International Online Journal of Education and Teaching (IOJET), Vol. 13 , No. 1, 2026 (pp. 46-57)

RESEARCH ARTICLE WWW:IoJet.org

The Effects of Stem Applications Conducted with Middle School Students on their Engineering Knowledge Levels and An Examination of Student Opinions Regarding the Process

Pınar EROĞLU[1]*, Alev DOĞAN[2]

[1]Gazi University, Graduate School of Educational Sciences, Ankara, Turkey

[2]Gazi University, Gazi Faculty of Education, Ankara, Turkey

Keywords:

STEM activities,
Engineering design process,
8th grade middle school

Author's Email :
pakgulbale@gmail.com,
alevd@gazi.edu.tr

Author's Orcid :
0000-0001-8343-0003,
0000-0002-8907-1344

Received : 03.08.2025

Revised : 07.12.2025

Accepted : 13.12.2025

Abstract

The purpose of this study is to investigate the effect of STEM applications on the engineering knowledge levels of 8th grade students and their opinions regarding the application process. The study was planned and conducted using a mixed research design that evaluated both quantitative and qualitative data. A total of 30 volunteers, 15 girls and 15 boys, participated in the study. Six activities focusing on the stages of the engineering design process, covering physics, chemistry, and biology, were implemented over a period of six weeks during scheduled after-school hours. In the study, the "Engineering Knowledge Level Scale" adapted into Turkish by Aydın, Saka, and Guzey (2018) was used as a data collection tool to measure students' engineering knowledge, and a student opinion form was used to examine students' views on the application process. The data obtained were analyzed using the SPSS program and content analysis method. When the scale data were evaluated, a statistically significant difference in favor of the mean of the final test scores was found. According to the results obtained from qualitative findings, it was determined that students struggled most with the steps of construct a prototibe, develop possible solutions, and redesigning in the engineering design process, while they performed better in the steps of investigating and identifying needs/problems. Generally, it has been determined that STEM activity applications contribute to the engineering knowledge level of 8th grade middle school students and reveal their strengths and weaknesses in the engineering design process steps.

How to cite this article: EROĞLU P., DOĞAN, A. (2026). The Effects of Stem Applications Conducted with Middle School Students on their Engineering Knowledge Levels and An Examination of Student Opinions Regarding the Process. International Online Journal of Education and Teaching, Vol. 13, No. 1, 2026, 46-57

Introduction

STEM education is an integrated educational approach based on achieving harmony among the disciplines of science, technology, engineering, and mathematics (Şahin et al., 2014). STEM education aims to enable students to synthesize knowledge and concepts, enhance their critical, creative, and problem-solving skills, make them aware of technological and engineering design processes, and support them in developing positive attitudes toward these fields (Akgündüz et al., 2015; NAE, 2010). To this end, in STEM education applications, students actively utilize their interdisciplinary knowledge and skills to solve real-world problems using the steps of the engineering design process (Holbrook & Kolodner, 2000; Hmelo, Holton, & Kolodner, 2000). The engineering design process is a process that begins with the identification of the problem and ends with a solution that has certain limitations and criteria for achieving the targeted learning outcomes (Ercan, 2014). A review of the literature indicates that students involved in the engineering design process at an early age are more successful in learning science concepts (Cantrell et al., 2006; Wendell & Rogers, 2013). A review of the relevant literature reveals studies supporting this view (Stohlmann, Moore, & Roehrig, 2012; Kelley & Knowles, 2016). Additionally, Yıldırım & Altun (2015) stated that using STEM education and engineering design processes simultaneously supports students' higher-order thinking skills, contributes to the development of their creativity, and helps students gain an interdisciplinary perspective. A review of the relevant literature reveals studies supporting this view (Stohlmann, Moore, & Roehrig, 2012; Kelley & Knowles, 2016). However, integrating multiple disciplines simultaneously in STEM education is a difficult and complex process (Yıldırım, 2021). Furthermore, how STEM integration should be implemented in the classroom is not a well-defined area (Paez et al., 2019). One of the most suitable ways to achieve this is to incorporate science activities into the engineering design process and add them to teaching programs (English ve King, 2015; Felix, 2016). For this reason, many countries have gradually revised their education programs to adopt the STEM education approach in order to train individuals who meet the needs of the current century (Dugger, 2010; NAE, 2010).

