The Effect of E-STEM Education on Students' Perceptions and Engineering Design Process about Environmental Issues

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Abstract

E-STEM (Environmental, Science, Technology, Engineering and Mathematics) refers to the integration environmental education into STEM education and can have important role on students' understandings and engineering design process about environmental issues such as plant growth, acid rains, pollution, sustainable agriculture etc. since it engages students in real-world environmental problem-solving that integrates science, technology, engineering, and math. In this manner, the aim of this study was to investigate the effect of E-STEM Education on fifth grade students' perceptions and their engineering design process about environmental issues. To reach this aim, a one-group pre- and post-test model was used. The research group of study is five 5th grade students at private school, Istanbul, Turkey. The data was collected with open-ended questions, focus group interview and researchers' observation notes. In data analysis, students' responses to open-ended questions were analyzed with content analysis and classified in terms of adequacy. Transcribed discussions from focus group interview and researchers' observation notes were assessed based on Engineering Design Process Framework. As a result of the study, students' perceptions and engineering design process about environmental issues improved through E-STEM Education.

Keywords: E-STEM education, environmental education, STEM education, perceptions, engineering design process

1. Introduction

Environmental problems like global warming, climate change, habitat destruction, loss of biodiversity, food insecurity, air, water and soil pollution have continuously increasing day by day. Therefore, the importance of increasing individual levels of environmental literacy is emphasized by researchers (Roth, 1992; Scholz, 2011). Environmentally literate individuals know and are aware of natural systems and the impact of human activities on these systems (Teksöz, Şahin, & Ertepınar, 2010). Many research showed that individuals' knowledge about environmental issues are far from satisfactory and their levels of connectedness to nature is low. (Atasoy & Ertürk, 2008; Ernst & Theimer, 2011; Teksöz et al., 2010). Thus, environmental education should be given priority at all levels of education from pre-school to college; that is, all students should be taught environmental literacy. At this point, education should be designed to prepare responsible and environmentally literate citizens to meet the complex environmental challenges we are currently facing. Since environmental issues grow day by day and the need for education increase, STEM education, which promotes 21st-century skills like problem-solving, innovation, creativity and critical thinking etc., can be an effective way for teaching environmental issues. E-STEM (Environmental-STEM) education is one of the new forms of environmental education (Candan Helvacı, 2021). Therefore, the aim of this study was to investigate the effect of E-STEM Education on fifth grade students' perceptions and their engineering design process about environmental issues and the research question of this study is as follows:

- How E-STEM Education can develop students' perceptions and engineering design process about environmental issues?

1.1 E-STEM Education

STEM education refers to teaching and learning in the fields of science, technology, engineering and mathematics, and typically includes all formal and informal education activities at all levels of education (Gonzalez & Kuenzi, 2012). According to Bybee (2010), the aim of STEM education is to create a STEM literate society, and an innovation focused labor force that has 21st century skills, and that is able to conduct advanced research and development. Balka (2001) defined STEM literacy as 'the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and to innovate to solve them' (p. 7). Although it is desirable to meet the labor force requirements in STEM areas to be able to adapt to the developing and changing world in the 21st century, the main objective of STEM training is not to raise all students to become scientists or engineers. In fact, its aim is to develop the competences of individuals to make informed decisions on societal and environmental issues. Namely, there is a need for individuals who are capable of making informed decisions as a stakeholder in areas such as environment, energy, food and agriculture where STEM disciplines intersect. STEM and environmental education are complementary and can be brought together in education. Therefore, one of the versions of the STEM Education adapted to the conditions of the 21st century is E-STEM (Environmental, Science, Technology, Engineering and Mathematic) introduced by National Association for Environmental Education (NAEE) (Fraser, Gupta, Flinner, Rank & Ardalani,2013). E-STEM (Environmental STEM) refers to the integration of environmental education into STEM education. The aim of this integration is to guide environmental issues to bring students 21st century skills such as critical thinking, problem solving, communication and collaboration. E-STEM education can develop students' environmental literacy, build STEM skills, and create pathways to environmental and STEM careers by engaging students in meaningful, real-world environmental problem-solving that integrates science, technology, engineering, and math (STEM).(NAAEE, n.d). Environmental STEM education can provide to investigate environmental issues and help image and implement solutions or resolutions (Blackley & Sheffield, 2016). In recent years, the importance of the integration of environmental education with STEM and the role of environmental issues in facilitating STEM education has been increasing because while STEM training offers important opportunities for an effective environmental education, environmental issues are likely to facilitate a meaningful handling of STEM education (Fraser, Gupta, Flinner, Rank, & Ardalani 2013; Kuvaç & Koç-Sarı, 2018).

2. Method

2.1 Research Design

This research was designed as a one-group pre- and post-test model to determine the effect of a treatment or intervention on a given research group (Cohen, Manion & Morrison, 2007; Fraenkel, Wallen & Hyun, 2012). In the scope of this research, the effect of E-STEM Education on fifth grade students' perceptions and their engineering design process about environmental issues were investigated. In this study, one of the researchers was the teacher of these students and students were comfortable in their natural setting during the implementation.

