit characteristics of normal distribution, the values of Skewness (asymmetry) and Kurtosis (peakedness) were examined. Skewness measures the degree of asymmetry in a distribution, while Kurtosis is an index that indicates the extent to which there are either too many or too few outliers in the center of the distribution. A normal distribution is considered when the values of Skewness and

Kurtosis fall between -1.5 and +1.5 (Tabachnick & Fidell, 2013). Based on this information, it was determined that the pre-test and post-test data exhibited normal distribution characteristics, as their Skewness and Kurtosis values were within the range of -1.5 to +1.5. To determine whether there was a significant difference between the means of the pre-test and post-test data, an independent t-test was conducted.

Findings Related to Analogical Reasoning Skills

The purpose of this study was to assess students' ability to establish a relationship between models and analogical reasoning. Below, the responses to questions related to analogical reasoning were analyzed both quantitatively and qualitatively.

The Quantitative Results of Analogical Reasoning Skills Questionnaire

Table 5. *Results of Analogical Reasoning Skills*

	Paired Diffrerences					t	df	Sig.(2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 posttest-pretest	2,714	3,780	,714	1,249	4,180	3,800	27	,001

As seen in Table 5 above, since the significance value is .001 < .050, a significant difference was found between the post-test and pre-test results of the analogical reasoning skills questionnaire. The effect size of the intervention on the development of analogical reasoning skills in 6th grade students was determined using Cohen’s d analysis. The Cohen’s d values were interpreted as follows: less than 0.50 indicated a small effect; values between 0.50 and 0.80 indicated a medium effect, and values greater than 0.80 indicated a large effect (Akgün, Büyüköztürk, Çakmak, Demirel & Karadeniz, 2016). As a result of the analyses, the difference between the pre-test and post-test scores on the analogical reasoning test was found to be statistically significant (t (27) = 3.800; p < .050). The effect size of this difference was calculated as Cohen’s d = 0.71, which is interpreted as a medium effect size (Cohen, 1988). Based on these results, it can be concluded that STEM activities supported by toy design contribute positively by enhancing students’ analogical reasoning scores.

The Qualitative Results of Analogical Reasoning Skills Questionnaire

In the first question, students were asked to establish an analogical relationship between a model of a hand and a real human hand by writing "short bone," "joint," and "ligament" next to the arrows. In the pre-test, 20 out of 28 students correctly identified that the straws represented short bones, the threads represented tendons, and the structure between the short straws resembled the joints in the fingers. In the post-test, 26 students gave the correct answer. This indicates that the majority of students were able to establish the analogy between the bones, joints, and tendons and the straws, spaces between straws, and threads in the model correctly. In the pre-test, students who partially answered the question wrote "short bone" and "joint" next to the arrows but were unable to provide a clear explanation for their reasoning. Among the 6 students who answered the question incompletely, 4 left the question blank, and 2 provided irrelevant responses.

In the second question, students were expected to establish the relationship between the working principles of everyday objects they encounter and the types of joints, in terms of analogical reasoning skills. The correct matching answer is: "Door hinge: Semi-movable joint, Window hinge: Semi-movable joint, Puzzle pieces: Immovable joint and Faucet head: Movable joint." In the pre-test, 26 students were able to correctly establish the analogy between movable joints and everyday objects. In the post-test, all 28 students correctly matched all the examples from daily life with the types of joints.

In the third question, students were asked to design a skeletal model using pasta. The question required students to write down the structures represented by the long pasta, describe what the colored beads between the pasta represented, and explain what the overall shape could represent. In the pre-test, 14 students were able to correctly establish the analogies and provide accurate answers. 10 students received partial points by correctly identifying some of the required structures. Four students either left the question blank or provided irrelevant answers and did not receive any points. In the post-test, 23 students successfully answered the question by correctly establishing the analogies. Two students answered incorrectly, while three students received half points for providing partially correct answers.

In the fourth question related to analogical reasoning, students were asked to explain the working principle of the arm muscles and identify the type of joint between the arm bones. In the pre-test, 15 students correctly explained the contraction and relaxation of the arm muscles and accurately identified the type of joint present in the arm. Seven students received partial points because they either correctly explained the working principle of the arm muscles but wrote the wrong joint type, or they correctly identified the joint type but failed to explain the working principle of the arm muscles. Four students gave irrelevant answers, and two students left the question blank. As a result, six students did not receive any points. In the post-test, 20 students answered the question correctly and completely, earning full points. Five students answered partially correctly, earning half points. Three students did not receive any points.

In the fifth question related to analogical reasoning, students were asked to provide brief answers regarding what other materials could be used to create the spinal model shown in the diagram. During the application phase, students designed this spinal model themselves. In the pre-test, 18 students were able to think of and write down materials that could be used to design the model. One student received half points for indicating both usable and unusable materials. Of the nine students, five gave incorrect answers, writing the same materials that were given as examples. One student filled out the required materials section with "spine, bone, and joint," which was incorrect. Four students left the question blank. In the post-test, 22 students correctly identified different materials that could be used and received full points. One student received half points for mixing usable and unusable materials together. Five students did not answer the question and therefore did not receive any points. The materials written by students as correct answers included examples such as "Cotton, sponge, modeling clay, cardboard, beads, toilet paper roll, and plastic cup."

Findings Related to Problem Solving Skills

In this section, the findings comparing the pre-test and post-test scores obtained by students from the problem-solving skills survey are presented in Table 6 below.