Although STEM education is not explicitly mentioned in the 2013 science curriculum in our country, it has been observed that there are learning outcomes related to the use of design skills in relation to existing problems (MEB, 2013). Subsequently, with the changes made in 2017, the course "Science and Engineering Applications" was included in the curriculum under the science course with the aim of making the relationship between science and engineering disciplines more tangible and enabling students to gain more experience in engineering and science applications (MEB, 2018). Although the science and engineering concepts and activities added to the current program were a positive start, they contained some structural and implementation shortcomings. Therefore, in 2024, this unit was revised again in the Turkey Century Education Model Science Teaching Program and, instead of being grouped into a single unit, it was included under the heading under the heading "Science and Engineering Applications." The current science curriculum aims to present students with real-world problems under the heading "Science and Engineering Applications," encouraging them to seek solutions from an engineer's perspective and learn through experiencing the engineering design process (MEB, 2024). This way, theoretical knowledge has been integrated with practice.

Therefore, this study sought to answer the following questions.

1. What is the effect of STEM activity applications on the engineering knowledge level of 8th grade students?
2. What are the students' opinions regarding the implementation process of STEM activities?

Method

Model of the Study

This study employed a mixed-methods research design combining quantitative and qualitative data to investigate the effect of STEM activity applications on the engineering knowledge levels of 8th-grade middle school students and to examine student opinions during the application process. The mixed research design is defined by Creswell and Plano

Clark (2007) as research that collects data using qualitative and quantitative methods and allows for combining them in data analysis. The complexity and multidimensionality of phenomena and events necessitate the examination of both quantitative and qualitative dimensions, i.e., the use of a mixed research design (Yıldırım & Şimsek, 2021).

Participants

The participants in the study consisted of 30 volunteer students, 15 girls and 15 boys, who were enrolled in the 8th grade at a public middle school in Ankara during the 2022-2023 academic year. Participants were selected using the convenience sampling method. Convenience sampling is a sampling method commonly used in qualitative research and is useful for exploring a situation in depth (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2021).

Data Collection Tools

Engineering Knowledge Level Scale

In the study, the Engineering Knowledge Level Scale developed by Harwell, Moreno, Phillips, Guzey, Moore, and Roehrig (2015) and adapted into Turkish by Aydın, Saka, and Guzey (2018) was used to determine the engineering knowledge levels of 8th grade students. The scale consists of 15 multiple-choice questions. According to the reliability analysis results of the scale, the reliability coefficient is 0,71.

Student Opinion Form

The student opinion form used in the study to determine student opinions about the implementation process was created by the researcher based on the opinions of two science teachers. According to Patton (1987), the interview form is created to gather information on similar topics from different people. During the research process, this form was filled out individually by students after each STEM activity. The questions on the student opinion form are as follows.

Question 1: Which science concepts would you associate with this activity? What did you learn?

Question 2: Which part of the event design process do you enjoy the most? Why?

Question 3: Were there any stages that you found difficult when designing the event?

Question 4: If you had the chance to redesign the event, which parts would you change and how?

Data Collection and Analysis

The activities to be used in the pre-implementation research were determined based on Hyness et al.'s (2011) engineering design process cycle, which encompasses physics, chemistry, and biology and aims to produce solutions to real-life problems. The activities were defined as "Catapult, Artificial Arm, Hydrolift, Acid-Base Indicator, Microbit New Year's Card, Biological Material Epoxy" (Yıldırım, 2021; Arslan, 2021). Studies emphasize that the 5E learning model is a suitable model in terms of the applicability of STEM activities in classroom settings (Akgündüz, 2018). Lesson plans based on the 5E learning model were prepared for the STEM activities to be implemented in the study, and opinions were sought from two science education academics, one science teacher, and one information technology teacher who are experts in their fields. Before starting the application process, volunteer students who wished to participate in the study were informed about the process and the necessary permissions were obtained.

Students participating in the research were divided into groups during the implementation of the activities. During the process of assigning students to groups, a web 2.0 tool called random name generator (ClassTools/RandomNamePicker, https://www.classtools.net/random-name-picker/index.php) was used to create three groups—high, medium, and low—based on students' academic performance in science classes. high, medium, and low, and the groups were set up to be heterogeneous within themselves and homogeneous between each other. Before starting the STEM activity applications, an engineering knowledge level scale was administered as a pre-test. Subsequently, the activities were conducted with 30 students in the science laboratory for 2 hours per week over a period of 6 weeks. At the end of the applications, students' opinions about the process were collected using a student opinion form, and the engineering knowledge level scale was also applied as a final test.

In the analysis of the data obtained from the engineering knowledge level scale in the study, scoring was first performed by assigning 1 point for a correct answer and 0 points for an incorrect answer. Subsequently, the normality of the data was tested to determine whether the data obtained from the scale was suitable for parametric tests (Tables 1-2). After determining that the obtained data followed a normal distribution, a paired samples t-test was performed to determine whether there was a statistically significant difference between the pre-test and post-test scores on the engineering knowledge level scale, and the effect size was calculated (Table 3) (Büyüköztürk, 2013; Can, 2024).