2.2 Research Group

The research group of this study consisted of five 5th grade students who are range in 9-10 years old at a private school, Istanbul, Turkey. 2 of them were male and 3 of them female. All students experienced E-STEM education for the first time. They were informed by teacher about the aim of the study and their roles during the implementation. They participated to this research voluntarily.

2.3 Implementation

In current research, as a pre-test, each student answered open ended questions about factors affecting plant growth, acid rains, soil pollution and sustainable agriculture to determine their perceptions about these issues. Then E-STEM activity were implemented for 8 lesson hours which lasted 4 weeks. In this activity, students planted flowers in four different pots. They placed 2 planted flowers in directly sun-exposed area of the classroom (Figure 1) and others were putted into the greenhouse which are designed by students with basic materials (chenille stems, freezer bag, colored cartoon, band) (Figure 2). Every week, while students watered 2 flowers with natural water (one of them is in directly sun-exposed area and one of them is in the greenhouse), they watered 2 planted flowers with acidic water i.e. vinegar (one of them is in directly sun-exposed area and one of them is in the greenhouse). During 4 weeks, students observed the change of flowers week by week and discussed the factors affecting plant growth, acid rain, soil pollution and their effects on plant growth and the concept of sustainable agriculture. In this study, students were observed by the researcher/teacher during process since researcher had the role of participant observer (Creswell, 2007) which

researchers are involved in the process and behave as a guide. After 4 weeks (8 lesson hours), students again answered the open ended questions as post-test and also focus group interview which lasted 21 minutes was done with students and during discussion, researcher recorded students' responses and dialogues with each other.

Figure 1. Planted Flowers in Sun-Exposed Area

Figure 2. Planted Flowers in Greenhouse

2.4 Data Collection and Analysis

The data were collected through open ended questions prepared by researchers, focus group interview and researcher'\teacher' observation notes in this study. In data analysis process, students' pre- and post-responses to open-ended questions were analyzed with content analysis and classified in terms of adequacy. Transcribed discussions from focus group interview and researcher'\teacher' observation notes were analyzed through deductive analysis which is a thematic analysis of data from predetermined framework (Creswell, 2007; Savin-Baden and Howell Major, 2013). Engineering Design Process Framework (Hynes et al., 2011) which starts with the defining the problem/need and ends with the completion of the decision were used in this data analysis.

3. Results

The aim of this study was to investigate the effects of E-STEM Education on fifth grade students' perceptions and engineering design process about environmental issues. Results were given in detail at below.

3.1 Students' Perceptions about Environmental Issues

In the scope of research, students' perceptions about factors affecting plant growth, acid rains, soil pollution and sustainable agriculture before and after E-STEM activity were revealed. Table 1 shows the students' perceptions about environmental issues in terms of adequacy level before and after E-STEM Education.

Table 1. Students' Perceptions about Environmental Issues

		Inadequate	Adequate	Informed
Factors affecting plant growth	Pre-	3	2	-
	Post-	-	3	2
Acid Rain	Pre-	4	1	-
	Post-	-	3	2
Soil Pollution	Pre-	3	2	-
	Post-	1	2	2
Sustainable Agriculture	Pre-	5	-	-
	Post-	2	2	1

According to the results, at the beginning, 3 students have inadequate information and 2 students have adequate information about factors affecting plant growth. After the E-STEM Education, most of the students (3 students) have adequate information and 2 students are informed about factors affecting plant growth (Table 1). Examples of students' responses were as follows:

Student C: 'I think only water affects.' (Inadequate)

Student A: 'Sunlight, water, temperature' (Adequate)

Student D: 'Water, light, temperature, nutrients and humidity can affect the growth of plants.' (Informed)

Results showed that most of the students (4 students) have inadequate information while only 1 student have adequate information about acid rains at the beginning. After the E-STEM Education, most of the students (3 students) have adequate information and 2 students are informed about acid rains (Table 1). Examples of students' responses were as follows:

Student E: 'Acid rains means that acids in wastes which are thrown to water mix in water, this water vaporize and drops as rains. I don't know, acid rain may not affect plants' (Inadequate)

Student D: 'If air pollution occurs, acid rains happens. Acid rains harm living things. Acid rains affect the plants negatively' (Adequate)

Student B: 'Some gases in air mix with rains and it rains to earth. Both living and nonliving things may be harmed. Acid rain harms the growth of plants and it can kill the plants' (Informed) (Figure 3)

Figure 3. Planted Flower Affected by Acid

Moreover, according to results (Table 1), most of the students (3 students) have inadequate perceptions about soil pollution and 2 of them have adequate solution before E-STEM implementation. After E-STEM practice, students' perceptions developed. 2 students are informed, 2 students have adequate information and only one student have inadequate perception about soil pollution. Examples of students' responses were as follows:

Student A: 'Rubbish. I don't know the effect of acid rains on soil.'(Inadequate)

Student E: 'Soil pollution happens because human throw rubbish to places. Acid rain may cause soil pollution' (Adequate)