Table 6. *The Results for Problem Solving Skills*

	Paired Diffrerences					t	df	Sig.(2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 posttest-pretest	7,786	9,331	1,763	4,168	11,404	4,415	27	,000

P=.000<.050

As seen in Table above, since the significance value is .000 < .050, a significant difference was found between the post-test and pre-test results of the problem solving skills survey. The effect size of the intervention on the development of problem solving skills in 6th grade students was determined using Cohen's d analysis. Cohen's d value bigger than 0,8 indicates a very large effect size (Akgün, Büyüköztürk, Çakmak, Demirel & Karadeniz, 2016). As a result of the analyses, the difference between the pre-test and post-test scores on the problem-solving skills test was found to be statistically significant (t(27) = 4.415; p < .050). The effect size of this difference was calculated as Cohen's d = 0.83, which is interpreted as a large effect size (Cohen, 1988). Based on these findings, it can be concluded that STEM activities supported by toy design contribute positively by improving students' problem-solving skills scores.

Findings Related to Engineering Design Skills

This section presents the findings comparing the pre-test and post-test scores obtained by students from the engineering skills survey.

Table 7. *Paired Sample t-Test Results for the Engineering Design Skills Survey*

	Paired Diffrerences					t	df	Sig.(2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 posttest-pretest	9,857	6,731	1,272	7,247	12,467	7,749	27	,000

P=.000< .050

As seen in Table above, since the significance value is .000 < .050, a significant difference was found between the post-test and pre-test results of the engineering design skills rubric. The effect size of this difference was calculated as Cohen's d = 1.46, which is interpreted as a large effect size. Cohen's d value bigger than 0,8 indicates a very large effect size. This means that the differences between the two groups are highly noticeable and practically significant (Cohen, 1988). As a result of the analyses, the difference between the pre-test and post-test scores on the engineering design skills test was found to be statistically significant (t(27) =

7.749; $p < .050$). Based on these results, it can be concluded that STEM activities supported by toy design contribute positively by enhancing students' engineering design skills scores.

Content Analysis of Engineering Designs

The toy design process consists of six stages: drawing, modeling, problem-solving, iteration, technology-assisted work, and reverse engineering. Below, these stages are evaluated individually. Students enjoyed themselves while designing STEM activities and spent time engaging with their designs through games. After completing the activities, they expressed that they had a great time and would like to participate in similar events again. They mentioned that they would keep the designs made from pasta as a souvenir. They stated that this activity was both fun and educational for them.

Evaluation of Students' Skeleton Drawings

The students' skeleton drawings were evaluated in terms of originality, relevance to the purpose, functionality, quality, and suitability to the given conditions.

The goal of the drawing activity is to ensure that students demonstrate what they have learned about the skeletal system and the structures that make up the skeleton through drawing. Students who produce high-quality drawings fully meet the criteria outlined in the design evaluation rubric. Across the class, 16 students' drawings are of good quality, and the skeletal system structures depicted are accurately identified. Six students' drawings are rated as medium because they partially meet the criteria in the design evaluation rubric. One of the criteria that aren't fully met is the functionality of the design. Six students' drawings are considered to meet the design evaluation rubric's criteria at a weak level, thus their drawings are rated as low quality.

Table 8. *Evaluation of Student Drawings According to Design Criteria*

CRITERIA	Weak (1 point)	Medium (2 Points)	Good (3 Points)
Relevance of the Design to the Purpose	6	3	16
Originality of the Design	0	0	28
Functionality of the Design	6	6	16
Visual Quality of the Design	6	6	16
Compliance of the Design with the Criteria (Conditions)	0	0	28

Out of the 28 students in the class, 16 students' drawings received a score of 3 for their relevance to the objective. Six students received a score of 2, and another six received a score of 1 for relevance. Since the designs are individual works created by the students themselves, they all received a score of 3 for originality. The drawings of 16 students are sufficiently functional to be used in another science class to explain the topic, thus receiving a functionality score of 3. Six students' designs are partially functional for explaining skeletal system structures in class, as they contain some accurate but also incorrect elements. Therefore, these six students received a functionality score of 2. The remaining six students' drawings are not functional due to incorrect representation of the structures and the quality of the drawings, which makes them unsuitable for class use, thus they scored 1 for functionality. The visual quality of 16 students' drawings is rated at 3. Six students' drawings have medium visual quality, so they received a score of 2. The remaining six students' drawings were rated at 1 due to weak visual quality. Overall, all students in the class received a score of 3 for fulfilling the criteria related to the skeletal system drawing and the representation of skeletal system structures, as requested by the activity.

Evaluation of Students' Iterative Activity

This activity is an iterative process that involves the three-dimensional modeling of the skeleton, which was initially drawn, using pasta. The iterative activity encompasses adjusting the design to fit the study and repeating the skeleton construction during the drawing phase. The aim of this activity was to help the class become familiar with the concept of design.

In high-level designs, long pasta pieces accurately represent bones, while short pasta pieces effectively depict joints. In medium-level designs, long pasta pieces were either not used correctly or not used at all. However, from a visual perspective, the medium-level designs are still of a good standard. In these designs, the excessive number of pasta pieces used in the neck region of the skeleton also reflects a gap in establishing an analogy with the real skeletal system. In low-level designs, both the visual appearance and the elongated neck of the skeleton fall short in terms of analogical reasoning.

Evaluation of the Models Created by Students During Toy Design

In the spine modeling activity, the entire class participated and worked collaboratively in groups of four to design their models. The objective of this activity was to design a spine model using the available materials while working in groups.