Subsequently, the student opinion form data were evaluated using content analysis methods. Content analysis enables a thorough analysis of the obtained data and helps to reveal dimensions and themes that were not previously apparent (Yıldırım & Şimsek, 2021). Common themes and codes were identified based on the students' responses to the student opinion form questions. Frequency values were then assigned according to the frequency of the students' responses, and the findings in the student opinion form were tabulated separately for each question (Table 4-Table 7).

Findings

Findings from the Engineering Knowledge Level Scale (EKLS)

Upon examining Table 1, it was determined that the p-values of the normality test for the data obtained from the scale were greater than 0,05. This indicates that the data obtained are normally distributed (Can, 2024). In addition, the descriptive statistical values of the data obtained from the EKLS were examined and presented in Table 2.

As shown in Table 2, when the descriptive statistics of the data obtained from the EKLS regarding students' engineering knowledge level are examined, it is seen that the mean, median, and mode values of the pre-test and post-test scores are close to each other. Furthermore, since the skewness and kurtosis values of the EKLS pre-test and post-test scores were between +1.5 and -1.5, the normality of the distribution of the obtained data was accepted.

Table 1: Engineering Knowledge Level Scale Access Score Normality Test Findings

	Kolmogorov-Smirnov			Shapiro-Wilk		
Tests	Statistic (D)	df	p	Statistic (D)	df	p
EKLS pre-test	,159	30	,200	,971	30	,563
EKLS post-test	,152	30	,200	,948	30	,247
EKLS access	,127	30	,200	,975	30	,691

Table 2: Descriptive Statistics for Pre-test and Post-test Scores on the Engineering Knowledge Level Scale

Tests	N	Mean	Mode	Median	Std. Deviation	Variance	Skewness	Kurtosis	Min	Max
EKLS pre-test	30	9,566	11	10,50	3,036	9,220	-,973	-,067	3	13
EKLS post-test	30	11.400	12	12	1,922	3,697	-1.053	,824	6	14

Table 3: EKLS Pre-test and Post-test Scores Related Sample t-test Results

	N	$\bar{X}$	S	df	t	p	d
EKLS Pre-Test	30	9,566	3,036	29	-3,254	0,003	-0,594
EKLS Post-Test	30	11,400	1,922				

*p> .05

According to the data obtained from Table 3, it was determined that the average of the post-test scores on the engineering knowledge level scale was higher than the average of the pre-test scores, and that, considering the t-test results, there was a statistically significant difference in favor of the post test scores. At the same time, it was determined that the effect size (d = -0.594) was moderate.

Findings from the Student Opinion Form

The findings obtained from the questions in the student opinion form are presented in Table 4 and Table 7.

Table 4 shows that students participating in the study associated the knowledge they acquired during STEM activity implementation with science, physics, chemistry, biology, history, mathematics, visual arts, and technology design courses.

Table 5 shows that students considered themselves to be better at the stages of investigating needs/problems and testing solutions than at the stages of the engineering design process during the activities.

Table 6 shows that students struggled more with developing possible solutions and construct prototypes during the activities than with the steps of the engineering design process.

Table 7 shows that when asked which part of the activity they would like to redesign, students generally responded with codes indicating using different materials, making no changes, or structurally altering their designs.

Table 4: Codes and Frequencies of Responses to Question 1 of the Student Opinion Form

Activity	Codes	Frequencies
Let's Build a Hydraulic Lift	Science	25
	Physics	5
Let's Build a Catapult	Science	17
	History	9
	Mathematics	4
Let's Make Epoxy from Biological Material	Science	14
	Biology	12
	Visual arts	3
	Technology design	1
Let's Make a Microbit New Year's Card	Science	12
	Physics	11
	Visual arts	4
	Mathematics	3
Let's Make an Artificial Arm	Science	18
	Biology	10
	Technology Design	2
Let's Make an Acid-Base Indica tor	Science	15
	Chemistry	15

Table 5: Codes and Frequencies of Responses to Question 2 of the Student Opinion Form

Activity	Theme	Codes	Frequencies
Let's Build a Hydraulic Lift	Identifying the need/problem	Task distribution	4
		Using time efficiently	2
	Researching the need/problem	Use of technological devices	20
		Using the library	4

