

## The Effect of STEM Activities on Seventh-Grade Students' Attitudes Towards Environmental Problems and Their Learning Responsibilities

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### Abstract

In this study, it is intended to find out the effects of Science, Technology, Engineering, and Mathematics [STEM] based environmental education activities on seventh-grade middle school students' attitudes towards environmental problems and their learning responsibilities. The study was conducted with 12 students attending a public middle school in a rural area in western Türkiye according to a single group pre-test - post-test model. Data were collected with the "Attitude Scale Towards Environmental Problems" developed by Kılıç and Kan (2020) and the "Scale of Responsibility towards Learning" developed by Yakar and Saracaloğlu (2017). In data analysis, comparisons were made with t-tests for related samples. According to the results, a statistically significant difference was obtained in both the students' attitudes towards environmental problems and their learning responsibilities. In the future, it is recommended that similar studies on environmental education be carried out especially in disadvantaged schools to increase students' awareness levels towards environment and support their learning responsibilities.

Keywords: Environmental education, STEM, middle school students.


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## **The Effect of STEM Activities on Seventh-Grade Students' Attitudes Towards Environmental Problems and Their Learning Responsibilities**

### **Introduction**

Technological and economic developments resulting from human activities have caused significant damage to the natural environment, and this negative situation is currently having an impact on a global scale (Schultz, 2002). It has even been stated that these problems have exceeded the borders of Earth and that pollution also occurs in space (Hall, 2014). The main environmental problems are soil, water and air pollution, extinction of animal and plant species, climate change, the garbage problem (Erten, 2004), metal pollution (Wasi et al., 2013), light pollution (Cinzano & Falchi, 2014), noise pollution (Morillas et al., 2018) and electromagnetic pollution (Redlarski et al., 2015). A key point that should be realized regarding this situation is that most environmental problems have a compound structure and the possible negative effects of these problems are irreversible (Wallner et al., 2003). In fact, all environmental problems directly or indirectly have negative influences on human health (Wasi et al., 2013). Although these issues are frequently on the agenda, a study conducted with high school students reported that the rate of students who were knowledgeable about issues such as global climate change, ecosystem destruction, loss of biodiversity, water pollution and deterioration in soil quality was below 25% (Kamil et al., 2020). Considering that there are both living and non-living factors in the composition of the environment, it is thought that a multi-dimensional approach should be taken to solve the problems in this regard.

### ***Environmental education and attitudes***

Environmental education is the education required for individuals to comprehend the characteristics of environmental problems, to propose solutions to them and to create changes in their behaviors related to the environment (Özbuğutu et al., 2014). In addition, environmental education serves as a tool by utilizing the methods used in the field of education to enable students to comprehend how their own behaviors affect the well-being of the environment and society (Ajiboye & Silo, 2008). As in other fields, starting education at an early age is important in terms of providing students with persistent behaviors and ensuring that they can maintain these behaviors throughout their lives. It is emphasized that various games or experiences related to nature can be used in students' development of beneficial and conscious behaviors towards the environment (Erten, 2004). In this regard, teachers have an important role because they can provide qualified education to their students and raise them equipped in this sense by being role models for them (Kuvaç, 2018). In addition to all this, it is stated that the environment changes in line with our attitudes towards it, and therefore the behaviors and attitudes of individuals determine the future of the environment (Gürer, 2018).

Attitude towards the environment can be briefly defined as the total of individuals' actions and thoughts towards behaviors that are beneficial to the environment (Erten, 2004). In order to have a more livable environment, everyone is expected to have positive attitudes towards the environment. However, studies have shown that there are differences in individuals' attitudes (Feinberg & Willer, 2013; Lee, 2009;

Papp, 2022; Schultz, 2002), perceptions (Sezer & Çoban, 2016) and sensitivities (İbiş, 2009) towards the environment. The reasons for different perceptions and attitudes towards the environment can be listed as economic status, life experience, beliefs, value judgements and educational status (Özgen, 2012). However, teachers can support students' perceptions and attitudes towards the environment with the help of effective educational programs. In this context, Borg et al. (2019) investigated the knowledge of preschool children who attended and did not attend eco-certified schools in Sweden about the effects of different types of transportation on the environment. As a result of their research, it was determined that students who attended eco-schools were found to have higher levels of knowledge than the students who attended non-eco-schools. On the other hand, there was no statistical difference between these two groups. In another study, Ajiboye and Silo (2008) examined the effects of environmental club activities carried out in out-of-school environments in Africa on the knowledge and attitudes of primary school students about the environment and reported significant improvements in the students. Additionally, Basile (2000) showed that the education program she carried out in a natural environment with the third-grade primary school students in the United States was effective in transferring students' declarative, procedural and schematic knowledge to both near and distant situations.

### ***Interdisciplinary structure of environmental education***

Environmental education has an interdisciplinary structure and benefits from many fields (Meredith et al., 2000). Examples of the fields that environmental education is related to include earth science, botany, and zoology. In addition, environmental education has focal points at the individual, social, and ecosystem levels (Ardoin et al., 2020). In this context, the concept of sustainability stands out in the literature. Sustainability refers to the balance between the rate of consumption of resources in a system and the rate at which the system renews itself (Schultz, 2002). Therefore, when today's human behavior is taken into account, the importance of individuals being aware of transferring natural resources to future generations while consuming them has emerged. Özdemir (2007) also draws attention to a number of principles that should be adopted in environmental education such as interdisciplinarity, holism, experientiality, questioning, flexibility, inclusiveness, globularness/localness, participation, constructivism, innovative learning, economy, efficiency, continuity and compatibility with nature. For these reasons, it is thought that providing environmental education to students in a way that they can establish relationships with different disciplines is an effective approach.

In the literature, STEM (science, technology, engineering, and mathematics) is one of the approaches used in providing environmental education to students. It is stated that environmental education based on the STEM approach contributes to students' understanding of environmental problems (Alkair et al., 2023), their conceptual understanding of ecology (Ghadiri Khanaposhtani et al., 2018), their environmental awareness (Başaran & Erol, 2023; Helvacı & Helvacı, 2019; Tadena & Salic-Hairulla, 2021), and their perceptions of environmental problems (Koculu & Girgin, 2022). It is seen that these studies were carried out with primary and secondary school students. In addition to the positive results obtained in environmental issues in the mentioned STEM educations, it is seen that students' skills such as

engineering design were also developed (Koculu & Girgin, 2022). An important skill that students should have in this process is learning responsibility.

### ***Responsibility for learning in the learning process***

According to Erişti (2017), behaviors related to responsibility for learning include in-school or in-class behaviors as well as the student's preparation for lessons outside of school. In addition, the researcher states that responsibility for learning comprises student's efforts in this direction and his/her previous learning, all of which are the key to in-class performance and success. In the 21st century, students taking more ownership of their learning should be at the center of education and programs (Carpenter & Steinberger Pease, 2013). Responsibility for learning is effective in students' achievement of targeted outcomes. As a result of Özbulat's (2020) study conducted with middle school students in Türkiye, it was determined that there was a high-level, positive, and significant relationship between students' responsibility for learning and their school motivation. Also, the researcher indicated that female students had higher learning responsibility than male students, and that fifth-grade middle school students had higher learning responsibility than other grades. However, in a study conducted by Devlin (2002) with university students in the United States, it was found that half of the participants perceived the concept of learning as an increase in a person's knowledge; none of them perceived the change that occurred in people in this context. On the other hand, education process intends to create meaningful changes in the behaviors of individuals.

Today, since environmental problems have reached a global dimension and have started to negatively affect all people, these problems should be included in the area of responsibility of each individual. A characteristic that individuals should possess in order to improve themselves in this regard is the responsibility to learn. The characteristics of students who have a responsibility to learn are expressed as having problem-solving skills, questioning, increasing their scientific and technological vocabulary, and benefiting from learning environments outside the classroom (Çınar et al., 2006). Thus, the responsibility to learn is not limited to behaviors within the school but also includes many behaviors outside the school such as students repeating what they have learned, coming to class prepared, and fulfilling their responsibilities outside the classroom (Erişti, 2017). A similar situation is also valid for environmental education. As a matter of fact, with environmental education, individuals are expected not only to gain theoretical knowledge (such as defining the concept of environment, listing the types of pollution, explaining sustainability) in the school environment, but also to reflect what they have learned in out of school environments (such as keeping the environment clean, planting saplings, conscious consumption). In addition, in a study conducted by Sezer and Çoban (2016) with middle school students, it was determined that one of the areas of responsibility of the students was the perception of responsibility towards the environment. On the other hand, in a case study conducted by Çam and Ünal Oruç (2014), it was revealed that science teachers did not apply student-centered teaching sufficiently, but they thought that teachers should guide the learning process and benefit from scientific inquiry and problem situations in this process. Therefore, considering the above-mentioned, it is thought that in today's world, where many environmental problems have negative impacts on life, students' attitudes towards these problems can be improved and their learning responsibilities can be increased with the help of activities based on the STEM approach.

The STEM approach has an interdisciplinary structure (Gao et al., 2020) similar to environmental education. Furthermore, STEM education is based on solving a real-world problem (English, 2016). Indeed, people today face numerous environmental problems that require solutions. In the process of finding solutions to environmental problems, individuals should effectively utilize characteristics such as creativity, critical thinking skills, collaboration, and leadership. Also, they should have individual responsibility. These characteristics also constitute the 21st-century skills targeted for development in the STEM process (Yıldırım, 2021). In these respects, it can be stated that the STEM approach and environmental education complement each other. What is more, Alkan and Yüzüak (2025) revealed that seventh-grade students thought there was a relationship between environmental issues and the STEM approach. So, that is why this study is based on the STEM approach.

### ***Purpose and importance of the study***

This study aims to reveal the effects of environmental education based on the STEM approach on seventh-grade middle school students' attitudes towards environmental problems and their responsibilities towards learning.