The first group, which produced a high-level design, fully meets all the design evaluation criteria. The design is visually of a high standard due to its size being close to the actual dimensions of the spine and its arrangement with neatly aligned egg cartons. Groups that produced medium-level designs partially met the design evaluation criteria. Three groups that produced low-level designs failed to create designs that sufficiently adhere to the criteria. They fall short in terms of visual quality, functionality, and meeting the required conditions. The reason for this deficiency is that these groups focused solely on stringing the egg cartons onto a thread, without paying attention to whether the design resembled the spine or not. Their designs remained as a few egg cartons simply strung onto a short thread. In comparison to other designs, Group 3's design is shorter and consists of less neatly arranged cartons in terms of size.

Table 9. *Evaluation of Student Models According to Design Criteria*

CRITERIA	**POINTS**						
	Group 1	**Group 2**	**Group3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**
Relevance of the Design to the Purpose	3	3	3	3	3	3	3
Originality of the	3	3	3	3	3	3	3

Design							
Functionality of the Design	3	2	1	2	2	1	1
Visual Quality of the Design	3	2	1	2	2	1	1
Compliance of the Design with the Criteria (Conditions	3	2	1	2	2	1	1
Total Points Received	15	12	9	12	12	9	9

The design created by the first group of students is the best and most suitable for the intended purpose of the activity. Factors such as the arrangement of the egg cartons being nearly the actual size of the spine and the placement of pink cartons between them make the design original. The design is functional in that it can be demonstrated to students in another science class to explain the spine. The visual quality of the design is considered good due to the arrangement of the egg cartons and their alignment with the spine's size. The design meets the criteria set for the activity. Other groups that created models at an intermediate level partially met the design evaluation criteria. Overall, these models are of medium quality in terms of visual appearance and functionality. Groups that created weak models did not adequately meet the design evaluation criteria. In general, weak designs failed to meet criteria such as visual appeal, functionality, and suitability to the activity's conditions.

Development of Students' Analogical Thinking through Reverse Engineering in Toy Design

Reverse engineering supports analogical reasoning. Due to the limited materials available for the students in this activity, the researcher supplemented the activity with additional materials and visuals to ensure that this phase of STEM was not lacking. The goal of the activity was for students to disassemble everyday objects, and make observations about their working principles. The students were asked to discuss which types of joints in the human body the working principles of the objects in the photos that are shown by the researchers to the students could resemble, and the reasons for these similarities were debated in class. The students' responses were as follows:

"The window hinge resembles a semi-movable joint because its movement is limited",

"The faucet head resembles a movable joint because it can rotate completely,"

"The toaster can be considered a semi-movable joint because it can move only slightly,"

"The shower head can be considered a movable joint because it can move in all directions."

In this activity, students played an active role in the class discussion and brainstorming based on the visuals but did not engage in any additional activities. Their ability to establish connections between everyday objects and types of joints in the human body was evaluated through active participation in the class.

Evaluation of Problem-Solving Activities Created by Students During Toy Design

The objective of this activity is to design a hand model capable of carrying classroom objects, working collaboratively in groups of four using the provided materials. Students from Group 1, Group 3, and Group 7 met all or most of the criteria in the design evaluation rubric with high scores. Group 1 scored 14 points, Group 3 scored 15 points, and Group 7 scored 15 points. Therefore, the designs from these groups are of a high level. The visual quality and functionality of these high-level designs are also of a good standard. Since the designs were made by the students using the materials they selected as a group, they demonstrate originality.

Table 10. *Evaluation of Students' Problem-Solving Activities According to Design Criteria*

CRITERIA	POINTS						
	Group 1	**Group 2**	**Group3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**
Relevance of the Design to the Purpose	3	3	3	3	3	3	3
Originality of the Design	3	3	3	3	3	3	3
Functionality of the Design	3	2	3	1	1	2	3
Visual Quality of the Design	2	1	3	2	2	1	3
Compliance of the Design with the Criteria (Conditions	3	2	3	1	1	2	3
Total Points Received	14	11	15	10	10	11	15

The designs created by the groups are in accordance with the objectives of the activity, thus they each received 3 points. Since the students worked collaboratively, making their own material selections and hand models, the originality of the designs from these groups was also rated 3 points. Two groups received a functionality score of 2. This is because their designs were able to carry light objects but were unable to carry heavier ones. Two other groups received a functionality score of 1, as their designs, which used cardboard instead of a sturdier material like corrugated board, were unable to carry objects. The two groups that received a functionality score of 3 were able to create fully functional models. The visual quality of the designs from these two groups was rated 3 points. However, two of the groups, despite showing functionality, received a visual quality score of 1. This was due to issues such as hand drawing quality, the cutting of the hand shape, inability to adjust the lengths of the strings, and misplacement of the straws. Two groups received a visual quality score of 2. Although these groups were unable to create a functional product, they still produced designs with an acceptable level of visual quality. Three groups fully met the criteria, earning 3 points. Two groups partially met the criteria in terms of functionality and visual quality, earning 2 points. Two groups, which failed to meet the required standards and conditions of the activity, received 1 point.