Activity	Theme	Codes	Frequencies
Let's Build a Catapult	Identifying the need/problem	Task distribution Using time efficiently	5 1
	Communicate the Solutions	Collaboration Using time efficiently Being fun Being eye-catching	8 7 5 4
Let's Make Epoxy from Biological Material	Test and Evaluate the Solutions	Motivation Choosing the right materials Collaboration Being fun	9 5 5 2
	Communicate the Solutions	Task distribution Collaboration Being fun	4 3 2
Let's Make a Microbit New Year's Card	Identifying the need/problem	Use of technological devices Task distribution Using time efficiently	17 2 1
	Test and Evaluate the Solutions	Motivation Choosing the right materials Collaboration Being fun	4 3 2 1
Let's Make an Artificial Arm	Researching the need/problem	Use of technological devices Task distribution	13 2
	Selecting the Best Solutions	Testing Motivation	9 6
Let's Make an Acid-Base Indicator	Researching the need/problem	Use of technological devices Using the library	10 6
	Test and Evaluate the Solutions	Testing Motivation Being fun	8 4 2

Table 6: Codes and Frequencies of Responses to Question 3 of the Student Opinion Form

Activity	Theme	Codes	Frequencies
Let's Build a Hydraulic Lift	Construct a prototype	Selection of suitable materials Method used Working mechanism Insufficient time	3 5 10 7
	Develop Possible Solutions	Inability to think creatively	4
	Communicate the Solutions	Inability to write a report	1
Let's Build a Catapult	Develop Possible Solutions	Inability to think creatively Selection of suitable materials	5 3
	Construct a prototype	Working mechanism Insufficient time	12 5
	Test and Evaluate the Solutions	Incorrect mechanism setup	5

Activity	Theme	Codes	Frequencies
Let's Make Epoxy from Biological Material	Construct a prototype	Quick mixing Excessive bubble formation	8 12
	Test and Evaluate the Solutions	Wrong casting Selection of suitable materials	7 3
Let's Make a Microbit New Year's Card	Construct a prototype	Lack of coding knowledge Not knowing the tools Insufficient time	10 5 3
	Develop Possible Solutions	Inability to think creatively	6
	Redesign	Inability to think creatively Lack of coding knowledge	4 2
Let's Make an Artificial Arm	Construct a prototype	Working mechanism Method used Insufficient time	10 6 3
	Test and Evaluate the Solutions	Tangled threads	6
	Redesign	Inability to think creatively	5
Let's Make an Acid-Base Indicator	Develop Possible Solutions	Lack of information Inability to think creatively	11 10
	Construct a prototype	Inability to think creatively	9

Table 7: Codes and Frequencies of Responses to Question 4 of the Student Opinion Form

Activity	Codes	Frequencies
Let's Build a Hydraulic Lift	Using different materials Making structural changes No changes	7 9 14
Let's Build a Catapult	Using different materials Making structural changes No changes	8 9 13
Let's Make Epoxy from Biological Material	Using different materials No changes	5 25
Let's Make a Microbit New Year's Card	Using different materials Making structural changes No changes	3 7 20
Let's Make an Artificial Arm	Using different materials Making structural changes No changes	9 9 12
Let's Make an Acid-Base Indicator	Using different materials Making structural changes No changes	2 2 26

Conclusion, Discussion and Recommendations

In this study, STEM activity applications were carried out with middle school students over a period of six weeks. The impact of these applications on students' engineering knowledge levels was determined, and student opinions regarding the application process were gathered.

As shown in Table 3, there is a statistically significant difference between the pre-test and post-test scores on the engineering knowledge level scale for middle school students, in favor of the post-test. According to these results, STEM activity applications have made a positive contribution to students' engineering knowledge level. It can be said that when STEM activity applications are carried out, activities centered on the steps of the engineering design process are conducted, and students' awareness in this area develops because they manage the design process themselves. A review of the literature reveals that Dare and colleagues (2017) conducted STEM activities using the engineering design process, and as a result, students' awareness of the engineering design process was observed to have increased. Indeed, when different studies on the subject are examined, it is stated that students who actively participate in the process diversify their knowledge of engineering through engineering-based activities (Oware, 2008). In this context, Ercan (2014) emphasized that STEM activities focused on the engineering design process developed a rich understanding of engineers' thinking styles and types of engineering among middle school students. Research has shown that students understand the engineering discipline better through STEM activities and use the knowledge they acquire more actively in practice (Yıldırım & Altun, 2015; Gülhan and Şahin, 2016; Çakmak, Bilen and Taner, 2019). Similarly, in his study, Uzel (2019) found that STEM activities conducted with sixth-grade students increased their engineering design skills. Furthermore, Ercan (2014)'s study with middle school students also indicated that engineering design-based activities improved students' engineering design process skills.