Although there are different studies conducted on environmental education in the literature, one of the importance of the current study is that it combines environmental education with STEM, one of the current approaches. Also, the study is carried out in a rural school with students who have relatively limited opportunities when compared to the students studying in the city centers. Thus, the study examines the effectiveness of the activities implemented on these students. In addition, while attitudes towards environmental problems are directly associated with environmental concepts in most studies in the literature, this study had a different approach by examining them in terms of cognitive, affective and behavioral components with the help of the scale used (Kılıç & Kan, 2020). Finally, in the literature, there is limited research aimed at developing students' learning responsibilities within the scope of science education (Yakar, 2017). Considering the importance of learning responsibility in terms of STEM education, it is expected that the study will contribute to the field of science education in this sense.

### ***Research questions***

The research questions of this study are as follows:

- Do STEM activities on environmental education have a significant effect on the attitudes of seventh-grade middle school students towards environmental problems?
- Do STEM activities on environmental education have a significant effect on the learning responsibility of seventh-grade middle school students?

## **Method**

### ***Research model***

In the study, a pre-experimental model, one of the quantitative research methods, was used. In this context, the research was conducted as a single group pre-test-post-test design. This model includes measurements made before and after the independent variable applied to a randomly selected group (Karasar, 2022). In the current research, there was a group of seventh-grade students, and the independent variable of the research was STEM activity applications on environmental education. The dependent variables were students' attitudes towards environmental problems and their learning responsibilities. The effectiveness of the research was examined with measurements made prior to and following the activity applications.

### ***The study group***

The study group consisted of a total of 12 seventh-grade students studying at a public middle school located in a rural area in western Türkiye in the 2023-2024 academic year. Six of the students were girls, and six were boys. The number of participants was limited because the middle school where the study was conducted was located in a village with a relatively low population and far from the city center. Also, transported education was not presented to these students to take them to schools which have more populations in their classrooms. On the other hand, considering the limited resources available to these students, the study aimed to make contributions to their learning. In this context, the study group was determined according to the easily accessible sampling approach. This approach is based on preventing the loss of time, money and labor (Büyüköztürk et al., 2010).

### ***Data collection instruments***

The data collection instruments used in this study were the "Attitude Scale Towards Environmental Problems" [ASTEP] and the "Scale of Responsibility towards Learning" [SRTL]. Quantitative data were collected with these scales. ASTEP was developed by Kılıç and Kan (2020) and aims to measure students' attitudes towards environmental problems. The researchers conducted validity (exploratory and confirmatory factor analysis) and reliability studies. Thus, the scale consists of 22 items (16 negative, 6 positive) and four factors. These factors are cognitive component, behavioral component, positive affective component and negative affective component. The Cronbach's alpha coefficient for original data obtained from the total scale was reported to be .88 whereas the Cronbach's alpha coefficients of the factors were asserted to range from .70 to .84 (Kılıç & Kan, 2020). The scale is a 5-point Likert-type scale, and the items are scored from 'strongly disagree=1' to 'strongly agree=5'. A reverse scoring is done for negative items.

SRTL was developed by Yakar and Saracaloğlu (2017) and aims to determine students' learning responsibilities. These researchers also conducted validity and reliability studies considering the scale. The scale has a single-factor structure and contains a total of 35 items. There are no negative items in the scale. In their original study, the Cronbach's alpha coefficient was reported to .94 by Yakar and Saracaloğlu

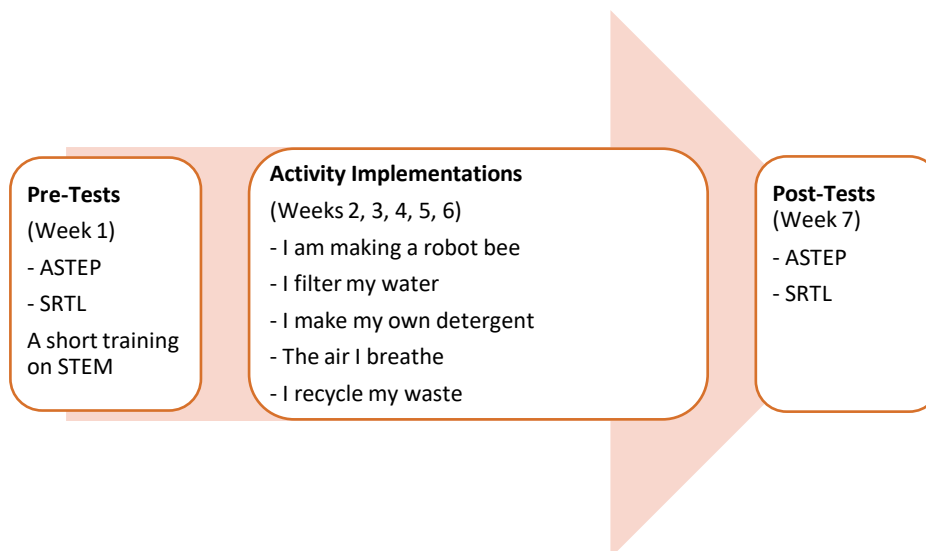
(2017). The scale items are in the 5-point Likert type, and they are scored from 'not suitable for me=1' to 'completely suitable for me=5'.

During the data collection process, students were first informed that two different scales would be administered, that these would not be used for grading purposes, and that they should respond to them in a way that aligned with their own opinions. Also, students were then given a brief explanation of how to answer the scales. Initially, the ASTEP was administered in approximately 30 minutes. Next, the SRTL was administered in a separate class period (40 minutes). Both scales were implemented in written form, under the supervision of the researcher, the first author of the study in the classroom environment of the students.

Within the scope of reliability analyses of the current study, the Cronbach's alpha value for the data obtained from the pre-test application of ASTEP was calculated to be .789, and .907 in the post-test application. The values determined for the pre-test and post-test based on factors were .874 and .840 for the negative affective component, .814 and .780 for the cognitive component, .717 and .730 for the behavioral component, and .615 and .700 for the positive affective component, respectively. The Cronbach's alpha value calculated for the pre-test data obtained from SRTL was .954 and it was determined to be .945 as a result of the post-test application.

### ***Research process***

This research was conducted in a public school in the first semester of the 2023–2024 academic year, based on the students' willingness to participate after obtaining the necessary permissions. The teaching process was carried out under the supervision of the first author of this study. The applications carried out in the research are summarized in Figure 1:



**Figure 1.** The flow of the research

The research first started with the pre-test applications of the data collection instruments. Then, the students were given a short training on STEM approach. This training took two class hours. In this process, the researcher first wrote the words "science, technology, engineering, and mathematics" on the

board and asked the students what came to their minds about these concepts. After receiving their answers, the researcher asked, "Do you know what an engineer does?". Afterwards, the researcher provided several explanations to the class and introduced the aim of the study to the students. She explained that in the coming weeks, the students would work as engineers, using their knowledge and skills from different fields to handle several environmental problems and design environmentally friendly products. Also, the researcher made a brief presentation to the students about STEM and engineering design process. Next, the groups were formed for the activities to be implemented. Accordingly, a total of three groups of four students were formed (two girls and two boys in each group). The STEM activities on environmental education were implemented in groups for five weeks. Each activity was planned to be four course hours per week and was implemented during the elective courses. The activities were developed by the researchers, considering the literature (Benek, 2019; Cocke et al., 2022; Kahraman, 2021; Kuvac, 2018) in order for students to produce solutions to environmental issues within the framework of STEM and to gain awareness on these issues. In the current study, the activities were started with striking, up-to-date and short texts on the subjects. Attention was paid to carrying out all activities with easily obtainable, recyclable and relatively affordable materials. In this context, the Cunningham engineering design process was used based on the design-based learning approach. According to this model, activities are carried out by asking questions, imagining, planning, creating and improving (Cunningham, 2009). In addition, the activities were based on the objectives of Science (MoNE, 2018a), Mathematics (MoNE, 2018b), Environmental Education and Climate Change (MoNE, 2022), Technology and Design (MoNE, 2018c), and Science Applications courses (MoNE, 2018d). These objectives are presented in Table 1 regarding each of the courses. Worksheets and lesson plans were prepared by the researchers for each activity. An example lesson plan (Appendix 1) with worksheets (Appendix 2) are presented in the Appendices.

**Table 1.** Connections of the STEM activities with the course objectives in the program.

Activities	Connections to course objectives
Activity-1: I am making a robot bee	<u>Science</u> : F.5.6.1.1. Questions the importance of biodiversity for natural life. Gives examples of plants and animals that are endangered or in danger of extinction in our country and around the world. F.5.6.1.2. Discusses the factors that threaten biodiversity based on research data. F.5.7.1.2. Establishes the diagram of the electrical circuit he/she drew.
	<u>Mathematics</u> : M.5.2.3.1. Recognizes length measurement units; converts meters-kilometers, meters-decimeters-centimeters-millimeters and solves related problems.
	<u>Environmental Education and Climate Change</u> : ÇEİD.1.6. Discusses behaviors that will negatively affect the natural balance through current examples. a) Students address behaviors that will negatively affect the natural balance in terms of environmental ethics through dilemmas. b) Students are expected to realize that they are responsible for developing attitudes and behaviors aimed at protecting the natural balance.
Activity-2: I filter my water	<u>Science</u> : F.5.6.2.1. Expresses the importance of interaction between humans and the environment. Addresses the negative effects of environmental pollution on human health. F.5.6.2.2. Offers suggestions for solving an environmental problem in the near environment or in our country. F.7.4.4.1. Chooses the most appropriate method among those that can be used to separate mixtures.
	<u>Mathematics</u> : M.6.3.5.2. Relates liquid measurement units to volume measurement units.
Activity-3:	<u>Environmental Education and Climate Change</u> : ÇEİD.3.3. Realizes that waste and garbage cause air, water, soil pollution and radioactive pollution.
	<u>Science</u> : F.5.6.2.1. Expresses the importance of interaction between humans and the environment. Addresses the negative effects of environmental pollution on human health. F.5.6.2.2. Offers suggestions for solving an environmental problem in the near environment or in our country.