Evaluation of the Toys Created by Students by Adding Electrical Circuits

The objective of this activity is to have students establish an analogy of the support system by constructing a simple electric motor using copper wire, a battery, and a magnet. The designs created by students with a high level of proficiency are functional. The copper wire shown in the diagram can rotate around the battery. Due to the sufficient distance between the wire and the battery, the rotation occurs smoothly. Since these designs are created by the students themselves, they demonstrate originality. The designs align with the objective of the activity. Both the high and medium-level designs meet the conditions and criteria of the activity. The high-level designs scored high on the criteria table. Although the products in medium-level designs are functional, they fall short in terms of visual quality. The weak designs, on the other hand, fail to meet the criteria in terms of functionality, visual quality, and overall standards. In the weak model, the wire was repeatedly shaped incorrectly, and due to the lack of distance between the wire and the battery, the design did not function as intended.

CONCLUSION AND DISCUSSION

Conclusion and Discussion on the Impact of Toy-Making Supported STEM Applications on Students' Analogical Thinking Skills

In the present study, the focus was also on analogical reasoning skills, and a rubric was used to assess these skills. Students were expected to establish an analogical connection between everyday items they use (e.g., windows, toasters, door hinges) and joint types in the context of the support and movement system. In this regard, the current study shares similarities with the previously mentioned studies. In this study, analogical reasoning was explored, with the goal of helping students connect everyday objects such as windows, toasters, and door hinges to joint types related to the support and movement system. Based on the data obtained from the study, it was observed that students were able to establish analogical connections between the given objects and joint types.

The findings of this study are consistent with previous research emphasizing the effectiveness of analogies in enhancing students' understanding and reasoning skills. For instance, Esin, Erdem, Yılmaz, and Gücüm (2004) investigated students' comprehension of enzymes and their analogical reasoning abilities. Their study reported significant improvements in the performance of the experimental group after analogy-based instruction, highlighting the role of analogies in facilitating conceptual learning. Although the current study also focused on analogical reasoning, it differed methodologically by employing a single-group design rather than incorporating both experimental and control groups. Additionally, variations in grade levels and topic focus further differentiate the two studies, yet both underscore the instructional potential of analogical reasoning in biology education.

Similarly, Aykutlu and Şen (2011) found that the use of analogies in lessons not only improved students' academic achievement but also increased their interest in the subject. Complementing this, Önen Öztürk, Demir, and Şahin (2011) pointed out that analogies have both positive and negative aspects depending on how and when they are used during instruction. Despite these nuances, the present study's findings show parallelism with these earlier works. The statistically significant improvement observed between students' pre-test and post-test scores in analogical reasoning provides empirical support for the value of analogical strategies in educational settings. Other significant studies on analogical reasoning include those by Gray (2021), Cao, Ding, Lee, Jiao, Zhai (2023), Smyrnaiou, Sotiriou, Georgakapoulou (2017), Gray and Holyoak (2021), and Slavit, Grace, Lesseig (2021).

Moreover, Rivet and Kastens (2012) demonstrated that the use of physical models can effectively foster analogical reasoning skills. Their results revealed that such tools helped students develop deeper conceptual understanding by drawing meaningful connections between abstract and concrete ideas. The outcomes of the present study align with this view, as students exhibited progress in analogical reasoning following the instructional intervention. Taken together, these findings support the growing consensus that analogies can be powerful tools for enhancing students' cognitive engagement, reasoning abilities, and academic performance in science education.

Conclusion and Discussion on the Impact of Toy-Making Supported STEM Applications on Students' Problem-Solving Skills

This study investigated the effect of toy-making supported STEM applications on 6th-grade students' problem-solving skills in the context of support and movement systems. The results of the pre-test and post-test of the problem-solving skills questionnaire indicated that STEM applications positively impacted students' problem-solving abilities. The average score for the pre-test was 70.50, while the post-test average was 78.29. The independent t-test applied to the comparison of the pre-test and post-test results yielded a p-value of 0.00, which is below the significance threshold of 0.05, indicating a statistically significant difference between the two tests.

Similar studies have also highlighted the positive impact of STEM activities on problem-solving abilities (Taşçı, 2019; Türk & Korkmaz, 2023; Vurucu, 2019). In the study by İnce, Mısır, Küpeli, and Fırat (2018), STEM-based activities integrated with the science curriculum were used to investigate students' problem-solving skills and academic achievement in the "Mystery of the Earth's Crust" unit. STEM-based activities were implemented in the experimental group within the framework of the curriculum, and the results showed that these activities had a positive effect on both problem-solving skills and academic success. This study shares similarities with the work of İnce, Mısır, Küpeli, Fırsat (2018) in terms of implementing STEM-based activities and using pre-test and post-test assessments. However, this study differs in that it also measured engineering skills and did not involve control and experimental groups, as was the case in İnce et al. (2018).

In their research, Yalçın and Erden (2023) explored the impact of design-focused STEM activities on preschool students, similarly to the work of Akçay Malcok and Ceylan (2022). The study involved 20 students, aged 5, from a kindergarten classroom. The research was conducted over 8 weeks, with 3 sessions per week. Data were collected through observations, interviews, research diaries, and content analysis. During the STEM activities, the students' understanding of the tasks, division of labor, communication skills, roles in the activity, and evaluation abilities were observed. The analysis of the data revealed that the design-focused STEM education significantly improved the students' problem-solving skills, communication abilities, and teamwork skills. Moreover, it was found that STEM activities encouraged students to engage in problem-solving and idea generation, while also fostering a sense of responsibility. This study shares similarities with the works of Yalçın and Erden (2023) and Akçay, et. al (2022), as both focus on STEM activities. While there are differences in the student profiles, the use of design-focused STEM activities and the emphasis on problem-solving skills are common features in all these studies.