According to the qualitative research results, when the students' views on the application process were examined in detail, the students expressed their opinions on the first question of the opinion form, "*Which science concepts do you associate this activity with? What did you learn?*" as follows. *(S1): "I learned to use Pascal's principle."; (S6): "While designing the artificial arm, I learned to make models like in technology design class."; (S9): "I learned that acidity-basicity is one of the properties used to classify substances in chemistry."; (S12): "I learned that people used catapults in warfare in ancient times."; (S17): "I learned to make draft drawings during group reports while designing."*

In response to the second question on the opinion form, students expressed their opinions using the following statements. *(Ö3): "We distributed tasks very well within the group. Also, our friends who had phones made our work easier by researching online."; (Ö25): "I think distributing tasks saved us time. Also, we are very happy with how the product we designed works."* When these views were evaluated, they stated that they found the steps of identifying the need/problem and researching the need/problem easier due to the use of technological tools, task distribution, and intra-group cooperation. Musaoğlu (2020) determined in his master's thesis that students were successful at this stage and emphasized that this was due to the problem context.

Regarding question 3 of the opinion form, students expressed themselves as follows: *(S19): "We didn't have many ideas for the design..."; (S7): "It was our first time encountering microbit. We had very little knowledge about how to code or how to connect the cables." (S28): "After identifying and researching the problem, we didn't have many ideas."* When evaluating these statements, it was determined that students struggled at the stage of developing possible solutions. Students stated that the reason for this was that they had difficulty finding original ideas and thinking creatively in their proposed solutions and that they did not have sufficient knowledge on the subject. A review of studies on the subject reveals similar findings. For example, Özer (2019) conducted a study with sixth-grade students and found that students were unable to develop more than one plausible solution during the "developing possible solutions" stage of the engineering design process, attributing this to their creativity skills. Therefore, it can be said that the difficulties experienced by students participating in the study at this stage stem from their lack of creativity skills. The engineering design process used in STEM activities contributes to students' scientific creativity and develops their problem-solving skills (Charyton, 2015; Samuels and Seymour, 2015). Researchers working on this topic have stated that the most creativity skills are used in the stage of developing possible solutions (Wendell et al., 2010; Brunsell, 2012). Indeed, students are creative because the design products resulting from STEM activities are original (Tunkham, Donpudsa, & Dornbundit, 2016; Charyton, 2015).

The study found that students struggled particularly with creating mechanisms with movement capabilities during the prototype construction stage. This is thought to be because students preferred to construct prototypes through trial and error rather than following systematic steps in product creation, relying on the selection of materials in the design phase and adhering to the drawn prototype draft. The students' statements on this subject are as follows: *(S3): "I don't think we have the manual skills; I found it very difficult to make the prototype of the artificial arm."; (S19): "...We generally tried to stick to the draft drawing we made in the report, but we couldn't use our time efficiently."; (S22): "I think our method was wrong when making the arm."* Similarly, a study conducted by Bozkurt-Altan, Yamak, and Buluş-Kırıkkaya (2016) found that students struggled when designing their products. A review of the relevant literature reveals that students' difficulties in the prototype construction phase vary depending on various factors such as time constraints, limited material variety, technological capabilities, and the type of problem presented (Kolodner, 2002; White, Lloyd, Kennedy, & Stewart, 2005; Stohlmann et al., 2012). Indeed, Musaoğlu (2020) emphasized in his study conducted with fifty-two middle school students that it is difficult for students to make a prototype that is functional. He also stated that successful performance in the prototype construction stage is related to producing possible solutions appropriate to the problem context by adhering to the draft drawing. Aydın and Karslı-Baydere (2019) emphasized that the reason students struggle when designing products stems from the variety of materials and insufficient technological capabilities.

The study found that another engineering design process step that students struggled with the most was the redesign step. This is because at this stage, students are required to take an objective, critical approach to the products they have created and consider how they can further improve their prototypes. In the student opinion form, students responded as follows: *(S7): "I think our design turned out very nice and successful. No changes are needed."; (S8): "I could make a different circuit by using less copper tape in the electrical circuit."; (S10): "I don't think I could use a material other than epoxy. Therefore, I could have made a different keyring by changing the materials we added to the epoxy in the design. Or I could change the mold."* In this regard, it can be said that the students participating in the study were unable to view their prototypes with a critical approach and therefore could not creatively generate ideas for features that needed improvement. Consequently, the reason middle school students struggled in the redesign stage may stem from their lack of critical thinking skills. In STEM education, students take responsibility for the results of the applications they make throughout the process and continuously evaluate themselves during the application process (Capraro & Slough, 2013). Ersoy and Başer (2011), in their study aimed at determining middle school students' critical thinking tendencies, emphasized that students' critical thinking skills were at a low level. Açışlı Çelik (2022) conducted a study with sixth-grade students investigating the effect of STEM activities on critical thinking skills and found that STEM activities contribute positively to critical thinking skills. Snyder and Snyder (2008) stated that collaborative activities in which students are not passive develop their critical thinking skills. A review of the relevant literature indicates that various researchers have noted that STEM activities contribute positively to critical thinking skills, one of the 21st-century skills (Evcim, 2021; Peters Burton, 2014; Capraro & Jones, 2013; Mangold & Robinson, 2013).