I make my own detergent	<p><u>Mathematics</u>: M.4.3.5.2. Uses kilograms and grams together when measuring mass. M.6.3.5.2. Relates liquid measurement units to volume measurement units.</p> <p><u>Environmental Education and Climate Change</u>: ÇEİD.3.3. Realizes that waste and garbage cause air, water, soil pollution and radioactive pollution.</p>
Activity-4: The air I breathe	<p><u>Science</u>: F.5.6.2.1. Expresses the importance of interaction between humans and the environment. Addresses the negative effects of environmental pollution on human health. F.5.6.2.2. Offers suggestions for solving an environmental problem in the near environment or in our country. F.6.6.3.1. Discusses what needs to be done for the health of body systems based on research data.</p> <p><u>Mathematics</u>: M.5.3.1.2. Collects data related to research questions and displays it with frequency tables and column charts.</p> <p><u>Environmental Education and Climate Change</u>: ÇEİD.3.3. Realizes that waste and garbage cause air, water, soil pollution and radioactive pollution.</p>
Activity-5: I recycle my waste	<p><u>Science</u>: F.7.4.5.1. Distinguishes recyclable and non-recyclable materials in household waste. F.7.4.5.2. Designs a project for the recycling of household solid and liquid waste. F.7.4.5.3. Questions recycling in terms of effective use of resources.</p> <p><u>Mathematics</u>: M.5.2.3.1. Recognizes length measurement units; converts meters-kilometers, meters-decimeters-centimeters-millimeters and solves related problems.</p> <p><u>Environmental Education and Climate Change</u>: ÇEİD.6.4. Explains the importance of recycling and recovery in terms of sustainable development.</p>
<b>Common objectives</b>	
<p><u>Technology and Design</u>: TT.7.B.1.3. Expresses the ability to develop solutions for identified problems. TT.7.B.1.4. Explains the research steps of the design process. TT.7.B.2.1. Creates draft drawings for design.</p> <p><u>Science Applications</u>: SBU.7.3. Explains the relationship between science, technology, engineering, and mathematics. SBU.7.8. Uses interdisciplinary relationships. SBU.10.1. Applies the "engineering design and entrepreneurship process" in product creation.</p>	

The first activity of the research was 'I am making a robot bee'. This activity was started by asking questions to check students' prior knowledge about bees. Next, a text about massive bee deaths was presented to the students by emphasizing that bees were among the endangered species. So, attention was drawn to an important environmental problem. Afterwards, the students were asked to design a robot bee. As a result of the activity, the students developed mobile bee models. Each group introduced their bee model to their friends in the classroom. Figure 2 presents the models developed in this activity:



**Figure 2.** A visual of the robot bees designed by the groups

The second activity was 'I filter my water'. This activity started with reading a short news article about the pollution in the Marmara Sea and water pollution was discussed in the class. As a result of this activity, the students designed a filter that would purify the dirty water and introduced the effectiveness of this filter to their friends by testing it on different types of dirty water.

The third activity was 'I make my own detergent'. This activity aimed to draw attention to soil pollution. It started with a short story about the negative effects of the smell of detergents purchased from the markets on health. As a result of the activity, the students designed a detergent that was environmentally

friendly for cleaning and could reduce soil pollution. In addition, the students tested the detergent they developed on dirty dishes and shared with their friends how effective the detergent was in cleaning the dishes.

The fourth activity was called ‘The air I breathe’. This activity was about air pollution. It started with reading a short text about how dirty air affected a little girl’s health. In the activity, the students developed a product to determine where air pollution could be more intense. In addition, the students tested the product they developed in different places such as in the classroom, in the garden, and at their homes. In this process, students collected data on the intensity of air pollution, turned them into graphs and presented their results to their friends in class.

The final activity was called ‘I recycle my waste’. This activity began with a short text on the locust invasion. The relationship between this situation and the environment was discussed in the class in addition to brainstorming about what students could do individually. In the activity, students designed products that they could use in their daily lives by using various waste materials and natural products accumulated at their homes. They introduced their designs such as candle holder, pencil box and storage box they developed to their friends.

Following the activities, the post-test applications of the data collection instruments were carried out in the end of the research.

### **Data analysis**

The analysis of the data collected in the study was carried out using the Statistical Package for Social Sciences [SPSS] 22.0 program. All the analyses were conducted at .05 significance level. In this context, first, normality analyses of the data sets were performed on the difference of pre- and post-test scores. Since the number of participants in the data sets was below 50, the Shapiro-Wilk test results were taken into account (Büyüköztürk, 2010). Accordingly, if the  $p$  value obtained is greater than .05, it is interpreted that the data set is normally distributed. In addition, the skewness and kurtosis coefficients of the data sets were also calculated. The fact that these coefficients are between -2 and +2 indicates normal distribution (Tabachnick & Fidell, 2013). Table 2 presents normality analysis results of the score differences of data sets obtained in the study:

**Table 2.** Results regarding normality analyses of data collected in the study.

Scale	Factor	Shapiro-wilk test			Kurtosis	Skewness
		Statistics	df	p		
ASTEP	Total scale	.946	12	.576	-1.031	0.212
	Negative affective component	.834	12	.024	0.043	1.232
	Cognitive component	.913	12	.232	-0.325	0.806
	Behavioral component	.832	12	.022	0.875	1.298
	Positive affective component	.964	12	.839	0.049	-0.441
SRTL	Total scale	.898	12	.197	-0.927	0.687

According to Table 2, it is seen that the  $p$  values for the score differences in the applications of the total of ASTEP, its cognitive component and positive affective component as well as the total STRL are greater than .05, thus providing a normal distribution. On the other hand, it was determined that the  $p$  values

for the score differences obtained from the applications of negative affective component and behavioral component of ASTEP are less than .05. However, when the kurtosis and skewness coefficients of all the data sets are taken into consideration, it is seen that they are in the range of -2 and +2 (Tabachnick & Fidell, 2013). Hence, despite the limited number of participants in the study, the data sets were found to fall within the normal distribution limits. Therefore, the t-test for related samples from parametric tests was used in the analyses performed to compare the scores of the students before and after the applications (Büyüköztürk, 2010). Similarly, the literature also utilizes the t-test in pre-test-post-test comparisons conducted on a single group (n=10/11/12) with a limited number of individuals (Atasever, 2023; Güzel & Çeçen, 2022; Karanlık, 2024). Furthermore, although the use of nonparametric tests is generally emphasized when working with small samples, de Winter (2013) demonstrates in his study that there is no obstacle to using the t-test even with extremely small samples ( $n \leq 5$ ).

The effect size, Cohen-d was calculated in cases where a significant difference was detected in the results of the analyses. In this direction, the Cohen-d values are interpreted as small for 0.2, medium for 0.5, and large for 0.8 and above (Cohen, 1988).

## Findings

### *Findings regarding students' attitudes towards environmental problems*

The findings obtained from the comparison of students' responses to the ASTEP between the pre-test and post-test applications using the t-test for related samples are given in Table 3.

**Table 3.** Comparison of students' attitudes towards environmental problems.

Scale / Factor	Application	$\bar{X}$	N	s	df	t	p	Cohen-d
Total scale	Pre-test	75.92	12	11.89	11	4.385	.001*	1.27
	Post- test	90.58	12	12.21				
Negative affective component	Pre- test	28.17	12	4.86	11	0.857	.410	-
	Post- test	29.92	12	5.79				
Cognitive component	Pre- test	18.25	12	4.67	11	4.342	.001*	1.25
	Post- test	22.25	12	3.47				
Behavioral component	Pre- test	14.50	12	5.05	11	2.504	.029*	0.72
	Post- test	18.75	12	2.45				
Positive affective component	Pre- test	15.00	12	3.64	11	3.602	.004*	1.04
	Post-test	19.83	12	3.10				

According to Table 3, as a result of the STEM activities implemented, it was determined that the attitudes of the students towards environmental problems showed a statistically significant increase, ( $t(11)=4.385, p<.05$ ). In addition, the effect value, Cohen-d was determined as 1.27. Accordingly, the education provided a large effect on student attitudes. Similarly, it was determined that the cognitive component ( $t(11)=4.342, p<.05$ ), behavioral component ( $t(11)=2.504, p<.05$ ), and positive affective component ( $t(11)=3.602, p<.05$ ) of student attitudes increased statistically significantly. The Cohen-d values calculated related to these factors were 1.25, 0.72 and 1.04, respectively. Hence, the education process provided a large effect on the cognitive and positive affective components of the attitudes similar to the

results obtained from the overall scale. Also, a medium effect was obtained on the behavioral component of students' attitudes. On the other hand, although there was a slight increase from pre ( $\bar{X}= 28.17$ ,  $s= 4.86$ ) to post-test ( $\bar{X}= 29.92$ ,  $s= 5.79$ ) in the negative affective component of the attitudes, it was determined that this did not create a statistically significant difference, ( $t(11)= 0.857$ ,  $p>.05$ ).

### ***Findings regarding students' responsibilities for learning***

The findings obtained from the comparison of students' responses to the SRTL between the pre-test and post-test applications using the t-test for related samples are presented in Table 4.

**Table 4.** Comparison of students' responsibilities for learning.

<b>Application</b>	<b><math>\bar{X}</math></b>	<b>N</b>	<b>s</b>	<b>df</b>	<b>t</b>	<b>p</b>	<b>Cohen-d</b>
Pre-test	123.75	12	29.63	11	3.366	.006*	0.97
Post-test	139.92	12	20.64				

Table 4 shows that there was a statistically significant increase in students' responsibilities for learning, ( $t(11)= 3.366$ ,  $p<.05$ ). In addition, it is seen that the Cohen-d effect size was calculated as 0.97. This value also indicates that STEM-based environmental education had a large effect on students' responsibilities for learning similarly to previous findings.