In their study, Kartini, et. al (2021) investigated whether STEM project-based learning environments enhanced students' problem-solving skills, particularly in the context of the Earth's layers and natural disasters. Indonesia, located within the Pacific Ring of Fire, is particularly vulnerable to natural disasters, which makes this topic highly relevant. The study aimed to ensure that future generations would not only gain knowledge about natural disasters but also develop their thinking skills in order to propose solutions to such problems. The research employed a pre-test and post-test design, along with trial writing questions as data collection tools. Thirty 7th-grade students participated in the study. The data analysis revealed a significant difference between the pre-test and post-test results regarding students' problem-solving abilities. Based on the findings, the study concluded that STEM project-based learning is recommended for enhancing students' problem-solving skills, especially in solving real-world issues. Although this study differs from Kartini et al. (2021) in terms of the specific topics addressed, both studies share similarities in the creation of a STEM-based learning environment and the examination of problem-solving skills. The findings of Kartini et al. (2021), which suggest that STEM-based activities positively affect students' problem-solving skills, are consistent with the results obtained in this study.

Conclusion and Discussion on the Effect of Toy-Making Supported STEM Applications on Students' Engineering Design Skills

This study explored the impact of toy-making supported STEM applications on the engineering design skills of 6th-grade students. During the implementation and through the comparison of pre-test and post-test results on the toy design skills scale, it was observed that STEM-based toy design activities, which included engineering design elements, had a positive impact on students' engineering design skills. These findings suggest that integrating engineering design into STEM activities enhances students' abilities in engineering, providing them with valuable skills for future problem-solving and innovation

The integration of toy design with STEM education in the present study is consistent with several prior studies that highlight the importance of hands-on, project-based learning in enhancing students' engineering design skills and overall STEM competencies. For instance, Machuve and Mkenda (2019) implemented renewable energy-based STEM activities in Tanzanian middle schools by engaging students in designing solar-powered motorized toys using second-hand materials. This activity not only introduced students to the concept of renewable energy but also fostered creativity, problem-solving, innovation, and sustainability awareness. Similarly, the current study incorporates toy design to support STEM learning and engineering skill development. However, while both studies use toy-based projects as a medium, the thematic focus differs: Machuve and Mkenda emphasized renewable energy, whereas the present study explores different STEM content areas. Nonetheless, both studies demonstrate the effectiveness of integrating engineering design processes into STEM activities through creative, student-centered projects.

In similar, Chang and Yen (2021) conducted a project-based STEM intervention in which students designed earthquake-resistant water towers. In the intervention part of the study, students apply engineering principles, such as calculating load, height, and seismic force. Their findings revealed a significant improvement in students' engineering design thinking skills, supporting the notion that long-term, hands-on STEM projects can positively impact learning outcomes. The current study also measured students' development of engineering design skills through STEM-focused projects, such as constructing robotic hands in the context of biological systems. Despite the difference in content—earthquake engineering versus biological mechanics—both studies highlight the value of applying STEM concepts in real-world contexts and confirm the role of project-based learning in enhancing students' design and problem-solving abilities.

Additionally, the Hydrobot project described by Bampasidis et al. (2021) presents another compelling example of STEM education centered on engineering design. Aimed at addressing gaps in the Greek education system's exposure to STEM practices, the Hydrobot initiative enabled students to design and refine underwater vehicles while acquiring mechanical, electronic, and design-related skills. Like the present study, the Hydrobot project placed students in active, authentic learning environments where they could engage in the full engineering design cycle. Although the technologies and learning goals varied, both studies emphasize the importance of providing students with real-world engineering experiences. The increased interest in STEM fields reported by Hydrobot participants mirrors the observed engagement and skill development in the current research, reinforcing the conclusion that hands-on STEM projects can meaningfully impact students' attitudes and abilities in science and engineering.

This study investigated whether toy-making supported STEM applications have an effect on 6th-grade students' academic success, problem-solving skills, and engineering skills in the context of the support and movement systems. The activities were conducted over 6 weeks with 2 hours each week and with a single group in a public school. The data were collected through pre-tests administered during the first week of the implementation and post-tests conducted in the week following the final week of the implementation. Comparing the pre-test and post-test data from the problem-solving skills survey, it was observed that these applications contributed positively to students' problem-solving abilities and analogical thinking skills about support and movement systems. Also, when comparing the pre-test and post-test data from the engineering skills toy design survey, and analyzing students' designs qualitatively by using a rubric, the findings revealed that STEM-based toy design activities positively influenced students' engineering design skills. These results suggest that integrating toy-making into STEM activities can be an effective way to enhance students' academic achievement, problem-solving abilities, and engineering design skills.

Recommendations

This study presents a framework that holds potential for further development. In future iterations, true experimental studies are required to verify the findings of this study since the present study employed a weak pretest-posttest design. Thus, the findings of this study needs to be taken cautiously. Moreover, variables and activities such as motivation, attitudes, coding, and the design of toys such as a contracting and expanding arm model could be incorporated alongside engineering design skills, and problem-solving abilities. Additionally, integrating the support and movement system with different topics could allow for the measurement of systems thinking skills. For this study to be further developed, it is essential for teachers to be willing and open-minded. Future studies may involve comparative research across different age groups to examine how STEM-based toy-making activities influence students at various developmental levels. As the current study employed a single-group design, future research should incorporate experimental designs with control groups to more rigorously assess the effects of the intervention. Extending the implementation period could provide insights into the long-term impact and retention of STEM learning outcomes. Gathering perspectives from students, teachers, and even parents could help evaluate the broader social and emotional impacts of the activities, adding a more holistic dimension to the analysis. Using different qualitative data collection methods such as video analysis or student journals to focus on students' thinking processes during the design tasks can lead to a deeper understanding of their cognitive engagement.