As a result, STEM activity applications have been shown to increase middle school students' level of engineering knowledge, contribute to their development in the stages of the engineering design process, and reveal the stages of the engineering design process in which they struggle. Considering that students struggle particularly in the stages of developing possible solutions, constructing prototypes, and redesigning, it is important for teachers to develop strategies that are guiding, creative, and supportive of critical thinking in these processes.

The recommendations resulting from the research findings are as follows:

STEM activities contribute to the application of theoretical knowledge from different disciplines and the development of 21st-century skills; therefore, more space should be given to these activities in formal education courses.

STEM activity applications should be structured not only to produce a product, but also to support process-oriented learning.

Research can be diversified with different types of STEM activities that support the development of students' critical and creative thinking skills.

To prevent students from struggling during the engineering design process stages, STEM activities should be implemented in a way that ensures students follow a specific systematic approach.

Acknowledgement

This study was produced from the doctoral dissertation of the first author titled "Investigating the Effects of STEM Activities on the Scientific Curiosity, Engineering Design Knowledge, and Career Interest of 8th Grade Middle School Students" under the supervision of the second author.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. The ethical approval of the study was obtained from Gazi University Ethics Committee on 24.05.2022 with the registration number of 10.

References

1. Açışlı Çelik, S. (2022). STEM etkinliklerinin ortaokul 6. sınıf öğrencilerinin problem çözme becerilerine, eleştirel düşünmelerine ve STEM'e yönelik tutumlarına etkisinin araştırılması. *Pamukkale University Journal of Faculty of Education*, *56*, 287-313. doi:10.9779.pauefd.1054678
2. Akgündüz, D. (2018). İlkokul ve Ortaokul Fen Bilimleri Eğitiminde STEM Eğitimi Uygulamaları. D. Akgündüz (Ed)., Okul Öncesinden Üniversiteye Kuram ve Uygulamada STEM Eğitimi içinde (s. 169-200). Anı, Ankara.
3. Akgündüz, D., Aydeniz, M., Çakmakçı, G., Çavaş, B., Çorlu, M. S., Öner, T., & Özdemir, S. (2015). STEM eğitimi Türkiye raporu: Günün modası mı yoksa gereksinim mi? [A report on STEM Education in Turkey: A provisional agenda or a necessity?]. İstanbul: Scala.
4. Arslan, S., Y. (2021). *Öğretmenler İçin Öğrenme Senaryoları Kitapçığı*. Ankara.
5. Aydın, E., & Karslı Baydere, F. (2019). 7th grade students' views about STEM activities: Example of separation of mixtures. *Ondokuz Mayıs University Journal of Education Faculty, 38*(1), 35-52. DOI: https://doi.org/10.7822/omuefd.439843
6. Aydın, G., Saka & M., Guzey, S. (2018). 4-5-6-7. and 8. Sınıf Öğrencileri İçin Mühendislik Bilgi Düzeyi Ölçeği. *Elementary Education Online, 17(2): pp. 750-768*
7. Bozkurt-Altan, E., Yamak, H., & Buluş-Kırıkkaya, E. B. (2016). Hizmet öncesi öğretmen eğitiminde FeTeMM eğitimi uygulamaları: Tasarım temelli fen eğitimi. *Trakya University Journal of Faculty of Education, 6*(2), 212-232.
8. Brunsell, E. (2012) The engineering design process. Brunsell, E. (Ed.) *Integrating engineering + science in your classroom* (3-5). Arlington, Virginia: National Science Teacher Association [NSTA] Press.
9. Büyüköztürk, Ş. (2013). *Sosyal Bilimler İçin Veri Analizi El Kitabı*. Ankara: Pegem
10. Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş.& Demirel, F. (2021). *Eğitimde Bilimsel Araştırma Yöntemleri*. Ankara: Pegem
11. Can, A. (2024). *SPSS ile Bilimsel Araştırma Sürecinde Nicel Veri Analizi*. Ankara: Pegem
12. Cantrell, P., Pekcan, G., Itani, A., & Velasquez-Bryant, N. (2006). The effects of engineering modules on student learning in middle school science classrooms. *Journal of Engineering Education, 95(4), 301-309. doi:* https://doi.org/10.1002/j.2168-9830.2006.tb00905.x
13. Capraro, M. M., & Jones, M. (2013). Interdıscıplınary STEM project-based learnıng. In R.M. Capraro, M.M. Capraro, & J. Morgan (Eds.), STEM Project-Based Learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) approach (pp.51–58). Rotterdam: Sense
14. Capraro, R. M., & Slough, S. W. (2013). Why PBL? Why STEM? Why now? An introduction to STEM project-based learning. Robert M. Capraro, Mary Margaret Capraro and James R. Morgan (Ed.), *STEM project-based learning* içinde (s. 1-5). Rotterdam: Sense
15. Charyton, C. (2015). Creative engineering design: The meaning of creativity and innovation in engineering. Christine Charyton (Ed.), *Creativity and innovation among science and art* içinde (s. 135-152). London: Springer-Verlag.