Student B: 'Soil pollution refers to pollute soil with man-made wastes. The reason is that people throw the rubbish to places and those rubbish stay in soil for a long time. In addition, unconscious fertilization may cause soil pollution. Acid rains can pollute soil and they can harm the properties of soil.' (Informed)

In addition, results showed that none of 5th grade students heard the concept of sustainable agriculture. After E-STEM activity, 3 of them (2 students-adequate level and 1 student-informed level) have an opinion about sustainable agriculture. Examples of students' responses were as follows:

Student C: 'No, I didn't hear. I don't know.' (Inadequate)

Student B: 'I have never heard sustainable agriculture but long lasting agriculture comes to my mind. That is to say, according to me, agriculture happens effectively in long term.' (Adequate)

Student D: 'More advanced and effective agriculture (Little energy, fertile products). Sustainable agriculture contributes to environment and economy because make fertile products by consuming less energy.' (Informed)

3.2 Students' Engineering Design Process

In order to examine students' engineering design process**,** focus group interview and researcher'\teacher' observation notes was analyzed. As a result, some important points of engineering design process emerged while students were designing 'Greenhouse' as E-STEM activity (Figure 4-5). These are identifying the need/problem, searching to gather information from different sources, generating different solutions, constructing the model by evaluating and communicating about the solution. In this E-STEM activity, students learned to think and work as scientists and engineers while designing 'Greenhouse'. Moreover, according to results, students developed imagination, creativity, collaborative learning and problem solving ability thanks to design process. Students' responses are like that:

Student D: 'Firstly, we determined the problem/need, then we searched about the problem and got information, and thought how we can solve this problem and designed our Greenhouse, and we discussed about our model.'

Student B: 'In this lesson, we learned new things about environmental issues like acid rains, soil pollution and their effects by observing and experiencing. We strengthened our brains. Well then we have a growing power to solve the problems and develop new models.'

Student A: 'The purpose of our Greenhouse is to reduce extreme weather conditions such as temperatures, acid rains and frosts. This activity has developed my imagination and problem solving skills.'

Student E: 'I have created with my friends. While developing the idea, everyone already said what they want. We chose the best one by evaluating and discussing them. I think we learned to study collaboratively. My creativity improved.'

Student C: 'We talked and discussed the Greenhouse model and we investigated with our friends. We also collected information. We thought and made the most beautiful and the best model. We tried to understand the problem by asking questions like scientists or engineers. Our problem-solving ability increased, I think.'

Figure 4 & 5. 'Greenhouse' Design

4. Discussion and Conclusion

In this study, the effect of E-STEM Education on fifth grade students' perceptions and their engineering design process about environmental issues were investigated. As a result of the mutual learning in E-STEM activity, students' perceptions and engineering design process about environmental issues developed. Helvaci & Helvaci (2019) revealed that E-STEM Activity had positive effects on students' environmental awareness. Schroth & Daniels (2020) emphasized that students can use the steps of engineering design process like identify problems, develop research questions, gather and analyze data, develop possible solutions, and disseminate this information to others while exploring environmental and sustainability issues. In addition to this, learners can improve critical and creative thinking skills as well as science, technology, engineering, and mathematics (STEM) skills (Schroth & Daniels, 2020). Gupta, LaMarca, Rank & Flinner, (2018) showed that E-STEM approach can advance science learning by engaging students in interactive science learning opportunities like involving scientific explorations, observing nature, grasping the interconnectedness of natural systems, and developing environmental responsibilities. Although there is a few study, it is needed more research about in the area of E-STEM integration for elementary schools and the long-term implications (Livers, 2022). Engaging students in scientific and engineering design processes enables them to learn by exploring, modeling and experiencing the development of scientific knowledge and understand the world (Krajcik & Delen, 2017; Saçkes, et al., 2011). E-STEM education provides this opportunity to students by engaging them to

understand disciplinary ideas of multiple area and integration of them; moreover, it helps to recognize the situations occur around them in more meaningful way and let them understand the world more deeply. Thanks to E-STEM education, students can get the ability to think critically about the environmental issues and the effects of people on the environment (Gupta et al., 2018). The integrated disciplinary approach E-STEM education can be useful in preparing students to understand and ultimately address environmental challenges (Burgess & Buck, 2020). In order to raise students as scientifically and environmentally literate, science curriculums can be designed and E-STEM approach can be implemented as effective and innovative way in classrooms to inspire students to apply what they learn to solve complex environmental issues.

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Appendix A: Open-ended Questions

1. What are the factors affecting plant growth?

2. What is acid rain? Does acid rain affect the growth of plants?

3. What is soil pollution? Does acid rain cause soil pollution?

4. Have you ever heard the concept of 'sustainable agriculture'? What comes to your mind when it is said sustainable agriculture?

Appendix B: Focus Group Interview Questions

1. What is the purpose of designing the 'Greenhouse' in this activity?

2. Which steps did you follow while designing the 'Greenhouse'?

3. Which skills did you develop while designing a 'Greenhouse'?

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