REFERENCES

Akarsu, M., Akçay, N. O., & Elmas, R. (2020). STEM eğitimi yaklaşımının özellikleri ve değerlendirilmesi. *Bogazici University Journal of Education, 37*, 155-175. https://dergipark.org.tr/en/pub/buje/issue/58376/842413

Akcay Malcok, B., & Ceylan, R. (2022). The effects of STEM activities on the problem solving skills of 6-year-old preschool children. *European Early Childhood Education Research Journal, 30*(3), 423-436. https://doi.org/10.1080/1350293X.2021.1965639

Anwar, S., Menekse, M., Guzey, S., & Bryan, L. A. (2022). The efectiveness of an integrated STEM curriculum unit on middle school students' life science learning. *Journal of Research in Science Teaching, 59*(7), 1204–1234. https://doi.org/10.1002/tea.21756

Arastaman, G., Fidan, İ. Ö., & Fidan, T. (2018). Nitel araştırmada geçerlik ve güvenirlik: Kuramsal bir inceleme. *Van Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi, 15*(1), 37-75. https://dergipark.org.tr/en/pub/yyuefd/issue/40566/491262

Arık, M., & Topçu, M. S. (2020). Implementation of engineering design process in the K-12 science classrooms: Trends and issues. *Research in Science Education, 52*, 21-43. https://doi.org/10.1007/s11165-019-09912-x

Arslanhan, H., & İnaltekin, T. (2020). Tasarım temelli öğrenme uygulamalarının fen bilimleri öğretmen adaylarının STEM anlayışlarını geliştirmeye etkisi. *Van Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi, 17*(1), 231-265.

Aydın, S. (2014). Olgu bilim araştırması. Metin, M. (Edt.), In *Kuramdan uygulamaya eğitimde bilimsel araştırma yöntemleri* (s. 300-301). Pegem Akademi.

Aykutlu, İ., & Şen, A. İ. (2011). Fizik öğretmen adaylarının analoji kullanımına ilişkin görüşleri ve elektrik akımı konusundaki analojileri. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 41*(41). https://dergipark.org.tr/en/download/article-file/87385

Bampasidis, G., Piperidis, D., Papakonstantinou, V. C., Stathopoulos, D., Troumpetari, C., & Poutos, P. (2021). Hydrobots, an underwater robotics STEM project: Introduction of engineering design process in secondary education. *AEE Journal 9*(1), 1.

Bartholomew, S. (2017). Integrated STEM through tumblewing gliders. *K-12 STEM Education, 3*(1),157–166.

Bartholomew, S. R., & Strimel, G. J. (2017). Factors influencing student success on open-ended design problems. *International Journal of Technology and Design Education, 28*(3), 753–770.

Ben-Horin, Y., & Rosenberg, D. (2016, March). *When something is like something else: Hands-on STEM through analogies*. In Conference Proceeding. New Perspectives in Scienze Education (p. 300). libreriauniversitaria. it Edizioni.

Bilen, K., Ergün, A., & Şimşek, V. (2021). Okul öncesi döneme yönelik bir STEM etkinliği: Paraşüt tasarlama. *Scientific Educational Studies, 5*(2), 126-158. https://dergipark.org.tr/tr/pub/ses/article/1007703

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classroom. *Journal of Engineering Education, 97*(3), 369-387.

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö.E., Karadeniz, Ş. & Demirel, F. (2016). *Bilimsel araştırma yöntemleri.* Pegem yayıncılık.

Cantrell, P., Pekcan, G., Itani, A., & Velasquez-Bryant, N. (2006). The effect of engineering modules on student learning in middle school science classroom. *Journal of Engineering Education, 95*(4), 301.

Cao, C., Ding, Z., Lee, G. G., Jiao, J., Lin, J., & Zhai, X. (2023). Elucidating STEM concepts through generative AI: A multi-modal exploration of analogical reasoning. *arXiv preprint arXiv:2308.10454.* http://dx.doi.org/10.48550/arXiv.2308.10454

Çeken, R. (2010). Fen ve teknoloji dersinde balonlu araba etkinliği. *İlköğretim Online, 9*(2), 1-5.

Christensen, B. T., & Schunn, C. D. (2007). The relationship of analogical distance to analogical function and preinventive structure: The case of engineering design. Memory & cognition, 35, 29-38. https://link.springer.com/article/10.3758/BF03195939

Clark, A. C., & Ernst, J. V. (2006). A model for the integration of science, technology, engineering, and mathematics. *The Technology Teacher, 66*(4), 24–26. https://www.proquest.com/openview/cdab50a3d4198c8001fc5064fc84231a/1?pq-origsite=gscholar&cbl=34845

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* L. Erlbaum Associates.

Creswell, J. W. (2021). *Karma yöntem araştırmalarına giriş*. (M. Sözbilir, Çev). Pegem Akademi.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Sage Publications.