16. Creswell, J. W. & Plano Clark, V. L. (2007). Designing and conducting mixed methods research. Thousand Oaks, CA:Sage.
17. Çakmak, B., Bilen, K. & Taner, M.S. (2019). Ortaokul öğrencilerinin mühendis ve mühendislik algıları. *Anadolu Öğretmen Dergisi, 3(1), 32-33.*
18. Dare, E. A., Rafferty, D., Scheidel, E., & Roehrig, G. H. (2017). Flood rescue: A gender inclusive integrated STEM curriculum unit. *K-12 STEM Education, 3(2), 193-203.*
19. Dugger, W. E. (2010). Evolution of STEM in the United States. Presented at the 6th Biennial International Conference on Technology Education Research, Gold Coast, Queensland, Australia. http://www.iteaconnect.org/Resources/PressRoom/Australia-Paper.pdf
20. English, L. D. & King, D. T. (2015). STEM learning through engineering design: Fourth-grade students' investigations in aerospace. *International Journal of STEM Education*, 2(1), 14. doi:10.1186/s40594-015-0027-7
21. Ercan, S. (2014). *Fen Eğitiminde Mühendislik Uygulamalarının Kullanımı: Tasarım Temelli Fen Eğitimi*. (Unpublished PhD Thesis), Marmara University, Graduate School of Educational Sciences, Istanbul.
22. Ersoy, E. & Başer, N. (2011). İlköğretim İkinci Kademede Eleştirel Düşünmenin Yeri. *Adnan Menderes University Eğitim Fakültesi Eğitim Bilimleri Dergisi, Haziran 2011, 2 (1), 1-10*
23. Evcim, İ. (2021). Fen bilimleri dersinde STEM entegrasyonuyla kuvvet ve enerji ünitesinin geliştirilerek, öğrencilerin eleştirel düşünme becerilerine ve girişimcilik yeterliliklerine etkisinin incelenmesi. [Unpublished PhD Thesis]. Yıldız Technical University
24. Felix, A. (2016). *Design based science and higher order thinking* (Unpublished PhD Thesis). Virginia Polytechnic Institute and State, Virginia
25. Gülhan, F. ve Şahin, F. (2018). Ortaokul 5. ve 7. sınıf öğrencilerinin mühendisler ve bilim insanlarına yönelik algılarının karşılaştırmalı olarak incelenmesi. *Necatibey faculty of Education Journal of Elektronic Science and Mathematics Education, 12*(1), 309-338.
26. Harwell, M., Moreno, M., Phillips, A., Guzey, S. S., Moore, T. J., & Roehrig, G. H. (2015). A study of STEM assessments in engineering, science, and mathematics for elementary and middle school students. *School Science and Mathematics*, *115*(2), 66-74. DOI:10.1111/ssm.12105
27. Hmelo, C. E., Holton, D. L. & Kolodner, J. L. (2000). Designing to learn about complex systems. *Journal of the Learning Sciences, 9(3), 247-298.*
28. Holbrook, J. ve Kolodner, J.L., (2000). Scaffolding the development of an inquiry-based (science) classroom. B. Fishman ve S. O'Conner-Divelbiss (Haz.), *Proceedings of ICLS 2000: International Conference of the Learning Sciences* (pp. 221-227). Mahwah, NJ: Lawrence Erlbaum Associates.
29. Hynes, M., Portsmore, M., Dare, E., Milto, E., Rogers, C., & Hammer, D. (2011). Infusing engineering design into high school STEM courses. Retrieved from; https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1165&context=ncete_publications
30. Kelley, T. R. & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(1), 1-11. doi:10.1186/s40594-016-0046-z
31. Kolodner, J., (2002). Facilitating the learning of design practices: Lessons learned from an inquiry into science education. *Journal of Industrial Teacher Education, 39*(3), 9-40.
32. Mangold, J. & Robinson, S. (2013). The engineering design process as a problem solving and learning tool in K12 classrooms. 120th ASEE Annual Conference & Exposition, Atalanta, Temmuz, 23-26.
33. Ministrty of Education (MEB). (2013). *Fen Bilimleri Dersi Öğretim Programı (İlkokul ve Ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar)*. Ankara.
34. Ministrty of Education (MEB). (2017). *Fen Bilimleri Dersi Öğretim Programı (İlkokul ve Ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar)*. Ankara.
35. Ministrty of Education (MEB). (2018). *Fen Bilimleri Dersi Öğretim Programı (İlkokul ve Ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar)*. Ankara.
36. Ministrty of Education (MEB). (2024). *Fen Bilimleri Dersi Öğretim Programı (İlkokul ve Ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar)*. Ankara.
37. Musaoğlu, G. (2020). *Yedinci Sınıf Öğrencilerinin Fen Bilimleri Dersi Uzay Kirliliği Konusunda Mühendislik Tasarım Düzeyleri ve Ürün Tanıtımı Niteliklerinin İncelenmesi*. Master's Thesis. Recep Tayyip Erdoğan University, Fen Bilimleri Enstitüsü, Rize.
38. National Academy of Engineering (NAE). (2010). Standards for K-12engineering education. Washington, DC: National Academies Press
39. Oware, E. A. (2008). *Examining elementary students' perceptions of engineers* (Unpublished PhD Thesis). Purdue , USA.
40. Özer, İ. E. (2019). 6. Sınıf Kuvvet ve Hareket Ünitesinde Gerçekleştirilen Algodoo Temelli Etkinliklerin Öğrencilerin Tasarım Becerilerine ve Akademik Başarılarına Etkisi. (Unpublished Master's Thesis) Aksaray University, Graduate School of Natural Sciences, Aksaray.
41. Paez T. M., Aguilera D., Palacios F. J. P.& Gonzalez J. M. V., (2019) What are we talking about when we talk