### **Discussion, Conclusion and Recommendations**

This study addresses the effectiveness of a STEM education program developed to deal with several environmental issues for seventh-grade students at a rural middle school in western Türkiye. The study has also been linked to the learning responsibility, an important skill that individuals should possess today. Thus, the impact of students' efforts to generate solutions to the environmental problems through the engineering design process on their attitudes towards environmental problems and their responsibility for learning was investigated. As a result of the STEM activities implemented in this study, significant improvements were achieved in students' attitudes towards environmental problems and their learning responsibilities. The problems such as air, water, and soil pollution, biodiversity and waste materials were addressed in the study. These are current problems and are also among the issues that pre-service teachers wanted to improve themselves in the study of Kuvaç (2018). With the help of the method followed in this study, the planned activities are quite effective on seventh-grade middle school students. The significant improvements obtained in students' attitudes towards environmental problems are well-matched with the positive results determined in environmental education studies based on the STEM approach in the literature (Alkan & Yüziak, 2025; Başaran & Erol, 2023; Helvaci & Helvaci, 2019; Kocak et al., 2023; Koculu & Girgin, 2022; Pertiwi et al., 2024; Tadena & Salic-Hairulla, 2021; Tramonti et al., 2024; Widiyanti & Suyanto, 2025). Furthermore, considering that one of the goals of STEM education is to develop students' 21st-century skills (Bybee, 2010), the significant improvements in students' learning responsibility in the current study are also consistent with this goal.

As mentioned before, in this study, the attitudes of middle school students towards environmental problems were examined in terms of 'cognitive', 'affective' (positive and negative) and 'behavioral' factors with the scale developed by Kılıç and Kan (2020). Thus, it can be stated that the current study involved different dimensions of the attitudes than the studies of Aksu (2009), Güven (2013), and Özgen (2012). On the other hand, while the changes in the total attitude scores of both university students (Güven, 2014) and middle school students (Özgel et al., 2018) towards environmental problems as a result of environmental education are discussed, it is noteworthy that these changes are not examined on a factor basis. Therefore, the study is expected to contribute to the literature.

In the current study, significant improvements were obtained in students' total attitudes towards environmental problems as well as in their cognitive, behavioral and positive affective attitudes. This result can be associated with the study focusing on different types of environmental problems in each week of the teaching process. Thus, students were allowed to design products related to various environmental problems and it was aimed to develop students' attitudes with different problem situations. Similarly, Dallı (2019) designed a STEM-based teaching program for the eighth-grade students on matter cycles and environmental problems, and within the scope of this research, the experimental group students developed products that would reduce environmental pollution. In the mentioned research, different topics such as carbon, oxygen, water and nitrogen cycles, greenhouse effect, ozone layer, global climate change and ecological footprint calculation were discussed in the seven-week period. Alkair et al. (2023) also conducted four STEM-supported workshops with the fourth-grade students, and in these workshops, they addressed the subjects of being environmentally friendly, waste, water pollution, and rising temperature on Earth. In the workshops, students followed the engineering design steps and produced prototypes and posters. On the other hand, there are also studies that address only one issue based on STEM instead of multiple environmental issues. For example, Tanrıverdi (2021) conducted activities with the fourth-grade students on light pollution. The researcher concluded that problem-based STEM activities were effective in improving students' light pollution awareness and academic achievement. Besides, Çimen (2021) conducted activities with the seventh-grade students on household waste and recycling. This researcher also concluded that problem-based STEM activities increased students' awareness of household waste and recycling as well as increasing their academic achievement. Besides, the researcher noted that students' participation in class increased and that the classroom created an enjoyable learning environment. In another study, Doğru (2020) conducted activities with the sixth-grade students on waste materials and recycling. As a result of the design-based STEM activities, this researcher determined a significant improvement in students' STEM attitudes. Furthermore, the researcher observed that students' perceptions of recycling improved and that they enjoyed STEM activities.

In this study, it might be asserted that the significant increase in the students' cognitive attitudes is consistent with the research results in the literature showing increases in the students' environmental awareness (Çimen, 2021; Tanrıverdi, 2021), consciousness (Bulduz et al., 2018; Yavuz, 2020) and environmental literacy (Kocak et al., 2023) with the help of STEM education. In addition, Alkair et al. (2023) obtained significant improvements in students' understanding of environmental problems as a result of four different STEM-supported environmental activities they carried out. In the current study, students' cognitive attitudes were supported with the help of the cases such as the significance of bees in the

ecosystem, locust invasions, and respiratory difficulties experienced by young children presented to the students with the help of texts. Another result of the study which indicated a significant increase in the students' behavioral attitudes might be associated with the literature stating that students' behaviors towards the environment improve with various environmental education practices (Hsu, 2004; Kaya-Capocci et al., 2025; Kuvaç, 2018; Mete & Filik İşçen, 2015). For example, Mete and Filik İşçen (2015) determined that students exhibited behaviors in line with creating a clean and green environment as a result of the environmental club activities they conducted with middle school students. In the current study, students personally experienced the negative effects of environmental problems through both the texts they read and the measurements they made. In this context, students took actions to eliminate these problems by filtering dirty water, developing nature-friendly detergents that would clean dirty dishes in the best way, and transforming waste products into new and useful forms. Therefore, it is quite natural that these experiences gained by the students are reflected in their behavioral attitudes. Another finding similar to this result is that after the STEM training conducted by Kaya-Capocci et al. (2025) with high school students, the students faced problem situations to solve them instead of avoiding them and integrated these skills into their daily lives. Moreover, the study yielded a significant development in the positive affective attitudes of the students. This result might be related to the significant increases in students' attitudes towards the environment (Çalışıcı, 2018; Demir, 2021; Kuvaç, 2018) and affective tendencies towards the environment (Buldur et al., 2018) in studies on the environment and STEM. All of these studies support the results obtained from the current study.

In contrast to the above-mentioned positive results regarding attitudes towards environmental problems, no significant development was detected in the negative affective component of student attitudes. This component of attitudes towards environmental problems consists entirely of negative expressions and is distinguished from other components by its structure. The implemented activities did not have an effect that would create a significant difference in the responses of students to the items in this component. In addition, it is seen that the score difference determined as a result of the applications in this factor was the lowest compared to other factors. In contrast, in the research conducted by Muñoz-García et al. (2022), where they examined adults' attitudes towards the environment in terms of cognitive, affective and behavioral aspects, it was found that the highest attitudes were gathered under the affective factor. However, it is seen that all the items under the affective factor in the scale used by these researchers are positively expressed. In the current study, the result obtained from this factor, which measures negative affective attitudes, unlike the positive affective component, can be associated with the fact that students show similar reactions to negative expressions before and after the instruction. Therefore, it is thought that the reasons for this situation can be examined from different perspectives by examining the negative attitudes in more detail with different data collection instruments.

Another variable focused on in the study and yielded positive results is the students' learning responsibilities. In the STEM-based environmental education provided in this study, students answered the questions asked by their teacher and brainstormed with their group friends. In addition, by distributing tasks during group work, students completed their duties and responsibilities willingly and participated in the activities with pleasure. They fulfilled the responsibilities given to them both in the classroom and as homework. Thus, in this process, students both worked individually and interacted with their friends.

Therefore, it can be stated that all of these were positively reflected on the students' learning responsibilities. Besides, in a study of Stefanidou et al. (2024) which investigated the views of Greek primary school students in terms of STEM, students studying in rural areas were determined to have significantly higher scores in helping classmates and taking into account their opinions compared to the students in urban areas. Coffman (2003) lists what teachers should do to develop students' learning responsibility as drawing attention to their active participation in the lesson, group work, and use of high-level cognitive skills. In this study, it is thought that there is a connection between the work students do in teams and their learning responsibilities. This situation is also emphasized in other studies conducted with students in face-to-face learning environments in the literature (Ayish & Deveci, 2019; Sasson & Yehuda, 2023). In addition, the relationship between group work and learning responsibility is emphasized during hybrid education practices (Kumaş, 2023).

In the literature, several studies support the finding that STEM activities carried out with the seventh-grade students for five weeks in the current study improved students' learning responsibilities. For example, Yakar (2017) made contributions to the sixth-grade students' learning responsibilities, motivation for learning science, and science achievement with the help of learning tasks he used in science class in his action research. Sasson and Yehuda (2023) created innovative learning environments for high school students within the framework of the constructivist approach and developed students' learning motivation and individual learning responsibilities by having them work in groups during the day. In addition, Gömleksiz et al. (2011) examined the effects of activities in the third, fourth, and fifth-grade student workbooks on students' learning responsibilities according to the opinions of teachers teaching at these grade levels. As a result of the study, it was revealed that teachers found these activities 'very effective', but it is noteworthy that teachers found no feature that they thought was 'completely effective'. Therefore, it can be stated that appropriate methods, activities and materials should be developed to enhance students' learning responsibilities. On the other hand, a study conducted with engineering students revealed that students viewed their individual learning responsibilities superior to group learning responsibilities (Ayish & Deveci, 2019). This situation suggests that students' level of education may have different effects on their learning responsibilities. The university education process and the concerns students experience such as postgraduate education and getting a good job may produce different results in their perception of learning responsibilities compared to students at the middle school level. Therefore, the reasons for this situation can be addressed in the future studies elaborately.

In addition to the aforementioned, several difficulties, which can be associated with students' learning responsibilities, were encountered during the research process. First, it was observed that, despite the increase in students' learning responsibilities, they did not bring several materials they were asked to use in classroom activities to the classroom. Instead, these were provided by one of the researchers. Another difficulty encountered in the study was the students' reluctance to complete the worksheets requiring written responses. Similar situations were also encountered by the researchers or teachers in other science education research (Tuti & Terzi, 2025; Yıldız et al., 2025). So, specific precautions might be taken to develop students' responsibilities in the forthcoming studies. For example, small prizes might be given to the students to trigger their in-class performances by their teachers.

Finally, the results obtained from this study were acquired from a group of students living and attending a governmental school in a rural village far from the city center. The impact of a similar practice on students studying in urban centers could be examined in future studies. Indeed, Stefanidou et al. (2024) determined that although both students living in rural and urban areas perceived themselves as competent in science and mathematics, students living in rural areas were found to be more sensitive to environmental issues than the students in urban areas. Furthermore, these researchers found that female students were more aware of this issue than male students. Therefore, further studies could address the gender effect and offer enriched results for the literature.