Cunningham, C. M. (2009). Engineering is elementary. *The bridge, 30*(3), 11-17. https://www.researchgate.net/publication/285776570_Engineering_Is_Elementary

Cunningham, C. M., Lachapelle, C. P., Brennan, R. T., Kelly, G. J., Tunis, C. S. A., & Gentry, C. A. (2020). The impact of engineering curriculum design principles on elementary students' engineering and science learning. *Journal of Research in Science Teaching, 57*(3), 423–453. https://doi.org/10.1002/tea.21601

Cuperman, D., & Verner, I. M. (2019). Fostering analogical reasoning through creating robotic models of biological systems. *Journal of Science Education and Technology, 28*, 90-103. https://doi.org/10.1007/s10956-018-9750-4

Daugherty, J., & Mentzer, N. (2008). Analogical reasoning in the engineering design process and technology education applications. *Journal of Technology Education, 19*(2), 7. https://vtechworks.lib.vt.edu/server/api/core/bitstreams/af1e127f-7ae1-4cd1-a6c5-51ebbc666432/content

Egwutvongsa, S. (2020). Toys for children with the concept of STEM: Study of the result from children's playing activities. *Journal for the Education of Gifted Young Scientists, 9(2), 77-90.* http://dx.doi.org/10.17478/jegys.849063

Eisenkraft, A. & Chen Freake, S.Y. (2018). *Beyond the egg drop*. NSTA press.

Ercan, S., & Şahin, F. (2015). The Usage of engineering practices in science education: Effects of design based science learning on students' academic achievement. *Necatibey Faculty of Education Electronic Journal of Science & Mathematics Education, 9*(1), 128-164.

Ergül, A. (2023). Analojik akıl yürütmenin biyomimikri ile desteklenmesi: Doğa ile öğrenen çocuklar. *Türk Eğitim Bilimleri Dergisi, 21*(2), 879-904. https://doi.org/10.37217/tebd.1161851

Esin, A., Erdem, E., Yılmaz, A., & Gücüm, B. (2004). Enzimler konusunun anlamlı öğrenilmesinde analojiler oluşturmanın etkisi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 27*,21-29. https://dergipark.org.tr/en/download/article-file/87792

Felix, A., & Harris, J. (2010). A project-based, STEM-integrated alternative energy team challenge for teachers. *The Technology Teacher, 69*(5), 29–34.

Gerring, J. (2007). *Case study research: Principles and practices*. Cambridge University Press.

Goel, A. K., & Shu, L. H. (2015). Analogical thinking: An introduction in the context of design. *Ai Edam, 29*(2), 133-134.

Gök, B., & Sürmeli, H. (2022). The Effect of scientific toy design activities based on the engineering design process on secondary school students" scientific creativity. *Asian Journal of University Education, 18*(3), 692-709.

Gray, M. (2021). *An analogical approach to STEM education*. University of California.

Gray, M. E., & Holyoak, K. J. (2021). Teaching by analogy: From theory to practice. *Mind, Brain, and Education, 15*(3), 250-263. https://doi.org/10.1111/mbe.12288

Hey, J., Linsey, J., Agogino, A. M., & Wood, K. L. (2008). Analogies and metaphors in creative design. *International Journal of Engineering Education, 24*(2), 283.

Hynes, M., Portsmore, M., Dare, E., Milto, E., Rogers, C., Hammer, D., & Carberry, A. (2011). Infusing engineering design into high school STEM courses. *NCETE*, 1-7.

İnce, K., Mısır, M. E., Küpeli, M. A., & Fırat, A. (2018). 5. Sınıf fen bilimleri dersi yer kabuğunun gizemi ünitesinin öğretiminde STEM temelli yaklaşımın öğrencilerin problem çözme becerisi ve akademik başarısına etkisinin incelenmesi. *Journal of STEAM Education, 1*(1), 64-78.

Jarrett, O. S., Bulunuz, M., Jarrett, R., & Bulunuz, N. (Spring, 2020). Teaching with toys: Scientific inquiry through play. *E-journal The American Association for the Child's Right to Play (IPAUSA).* http://www.ipausa.org/

Kaçan, S. D. (2015). Designing science games and science toys from the perspective of scientific creativity. *Journal of Education and Practice, 26*(6), 116-18.

Kartini, F. S., Widodo, A., Winarno, N., & Astuti, L. (2021). Promoting student's problem solving skills through STEM project-based learning in earth layer and disasters topic. *Journal of Science Learning, 4*(3), 257-266.

Kesercioğlu, T., Yılmaz, H., Çavaş, P. H., Çavaş, B. (2004). İlköğretim fen bilgisi öğretiminde analojilerin kullanımı: "örnek uygulamalar". *Ege Eğitim Dergisi, 5*(1). https://dergipark.org.tr/en/pub/egeefd/issue/4920/67311.

King, D., & English, L. D. (2016). Engineering design in the primary school: Applying STEM concepts to build an optical instrument. *International Journal of Science Education, 38*(18), 2762-2794. https://doi.org/10.1080/09500693.2016.1262567

Lewis, T. (2006). Design and inquiry: Bases for accommodation between science and technology education in the curriculum. *Journal of Research in Science Teaching, 43*(3), 255-281.

Lin, K. Y., Hsiao, H. S., Williams, P. J., & Chen, Y. H. (2020). Efects of 6E-oriented STEM practical activities in cultivating middle school students' attitudes toward technology and technological inquiry ability. *Research in Science & Technological Education, 38*(1), 1–18.

Machuve, J., & Mkenda, E. (2019). Promoting STEM education through sustainable manufacturing: Case study of photovoltaic toys. *Procedia Manufacturing, 33*, 740-745.

Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2013, January). *A framework for implementing engineering standards in K-12*. Paper to be presented at the international conference of Association for Science Teacher Education (ASTE), Charleston, SC.

National Research Council (NRC) (2009). *Engineering in K–12 education: Understanding the status and improving the prospects.* National Academies Press.