about STEM education? A review of literature. *Science Education, 103, 799-822. http://dx.doi.org /10.1002/ sce.21522*

42. Patton, M. Q. (1987). *How to use qualitative methods in evaluation*. Newbury Park, CA: Sage.
43. Peters-Burton, E. E. (2014). Is there a “Nature of STEM”?. *School Science and Mathematics, 114*(3), 99-101.
44. Samuels, K., & Seymour, R. (2015). The middle school curriculum: Engineering anyone? *Technology and Engineering Teacher, 74(6)*, 8-12.
45. Stohlmann, M., Moore, T. J. & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER),* 2(1), 28-34.
46. Snyder, L. G., & Snyder, M. J. (2008). Teaching critical thinking and problem-solving skills. *The Delta Pi Epsilon Journal, 50(2), 90-99.*
47. Şahin, A., Ayar, M. C. & Adıgüzel, T., (2014). Fen, teknoloji, mühendislik ve matematik içerikli okul sonrası etkinlikler ve öğrenciler üzerindeki etkileri. *Kuram ve Uygulamada Eğitim Bilimleri, 14, 1, 297-322.*
48. Tunkham, P., Donpudsa, S., & Dornbundit, P. (2016). Development of STEM activities in chemistry on “protein” to enhance 21 st century learning skills for senior high school students. *Humanities, Arts and Social Sciences Studies, 16*(3), 217-234.
49. Uzel, L., (2019). *6. Sınıf Madde ve Isı Ünitesinde Gerçekleştirilen Mühendislik Tasarım Temelli Uygulamaların Öğrencilerin Problem Çözme ve Tasarım Becerilerine Etkisinin Değerlendirilmesi*. (Unpublished Master’s Thesis). Aksaray University Graduate School of Natural Sciences.
50. Wendell, K. B., Connolly, K. G., Wright, C. G., Jarvin, L., Rogers, C., Barnett, M. & Marulcu, I. (2010). Incorporating Engineering Design İnto Elementary School Science Curricula. *American Society for Engineering Education Annual Conference & Exposition*, Louisville, June, 20-23.
51. Wendell, K. B. & Rogers, C. (2013). Engineering design-based science, science content performance, and science attitudes in elementary school. *Journal of Engineering Education 102(4), 513-540. https://doi.org/10.1002/jee.20027*
52. White, F., Lloyd, H., Kennedy, G., & Stewart, C. (2005). An investigation of undergraduate students’ feelings and attitudes towards group work and group assessment. *Research and Development in Higher Education*, 28, 618-623.
53. Yıldırım, B. (2021). *Teoriden Pratiğe STEM Eğitimi Uygulama Kitabı*. Nobel, Ankara.
54. Yıldırım, B. & Altun, Y. (2015). STEM Eğitim ve Mühendislik Uygulamalarının Fen Bilgisi Laboratuvar Dersindeki Etkilerinin İncelenmesi. *El-Cezeri Fen ve Mühendislik Dergisi, 2(2); 28-40.*
55. Yıldırım, A. & Şimsek, H. (2021). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*. Seçkin, Ankara