The following suggestions are put forward as a result of the research:

- Similar STEM activities on the environment can be implemented at all grade levels of middle schools and their effectiveness can be examined from different perspectives such as academic achievement.
- Considering the importance of learning responsibility in STEM and science education, various tasks such as writing a daily reflection of their science learning or bringing a simple material to be observed in class can be given to the students in order to enhance their learning responsibilities and its effects can be examined in a planned manner.
- More detailed results might be obtained from semi-structured interviews which directly focus on the change in students' attitudes toward environmental problems and their learning responsibilities. Thus, studies with mixed method might supply qualitative data as well as quantitative data. In here, further research might specifically deal with the attitudinal dimensions remaining unchanged (such as negative affective dimension in the present study).
- The change in students' attitudes and learning responsibilities as a result of the activity applications can be examined through larger groups. Besides, multi-factor research designs can be utilized to research the impact of the gender variable in this context. Thus, necessary measures can be taken to develop students' attitudes or learning responsibilities in a better way.
- STEM education on different subjects can be carried out with larger samples, especially in schools far from the city center and which can be considered disadvantaged in various respects. Thus, students' interest and motivation in STEM disciplines can be increased and these students can be encouraged to have a career in STEM fields in the future. Additionally, a similar study can be conducted with students living and studying in the city center and the research results can be compared.

## **Limitations**

As a limitation of this study, it can be stated that it focused on the attitudes towards environmental problems and learning responsibilities; however, student achievement was excluded from the study. On the other hand, there are studies indicating significant improvements in students' academic achievement as a result of STEM-based applications (Çalışıcı, 2018; Çimen, 2021; Doppelt et al., 2008; Guzey et al., 2016; Schnittka & Bell, 2011). Moreover, it is believed that a rise in students' learning responsibilities might

contribute positively to their academic success. Therefore, it is thought that this situation can be focused on in the future studies. Also, the current study did not involve any qualitative data describing the change in students' attitudes or learning responsibilities in a more detailed way. Besides, a key limitation of the study is that the study group involved a limited number of students due to the location and status of the place the students live. Thus, the findings are restricted to the quantitative data collected from a relatively small number of participants. Also, the results indicated large effects considering the Cohen-d values. On the other hand, it is stated that Cohen's d can increase rapidly when the sample size is limited as in the present case (Fritz et al., 2012). Hence, as stated in the suggestions, conducting applications with larger samples might provide more enhanced results for the field. In addition, Özbulat (2020) stated that female students' learning responsibilities are higher than male students, while Ayish and Deveci (2019) and Kitsantas and Zimmerman (2009) revealed that there is no such difference in students' learning responsibilities in terms of gender. Since the study group in this study consisted of a limited number of participants, such an analysis could not be conducted in the study. However, it is thought that through further studies to be conducted with a larger group of participants, such comparisons can be made and particular findings can be presented to the literature.

## Declarations

**Ethical statement:** Before collecting the research data within the scope of the research, permission dated 28/02/2023 and numbered E-19928322-108.01-235811 (2023/01 meeting) was obtained from Balıkesir University, Science and Engineering Sciences Ethics Committee and the permission dated 04/10/2023 and numbered 86143955 was obtained from Balıkesir Provincial Directorate of National Education.

**Conflict of interest:** The author(s) have no conflicts of interest.

**Data availability:** Data are available upon request from the authors.

## References

- Ajiboye, J.O., & Silo, N. (2008). Enhancing Botswana children's environmental knowledge, attitudes and practices through the school civic clubs. *International Journal of Environmental and Science Education*, 3(3), 105-114.
- Aksu, Y. (2009). *Fen ve teknoloji ile sınıf öğretmenlerinin çevre sorunlarına yönelik tutumlarının belirlenmesi (Burdur ili örneği) [The determination of the science and technology and primary school teachers attitudes towards environmental issues (Sample of Burdur province)]*. [Unpublished master's thesis]. Süleyman Demirel University, Institute of Applied and Natural Sciences.
- Alkair, S., Ali, R., Abouhashem, A., Aledamat, R., Bhadra, J., Ahmad, Z., Sellami, A., & Al-Thani, N.J. (2023). A STEM model for engaging students in environmental sustainability programs through a problem-solving approach. *Applied Environmental Education & Communication*, 22(1), 13-26. <https://doi.org/10.1080/1533015X.2023.2179556>
- Alkan, R., & Yüzüak, A.V. (2025). 7. sınıf öğrencilerinin geri dönüşümüne ilişkin STEM etkinliklerine yönelik görüşlerinin incelenmesi [Seventh-grade students' views on recycling-focused STEM

- activities]. *Anadolu Kültürel Araştırmalar Dergisi*, 9(1), 91-118. <https://doi.org/10.15659/jancr.v9i1.217>
- Ardoin, N.M., Bowers, A.W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation*, 241, 108224. <https://doi.org/10.1016/j.biocon.2019.108224>
- Atasever, A.N. (2023). Kariyer planlama psikoeğitim programı'nın üniversite öğrencilerinin kariyer geleceği'ne etkisi [The impact of the career planning psychoeducation program on the career future of university students]. *Rahva Teknik ve Sosyal Araştırmalar Dergisi*, 3(1), 45-57.
- Ayish, N., & Deveci, T. (2019). Student perceptions of responsibility for their own learning and for supporting peers' learning in a project-based learning environment. *International Journal of Teaching and Learning in Higher Education*, 31(2), 224-237.
- Basile, C.G. (2000). Environmental education as a catalyst for transfer of learning in young children. *The Journal of Environmental Education*, 32(1), 21-27. <https://doi.org/10.1080/00958960009598668>
- Başaran, M., & Erol, M. (2023). Recognizing aesthetics in nature with STEM and STEAM education. *Research in Science & Technological Education*, 41(1), 326-342. <https://doi.org/10.1080/02635143.2021.1908248>
- Benek, İ. (2019). *Sosyobilimsel STEM etkinliklerinin öğrencilerin tutumlarına ve 21. yüzyıl becerilerine etkisinin incelenmesi [Examination of the effect of socioscientific STEM's activities on students' attitudes and 21st century skills]*. [Unpublished PhD dissertation]. İstanbul University-Cerrahpaşa, Institute of Graduate Studies.
- Borg, F., Winberg, T.M., & Vinterek, M. (2019). Preschool children's knowledge about the environmental impact of various modes of transport. *Early Child Development and Care*, 189(3), 376-391. <https://doi.org/10.1080/03004430.2017.1324433>
- Buldur, S., Bursal, M., Yücel, E., & Yalçın Erik, N. (2018). Disiplinler arası bir doğa eğitimi projesinin ortaokul öğrencilerinin çevreye yönelik duyuşsal özelliklerine ve çevre bilinçlerine etkisi [The impact of an interdisciplinary nature education project on environmental attitudes and environmental consciousness of secondary school students]. *İnsan ve Toplum Bilimleri Araştırmaları Dergisi*, 7(5), 284-303. <https://doi.org/10.15869/itobiad.498087>
- Büyüköztürk, Ş. (2010). *Sosyal bilimler için veri analizi el kitabı [Handbook for data analysis in social sciences]* (29<sup>th</sup> Edition). Pegem Akademi Yayınları.
- Büyüköztürk, Ş., Akgün, Ö.E., Demirel, F., Karadeniz, Ş., & Çakmak, E.K. (2010). *Bilimsel araştırma yöntemleri [Scientific research methods]*. Pegem Akademi Yayınları.
- Bybee, R.W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 70(1), 30.
- Carpenter, J.P., & Steinberger Pease, J. (2013). Preparing students to take responsibility for learning: The role of non-curricular learning strategies. *Journal of Curriculum and Instruction*, 7(2), 38-55. <https://doi.org/10.3776/joci.2013.v7n2p38-55>
- Cinzano, P., & Falchi, F. (2014). Quantifying light pollution. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 139, 13-20. <http://dx.doi.org/10.1016/j.jqsrt.2013.11.020>
- Cocke, T.E., Geest, E.A., & Shufan, A.A. (2022). Learning about mosquitoes, diseases, and vectors: a classroom activity. *Science Activities*, 59(3), 142-150. <https://doi.org/10.1080/00368121.2022.2071816>
- Coffman, S.J. (2003) Ten strategies for getting students to take responsibility for their learning. *College Teaching*, 51(1), 2-4. <https://doi.org/10.1080/87567550309596401>
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Erlbaum.

- Cunningham, C.M. (2009). Engineering is elementary. *The Bridge*, 30(3), 11-17.
- Çalışıcı, S. (2018). *FETEMM uygulamalarının 8. sınıf öğrencilerinin çevresel tutumlarına, bilimsel yaratıcılıklarına, problem çözme becerilerine ve fen başarılarına etkisi [The effects of STEM applications on the environmental attitudes of the 8th year students, scientific creativity, problem solving skills and science achievements]*. [Unpublished master's thesis]. Gazi University, Institute of Educational Sciences.
- Çam, S.S., & Ünal Oruç, E. (2014). Learning responsibility and balance of power. *International Journal of Instruction*, 7(1), 5-16.
- Çınar, O., Teyfur, E., & Teyfur, M. (2006). İlköğretim okulu öğretmen ve yöneticilerinin yapılandırmacı eğitim yaklaşımı ve programı hakkındaki görüşleri [Primary school teachers and administrators' views about constructivist education approach and programs]. *İnönü Üniversitesi Eğitim Fakültesi Dergisi*, 7(11), 47-64.
- Çimen, B. (2021). *Eysel atıklar ve geri dönüşüm konusunda uygulanan probleme dayalı STEM etkinliklerinin öğrencilerin akademik başarı ve farkındalığı üzerindeki etkisi [The effect of problem-based STEM activities applied in domestic waste and recycling subject on students' academic achievement and awareness]*. [Unpublished master's thesis]. Ordu University, Institute of Natural and Applied Sciences.
- Dallı, A. (2019). *Madde döngüleri ve çevre sorunları konusunda STEM yaklaşımına dayalı öğretim tasarımı [Instructional design based on STEM approach on substance cycles and environmental problems]*. [Unpublished master's thesis]. Bursa Uludağ University, Institute of Educational Sciences.
- Demir, H. (2021). *Doğada STEM etkinliklerinin 7. sınıf öğrencilerinin çevresel tutumlarına, bilimsel yaratıcılıklarına, yansıtıcı düşünme becerilerine, STEM meslek alan ilgilerine ve tutumlarına etkisi [The effect of STEM activities in nature on 7th grade students' environmental attitudes, scientific creativity, reflective thinking skills, STEM occupational interests and attitudes]*. [Unpublished master's thesis]. Alanya Alaaddin Keykubat University, Graduate Education Institute.
- Devlin, M. (2002). Taking responsibility for learning isn't everything: A case for developing tertiary students' conceptions of learning. *Teaching in Higher Education*, 7(2), 125-138. <https://doi.org/10.1080/13562510220124231>
- de Winter, J.C. (2013). Using the student's *t*-test with extremely small sample sizes. *Practical Assessment, Research & Evaluation*, 18(10), 10.
- Doğru, C. (2020) *Atık malzemelerle yapılan STEM etkinliklerinin ortaokul öğrencilerinin çevresel farkındalık ve geri dönüşüm algısına etkisi [The effect of STEM activities made of waste materials on environmental awareness and recycling perception of secondary school students]*. [Unpublished master's thesis]. Erzincan Binali Yıldırım University, Graduate School of Natural and Applied Sciences.
- Doppelt, Y., Mehalik, M.M., Schunn, C.D., Silk, E., & Krysiniski, D. (2008). Engagement and achievements: A case study of design-based learning in a science context. *Journal of Technology Education*, 19(2), 22-39.
- English, L.D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education*, 3(1), 3. <https://doi.org/10.1186/s40594-016-0036-1>
- Erişti, B. (2017). Development of a learning responsibility scale. *Necatibey Faculty of Education Electronic Journal of Science & Mathematics Education*, 11(1), 481-503.
- Erten, S. (2004). Çevre eğitimi ve çevre bilinci nedir, çevre eğitimi nasıl olmalıdır? [What is environmental education and environmental consciousness, how should be the environmental education?]. *Çevre ve İnsan Dergisi*, 65/66, 1-13.