Önen Öztürk, F., Demir, S., & Şahin, F. (2011). Fen bilgisi öğretmen adaylarının bakış açısıyla analojiler. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 5*(2), 86-114.

Patton, M. Q. (2005). *Qualitative research.* John Wiley & Sons, Ltd.

Pehlivan, H. (2016). The Role of play on development and learning. *Journal of Human Sciences, 13*(2), 3280-3292.

Richland, L.E.(2014). *Educating students for innovation in STEM: Analogy is a key.* American Association for the Advancement of Science 2015 Annual Meeting.

Rivet, A. E., & Kastens, K. A. (2012). Developing a construct-based assessment to examine students' analogical reasoning around physical models in earth science. *Journal of Research in Science Teaching, 49*(6), 713-743. https://doi.org/10.1002/tea.21029

Roth, W.-M. (2001). Learning science through technological design. *Journal of Research in Science Teaching, 38*, 768–790. https://doi.org/10.1002/tea.1031.

Samsudin, M. A., Osman, K., & Halim, L. (2007, March). *Content scaffolding or cognitive scaffolding?Which scaffolding technique encourages students to think actively while doing problem based learning?* International Problem-based learning symposium (pp. 150-173).

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher, December/January*, 20-26.

Shahali, E. H. M., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2016). STEM learning through engineering design: impact on middle secondary students' interest towards STEM. *Eurasia Journal of Mathematics, Science and Technology Education, 13*, 1189-1211. https://doi.org/10.12973/eurasia.2017.00667a

Sheppard, S. D, Macantangay, K., Colby, A. & Sullivan, W. M. (2009). *Educating engineers: Designing for the future of the field.* Jossey-Bass.

Siew, N. M., Goh, H., & Sulaiman, F. (2016). Integrating STEM in an engineering design process: the learning experience of rural secondary school students in an outreach challenge program. *Journal of Baltic Science Education, 15*(4), 477.

Slavit, D., Grace, E., & Lesseig, K. (2021). Student ways of thinking in STEM contexts: A focus on claim making and reasoning. *School Science and Mathematics, 121*(8), 466-480.

Smyrnaiou, Z., Sotiriou, M., Sotiriou, S., & Georgakopoulou, E. (2017). Multi-semiotic systems in STEMS: Embodied learning and analogical reasoning through a grounded theory approach in theatrical performances. *Journal of Research in STEM Education, 14*, 99-112.

Stein, M., & Miller, D. (1997). Teaching with toys. *The Science Teacher, 64*(4), 22.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics*. Pearson Education Inc.

Taşçı, M. (2019).*Tersine mühendislik uygulamalarının 8. sınıf öğrencilerinde akademik başarılarına, problem çözme becerilerine, STEM tutum ve algılarına etkisinin incelenmesi*. Yüksek Lisans Tezi, Marmara Üniversitesi, İstanbul.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International journal of medical education, 2*, 53.

Thornburg, D. (2009). Hands and minds: Why engineering is the glue holding STEM together. *Thornburg Center for Space Exploration*. http://www.tcse-k12.org/pages/hands.pdf.

Topalsan, A. K. (2018). Sınıf öğretmenliği öğretmen adaylarının geliştirdikleri mühendislik tasarım temelli fen öğretim etkinliklerinin değerlendirilmesi. *Van Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi, 15*(1), 186-219.

Türk, E. F., & Korkmaz, Ö. (2023). Eğitsel robot setleri ile gerçekleştirilen stem etkinliklerinin etkililiği: deneysel bir çalışma. *Ahmet Keleşoğlu Eğitim Fakültesi Dergisi, 5*(1), 92-118.

Verhaegen, P. A., D‟hondt, J., Vandevenne, D., Dewulf, S., & Duflou, J. R. (2011). Identifying candidates for design-by-analogy. *Computers in Industry, 62*(4), 446-459.

Vurucu, C. (2019). *Erken çocukluk döneminde bilim ve mühendislik uygulamalarının öğrencilerin bilimsel süreç becerilerine, karar verme ve problem çözme becerilerine etkisi*. Yüksek Lisans Tezi, Marmara Universitesi, İstanbul.

Wang, H., Moore, T., Roehrig, G., & Park, M.S. (2011). STEM Integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1-13.

Yalçin, V., & Erden, S. (2023). Design oriented STEM education with preschool children. *Southeast Asia Early Childhood, 12*(1), 40-53.

Yasar, O., Little, L., Tuzun, R., Rajasethupathy, K., Maliekal, J., & Tahar, M. (2006). *Computation math, science, and technology (CMST): A strategy to improve STEM workforce and pedagogy to improve math and science education*. Springer-Verlag. 169-176.

Yasin, R. M., Lilia, H. & Azaman, I. (2012). Effects of problem-solving strategies in the teaching and learning of engineering drawing subject. *Asian Social Science, 8*(16), 65.

Yıldırım, A. & Şimşek, H. (2006). *Sosyal bilimlerde nitel araştırma yöntemleri*. Seçkin Yayıncılık.

Yıldırım, A. & Şimşek, H. (2013). *Sosyal bilimlerde nitel araştırma yöntemleri*. Seçkin Yayıncılık.

Zhou, N., Pereira, N. L., George, T. T., Alperovich, J., Booth, J., Chandrasegaran, S., ... & Ramani, K. (2017). The influence of toy design activities on middle school students' understanding of the engineering design processes. *Journal of Science Education and Technology*, *26*, 481-493. https://doi.org/10.1007/s10956-017-9693-1

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