- Feinberg, M., & Willer, R. (2013). The moral roots of environmental attitudes. *Psychological Science*, 24(1), 56-62. <https://doi.org/10.1177/0956797612449177>
- Fritz, C.O., Morris, P.E., & Richler, J.J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General*, 141(1), 2-18. <https://doi.org/10.1037/a0024338>
- Gao, X., Li, P., Shen, J., & Sun, H. (2020). Reviewing assessment of student learning in interdisciplinary STEM education. *International Journal of STEM Education*, 7(1), 24. <https://doi.org/10.1186/s40594-020-00225-4>
- Ghadiri Khanaposhtani, M., Liu, C.J., Gottesman, B.L., Shepardson, D., & Pijanowski, B. (2018). Evidence that an informal environmental summer camp can contribute to the construction of the conceptual understanding and situational interest of STEM in middle-school youth. *International Journal of Science Education, Part B*, 8(3), 227-249. <https://doi.org/10.1080/21548455.2018.1451665>
- Gömlüksiz, M.N., Kılınc, H.H., & Cüro, E. (2011). Öğrenci çalışma kitaplarında yer alan etkinliklerin öğrenme sorumluluğunu geliştirmeye etkisi [The effect of constructive instructional activities in student workbooks on developing students' responsibility towards learning]. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi (KEFAD)*, 12(4), 119-141.
- Guzey, S.S., Moore, T.J., Harwell, M., & Moreno, M. (2016). STEM integration in middle school life science: student learning and attitudes. *Journal of Science Education and Technology*, 25(4), 550-560. <https://doi.org/10.1007/s10956-016-9612-x>
- Gürer, A. (2018). *Yetişkinler, çevresel faktörler ve bilimsel bilgiye ulaşma araçları arasındaki ilişkilerin incelenmesi [The investigation of the relationships among adults, environmental factors and the tools used to reach scientific knowledge]*. [Unpublished master's thesis]. Marmara University, Institute of Educational Sciences.
- Güven, E. (2014). Tahmin-gözlem-açıklama destekli proje tabanlı öğrenme yönteminin çevre sorunlarına yönelik tutum ve davranışlara etkisi. *Eğitim ve Bilim*, 39(173), 25-38.
- Güven, E. (2013). Çevre sorunlarına yönelik tutum ölçeğinin geliştirilmesi ve öğretmen adaylarının tutumlarının belirlenmesi [Development of environmental problems attitude scale and determination of teacher candidates' attitudes]. *Gazi Üniversitesi Gazi Eğitim Fakültesi Dergisi*, 33(2), 411-430.
- Güzel, N.C., & Çeçen, A.R. (2022). Sistemik aile yaklaşımı temelli grup psikoeğitim programının boşanmış bireylerin boşanmaya uyum düzeylerine etkisi [The effect of the systemic family approach based group psychoeducation program on the adaptation level of divorced individuals]. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi*, 64, 127-151.
- Hall, L. (2014). The history of space debris. *Space Traffic Management Conference*. 19. <https://commons.erau.edu/stm/2014/thursday/19>
- Helvaci, S.C., & Helvaci, I. (2019). An interdisciplinary environmental education approach: Determining the effects of E-STEM activity on environmental awareness. *Universal Journal of Educational Research*, 7(2), 337-346. <https://doi.org/10.13189/ujer.2019.070205>
- Hsu, S-J. (2004). The effects of an environmental education program on responsible environmental behavior and associated environmental literacy variables in Taiwanese college students. *The Journal of Environmental Education*, 35(2), 37-48. <https://doi.org/10.3200/JOEE.35.2.37-48>
- İbiş, S. (2009). *Biyoloji öğretmen adaylarının küresel ve ulusal çevre sorunları hakkındaki görüşleri [Opinions of biology pre service teacher about national and global environmental problems]*. [Unpublished master's thesis]. Gazi University, Institute of Educational Sciences.

- Kahraman, E. (2021). *STEM eğitiminin ortaokul öğrencilerinin STEM mesleklerine yönelik ilgilerine, bilimsel yaratıcılıklarına ve fen öğrenmeye yönelik motivasyonlarına etkisinin araştırılması [Investigation of the effect of STEM education on middle school students' interest in STEM professions, scientific creativity and motivation for science learning]*. [Unpublished PhD dissertation]. Gazi University, Graduate School of Educational Sciences.
- Kamil, P.A., Putri, E., Ridha, S., Utaya, S., & Utomo, D.H. (2020, May). Promoting environmental literacy through a green project: A case study at Adiwiyata School in Banda Aceh City. *IOP Conference Series: Earth and Environmental Science*, 485(1), 012035. IOP Publishing. <https://doi.org/10.1088/1755-1315/485/1/012035>
- Karanlık, M.N. (2024). *Problem temelli yaratıcı düşünme etkinliklerinin çocukların yaratıcı düşünme becerilerine olan etkisi [The effect of problem-based creative thinking activities on children's creative thinking skills]*. [Unpublished master's thesis]. Marmara University, Institute of Educational Sciences.
- Karasar, N. (2022). *Bilimsel irade algı çerçevesi ile bilimsel araştırma yöntemi: Kavramlar, ilkeler, teknikler [Scientific research method with scientific will perception framework: Concepts, principles, techniques]* (37<sup>th</sup> Edition). Nobel Akademik Yayıncılık.
- Kaya-Capocci, S., Pabuccu-Akis, A., & Orhan-Ozteber, N. (2025). Entrepreneurial STEM education: Enhancing students' resourcefulness and problem-solving skills. *Research in Science Education*, 55(1), 103-134. <https://doi.org/10.1007/s11165-024-10189-y>
- Kılıç, Ç., & Kan, A. (2020). Çevre sorunlarına yönelik tutum ölçeği geliştirme çalışması [A study on developing attitude scale towards environmental problems]. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi*, 20(4), 1676-1690. <https://dx.doi.org/10.17240/aibuefd.2020.20.58249-540945>
- Kitsantas, A., & Zimmerman, B.J. (2009). College students' homework and academic achievement: The mediating role of self-regulatory beliefs. *Metacognition and Learning*, 4, 97-110. <https://doi.org/10.1007/s11409-008-9028-y>
- Kocak, E., Yalcin-Celik, A., & Uluyol, C. (2023). Pre-service teachers' environmental literacy: The role of STEM-based environmental education with microcontrollers. *Participatory Educational Research (PER)*, 10(5), 233-247. <http://dx.doi.org/10.17275/per.23.84.10.5>
- Koculu, A., & Girgin, Ş., (2022). The effect of E-STEM education on students' perceptions and engineering design process about environmental issues. *World Journal of Education*, 12(6), 49-55.
- Kumaş, A. (2023). Fen bilimleri derslerinde hibrit eğitim kapsamında aktif öğrenme aracı olarak teknolojinin kullanımı [The use of technology as an active learning tool in the scope of hybrid education in science courses]. *Trakya Eğitim Dergisi*, 13(2), 943-961. <https://doi.org/10.24315/tred.1100907>
- Kuvaç, M. (2018). *Fen, teknoloji, mühendislik ve matematik (STEM) temelli çevre eğitime yönelik öğretim tasarımının etkililiği [The effectiveness of instructional design on science, technology, engineering and mathematics (STEM) based environmental education]*. [Unpublished PhD dissertation]. İstanbul University-Cerrahpaşa, Institute of Graduate Studies.
- Lee, K. (2009). Gender differences in Hong Kong adolescent consumers' green purchasing behavior. *Journal of Consumer Marketing*, 26(2), 87-96. <https://doi.org/10.1108/07363760910940456>
- Meredith, J., Cantrell, D., Conner, M., Evener, B., Hunn, D., & Spector, P. (2000). *Best practices for environmental education: Guidelines for success*. A project of Ohio EE 2000, Ohio, USA: Environmental Education Council of Ohio. <https://files.eric.ed.gov/fulltext/ED472040.pdf>

- Mete, A., & Filik İşçen, C. (2015). İlköğretim öğrencilerinin çevreye yönelik bilgi ve tutumlarına çevre koruma kulübü'nün etkisi [The effects of the environmental club on secondary school students' environmental attitudes and knowledge]. *Turkish Studies*, 10/11, 1145-1164. <https://doi.org/10.7827/TurkishStudies.8688>
- Ministry of National Education [MoNE]. (2022). *Çevre eğitimi ve iklim değişikliği dersi öğretim programı (Ortaokul 6, 7 veya 8. sınıflar) [Environmental education and climate change course teaching program (Middle school grades 6, 7 or 8)]*. Ankara. <https://mufredat.meb.gov.tr/Dosyalar/202244102710628-2022-10-cevre-egitimi-iklim-degisikligi-ogretim-programi-web.pdf>
- Ministry of National Education [MoNE]. (2018a). *Fen bilimleri dersi öğretim programı (İlkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. sınıflar) [Science course teaching program (Primary and middle school grades 3, 4, 5, 6, 7 and 8)]*. Ankara. <https://mufredat.meb.gov.tr/Dosyalar/201812312311937-FEN%20B%C4%B0L%20MÖL%20C3%96%C4%9ERET%20PROGRAMI2018.pdf>
- Ministry of National Education [MoNE]. (2018b). *Matematik dersi öğretim programı (İlkokul ve ortaokul 1, 2, 3, 4, 5, 6, 7 ve 8. sınıflar) [Mathematics course teaching program (Primary and middle school grades 1, 2, 3, 4, 5, 6, 7 and 8)]*. Ankara. [https://ardahanodm.meb.gov.tr/meb\\_iys\\_dosyalar/2019\\_09/27114237\\_201813017165445-MATEMATYK\\_OYRETYM\\_PROGRAMI\\_2018v\\_2.pdf](https://ardahanodm.meb.gov.tr/meb_iys_dosyalar/2019_09/27114237_201813017165445-MATEMATYK_OYRETYM_PROGRAMI_2018v_2.pdf)
- Ministry of National Education [MoNE]. (2018c). *Teknoloji ve tasarım dersi öğretim programı (Ortaokul 7 ve 8. sınıflar) [Technology and design course teaching program (Middle school grades 7 and 8)]*. Ankara. <https://mufredat.meb.gov.tr/Dosyalar/2018124112937511-TEKNOLOJ%20TASARIM%20C3%96%C4%9ERET%20PROGRAMI%207-8.pdf>
- Ministry of National Education [MoNE]. (2018d). *Bilim uygulamaları dersi öğretim programı (Ortaokul ve İmam Hatip Ortaokulu 5, 6, 7 ve 8. sınıflar) [Science applications course teaching program (Middle school and Imam Preacher Middle School grades 5, 6, 7 and 8)]*. Ankara. [https://mufredat.meb.gov.tr/Dosyalar/2018813171537438-3-2018-90%20Bilim%20Uygulamalar%20Dersi%20\(5-8.%20S%C4%B1n%C4%B1flar\).pdf](https://mufredat.meb.gov.tr/Dosyalar/2018813171537438-3-2018-90%20Bilim%20Uygulamalar%20Dersi%20(5-8.%20S%C4%B1n%C4%B1flar).pdf)
- Morillas, J.M.B., Gozalo, G.R., González, D.M., Moraga, P.A., & Vílchez-Gómez, R. (2018). Noise pollution and urban planning. *Current Pollution Reports*, 4(3), 208-219. <https://doi.org/10.1007/s40726-018-0095-7>
- Muñoz-García, I.M., Alcántara-Manzanares, J., & Medina Quintana, S. (2022). Key aspects of adolescents' environmental attitudes with a view to transformative education. *Education Sciences*, 12, 591. <https://doi.org/10.3390/educsci12090591>
- Özbuğutu E., Karahan, S., & Tan, Ç. (2014). Çevre eğitimi ve alternatif yöntemler – literatür taraması [Environmental education and its alternative methods – a literature review]. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 11(25), 393-408.
- Özbulat, F. (2020). *Ortaokul öğrencilerinin öğrenmeye yönelik sorumluluk düzeylerinin ve okul motivasyonlarının incelenmesi [Investigation of learning responsibility levels and school motivations of secondary school students]*. [Unpublished master's thesis]. Sakarya University, Institute of Educational Sciences.
- Özdemir, O. (2007). Yeni bir çevre eğitimi perspektifi: “Sürdürülebilir gelişme amaçlı eğitim” [A new environmental education perspective: “Education for sustainable development”]. *Eğitim ve Bilim*, 32(145), 23-39. <https://doi.org/10.15390/ES.2007.738>
- Özgel, Z.T., Aydoğdu, M., & Güven Yıldırım, E. (2018). Doğa kampı destekli çevre eğitiminin çevre sorunlarına yönelik farkındalık ve tutuma etkisi [Impact of nature camp-assisted environmental

- education on awareness and attitude towards environmental problems]. *Ihlara Eğitim Araştırmaları Dergisi*, 3(2), 90-106.
- Özgen, N. (2012). Öğretmen adaylarının çevre sorunlarına yönelik tutumları: Türkiye örneği [Teacher candidates' attitudes towards environmental problems: The example of Turkey]. *Kastamonu Eğitim Dergisi*, 20(2), 403-422.
- Papp, Z. (2022). Environmental attitudes, environmental problems and party choice. A large-N comparative study. *Political Geography*, 97, 102652. <https://doi.org/10.1016/j.polgeo.2022.102652>
- Pertiwi, T.U., Oetomo, D., & Sugiharto, B. (2024). The effectiveness of STEM-Project- Based Learning in improving students' environmental literacy abilities. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 10(2), 476- 485. <https://doi.org/10.22219/jpbi.v10i2.33562>
- Redlarski, G., Lewczuk, B., Żak, A., Koncicki, A., Krawczuk, M., Piechocki, J., Jakubiuk, K., Tojza, P., Jaworski, J., Ambroziak, D., Skarbek, A., & Gradolewski, D. (2015). The influence of electromagnetic pollution on living organisms: Historical trends and forecasting changes. *BioMed Research International*, 2015(1), 234098. <http://dx.doi.org/10.1155/2015/234098>
- Sasson, I., & Yehuda, I. (2023). Redesigning the learning environment: Student motivation and personal responsibility for learning. *Current Psychology*, 42(35), 31251-31262. <https://doi.org/10.1007/s12144-022-04140-5>
- Schnittka, C., & Bell, R. (2011). Engineering design and conceptual change in science: Addressing thermal energy and heat transfer in eighth grade. *International Journal of Science Education*, 33(13), 1861-1887. <https://doi.org/10.1080/09500693.2010.529177>
- Schultz, P. (2002). Environmental attitudes and behaviors across cultures. *Online Readings in Psychology and Culture*, 8(1), 4. <https://doi.org/10.9707/2307-0919.1070>
- Sezer, A., & Çoban, O. (2016). Ortaokul öğrencilerinin sorumluluk değeri algıları [Responsibility value perception of secondary school students]. *Uşak Üniversitesi Eğitim Araştırmaları Dergisi*, 2(1), 22-39. <https://doi.org/10.29065/usakead.232420>
- Stefanidou, C., Mandrikas, A., Kyriakou, K., Stavrou, I., Boikos, I., & Constantine Skordoulis, C. (2024). Primary students' views toward STEM education in Greece. *Science Education International*, 35(2), 85-91. <https://doi.org/10.33828/sei.v35.i2.2>
- Tabachnick, B.G., & Fidell, L.S. (2013). *Using multivariate statistics* (6<sup>th</sup> Ed.), Boston: Allyn and Bacon.
- Tadena, M.T.G., & Salic-Hairulla, M.A. (2021, March). Raising environmental awareness through local-based environmental education in STEM lessons. *Journal of Physics: Conference Series*, 1835(1), 012092. IOP Publishing. <https://doi.org/10.1088/1742-6596/1835/1/012092>
- Tanrıverdi, E. (2021). *Çevre konularında uygulanan probleme dayalı STEM etkinliklerinin öğrencilerin ışık kirliliği farkındalıklarına etkisi [The effect of problem-based STEM activities on environmental issues on students' light pollution awareness]*. [Unpublished master's thesis]. Ordu University, Institute of Natural and Applied Sciences.
- Tramonti, M., Dochshanov, A.M., Fiadotau, M., Gronlund, M., Callaghan, P., Ailincăi, A., Marini, B., Joenvaara, S., Maurer, L., & Delle Donne, E. (2024). Game on for climate action: Big game delivers engaging STEM learning. *Education Sciences*, 14, 893. <https://doi.org/10.3390/educsci14080893>
- Tuti, G., & Terzi, S.Y. (2025). TÜBİTAK 4006 bilim fuarları süreçlerinin yürütücü öğretmen görüşlerine göre değerlendirilmesi [Evaluation of TÜBİTAK 4006 science fair processes based on the opinions of project coordinator teachers]. *Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Dergisi*, 63, 1161-1180. <https://doi.org/10.53444/deubefd.1592142>

- Wallner, A., Hunziker, M., & Kienast, F. (2003). Do natural science experiments influence public attitudes towards environmental problems?. *Global Environmental Change*, 13(3), 185-194. [https://doi.org/10.1016/S0959-3780\(03\)00042-6](https://doi.org/10.1016/S0959-3780(03)00042-6)
- Wasi, S., Tabrez, S., & Ahmad, M. (2013). Toxicological effects of major environmental pollutants: an overview. *Environmental Monitoring and Assessment*, 185, 2585-2593. <https://doi.org/10.1007/s10661-012-2732-8>
- Widiyanti, E.R., & Suyanto, S. (2025). Does the PBL-STEM model improve students' deductive, inductive, and reasoning skills in biology? *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 11(2), 638-648. <https://doi.org/10.22219/jpbi.v11i2.41084>
- Yakar, A. (2017). *Potansiyel gelişim alanı bağlamında bir eylem araştırması: öğrenme sorumluluğu, motivasyon ve başarı [An action research in the context of zone of proximal development: learning responsibility, motivation and achievement]*. [Unpublished PhD dissertation]. Adnan Menderes University, Institute of Social Sciences.
- Yakar, A., & Saracaloğlu, A.S. (2017). Öğrenmeye yönelik sorumluluk ölçeği [Scale of responsibility towards learning]. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi*, 42, 27-49. <https://doi.org/10.21764/efd.41545>
- Yavuz, N. (2020). *5. sınıf fen bilimleri dersi insan ve çevre ünitesinin öğretiminde STEM destekli etkinliklerin öğrencilerin çevre bilincine etkisinin incelenmesi [Investigation of the effect of STEM-supported activities covered in teaching the human and environment subject of the fifth-grade sciences course on students' environmental awareness]*. [Unpublished master's thesis]. Kastamonu University, Institute of Science.
- Yıldırım, B. (2021). *Teoriden pratiğe STEM eğitimi uygulama kitabı [STEM education from theory to practice application book]* (Revised 3<sup>rd</sup> Edition). Nobel Akademik Yayıncılık.
- Yıldız, S., Demiray, Ö.Ş.A., Zengin, F.K., & Keçeci, G. (2025). *Bilim fuarları: 4006-TÜBİTAK bilim fuarları destekleme programına dair öğretmen ve öğrenci görüşleri [Science fairs: Teachers' and students' opinions on 4006-TÜBİTAK science fairs supporting program]*. Duvar Yayınları. [https://www.duvaryayinlari.com/Webkontrol/IcerikYonetimi/Dosyalar/bilim-fuarlari-4006-tubitak-bilim-fuarlari-destekleme-programina-dair-ogretmen-ve-ogrenci-gorusleri icerik\\_g4586\\_B7URWbIU.pdf](https://www.duvaryayinlari.com/Webkontrol/IcerikYonetimi/Dosyalar/bilim-fuarlari-4006-tubitak-bilim-fuarlari-destekleme-programina-dair-ogretmen-ve-ogrenci-gorusleri icerik_g4586_B7URWbIU.pdf)

## Appendices

### Appendix 1. A sample from course plans (Activity-1: I am making a robot bee)

<b>Course Name</b>	Science Course
<b>Grade Level</b>	7 <sup>th</sup> Grade
<b>Course Hours</b>	Four Hours
<b>Activity Name</b>	I am making a robot bee
<b>Connections to the Course Objectives [Ministry of National Education]</b>	<p><u>Science:</u> F.5.6.1.1. Questions the importance of biodiversity for natural life. Gives examples of plants and animals that are endangered or in danger of extinction in our country and around the world. F.5.6.1.2. Discusses the factors that threaten biodiversity based on research data. F.5.7.1.2. Establishes the diagram of the electrical circuit he/she drew.</p> <p><u>Mathematics:</u> M.5.2.3.1. Recognizes length measurement units; converts meters-kilometers, meters-decimeters-centimeters-millimeters and solves related problems.</p> <p><u>Environmental Education and Climate Change:</u> ÇEİD.1.6. Discusses behaviors that will negatively affect the natural balance through current examples. a) Students address behaviors that will negatively affect the natural balance in terms of environmental ethics through dilemmas. b) Students are expected to realize that they are responsible for developing attitudes and behaviors aimed at protecting the natural balance.</p> <p><u>Technology and Design:</u> TT.7.B.1.3. Expresses the ability to develop solutions for identified problems. TT.7.B.1.4. Explains the research steps of the design process. TT.7.B.2.1. Creates draft drawings for design.</p> <p><u>Science Applications:</u> SBU.7.3. Explains the relationship between science, technology, engineering, and mathematics. SBU.7.8. Uses interdisciplinary relationships. SBU.10.1. Applies the "engineering design and entrepreneurship process" in product creation.</p>
<b>Strategy, Method and Techniques</b>	STEM approach, engineering design, inquiry, question and answer, lecture, group work, problem solving, discussion
<b>21st-Century Skills Aimed at the Activity</b>	Innovative thinking, analytical thinking, collaborative work, leadership, productivity, responsibility for learning
<b>Flow of the Activity Implementation</b>	<p><u>Introduction - Checking Prior Knowledge - Stimulating Curiosity</u> The students are divided into groups. Then, an activity sheet about bees are distributed. Three questions are asked about bees in this activity:</p> <div style="background-color: #FFD700; padding: 10px; border: 1px solid black; margin: 10px 0;"> <p>1. What types of bees do you know? .....</p> <p>2. Do all bees have the same function? .....</p> <p>3. How long do bees live on average? .....</p> </div> <p>These questions are intended to reveal students' existing basic knowledge about bees. After the groups answer the questions, the class watches the film "If there are bees, there is a tomorrow" <a href="https://www.youtube.com/watch?v=W_ON_6Mlm5k">https://www.youtube.com/watch?v=W_ON_6Mlm5k</a></p> <p>Students, who have recognized the role of bees in our lives, are shown a microscope image of a honeybee <a href="https://www.youtube.com/watch?v=EqE7VNNKx0U">https://www.youtube.com/watch?v=EqE7VNNKx0U</a> to highlight surprising details.</p>

### Attention-Gathering and Motivation

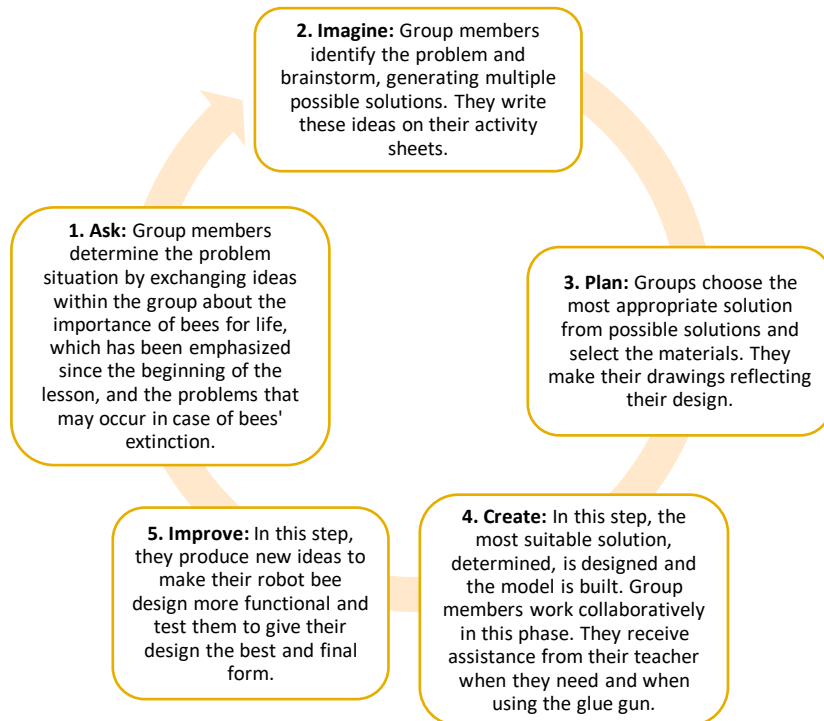
In this phase, activity worksheets (Please see *Worksheet 1*) are distributed to the groups. The text "Massive Bee Mortality" is read, and the groups are asked questions such as, "Would life exist without bees? What is the impact of bees on living things?" These questions prompt them to think.

Next, the text "Robot Bees" is read (Please see *Worksheet 2*), highlighting the impact of bees on living things and the environment. The groups are then asked, "As scientists who study bees and ecological balance, we expect you to create a robot bee model to maintain the natural balance."

### Materials:

- Battery holder • Battery • DC motor • Key • Electrical tape • Pompom
- Electrical cables • Colourful chenille • Paper clips • Straws • Glue • Glue gun

Implementations at Each Engineering Design Step: After discussing the impact of bees on the environment and humans, the students build robot bee models. This phase utilizes the Cunningham engineering design process steps:



The groups use the electric circuit to make their bees move. They utilize materials in proper lengths to construct bee's legs, wings etc. Also, they use chenille and pom-pom to give their models a real bee-like appearance.

### Evaluation

Group members fill out student journals about the activity. During this phase, students evaluate the activity as a whole. They discuss what have they learned. Guiding questions are as follows:

- Which part of the activity did you like? .....
- Which part of the activity did you find challenging? .....
- Which part of the activity would you like to change? .....

## Appendix 2a. Worksheet 1: massive bee deaths

### MASSIVE BEE DEATHS

Assoc. Prof. Dr. Sevgi Durna Daştan stated that the causes of the massive bee deaths may be climate change and the changing electromagnetic fields.

#### 'Climate Change is the First Factor'

Pointing out the existence of several factors threatening the survival of bees, Assoc. Prof. Dr. Sevgi Durna Daştan said, "Climate change, which has been on the global agenda in recent years, is one of the most significant factors affecting bees. The global warming and unbalanced climate movements negatively impact the lives of bees, as they do all living things. The negative effects of climate change on flora directly affect honeybees, which feed on flowers. Honeybees face malnutrition. Rainy and dry weather also negatively impact the plants' nectar and pollen yield.

SOURCE: <https://www.cumhuriyet.edu.tr/m/haberler-icerik.php?haberid=9110>

- ✓ Do you think life would exist without bees?  
.....
- ✓ What is the impact of bees on living things?  
.....

## Appendix 2b. Worksheet 2: robot bees



### ROBOT BEES

Imagine living in a world without bees. We probably wouldn't starve, but we would be deprived of some of our favourite fruits and plant species that provide food for both humans and animals, or we would have a very hard time finding them. Because 130 different plant species are fertilized, reproduced, and bear fruit thanks to pollination, primarily by bees. We would probably never have had the chance to taste or use honey, apples, almonds, beets, onions, alfalfa, blueberries, berries, hazelnuts, squash, cucumbers, carrots, watermelon, melon, avocado, kiwi, soybeans, sunflowers, apricots, cotton, broccoli, cauliflower, lettuce, coffee, peaches, limes, and oranges.

There's no doubt that bees and other insects are nature's best pollinators, and to date, no alternatives have emerged that are as effective as these natural pollinators. Some countries, eager to prepare for the worst and spurred by the mass bee die-offs, have begun exploring alternatives.

SOURCE: <https://bilimgenc.tubitak.gov.tr/makale/robot-arilar>

You are a scientist working on bees and ecological balance. To maintain natural balance, you are expected to create a robot bee model with your group. Complete your design by answering the questions below:

- Problem situation:.....
- Possible solutions suggested: .....
- The most convenient solution: .....
- Materials to be utilized: .....
- Your drawing for your design:
- Stages of your design:  
.....  
.....
- If you have one more chance, which parts of your design do you like to change/improve?  
.....  
.....