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Pre-service Teachers' Environmental Literacy: The Role of STEM-Based Environmental Education with Microcontrollers

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The aim of this study is to determine the effect of STEM-based environmental education in which microcontroller sets are integrated on pre-service teachers' environmental literacy. The study was carried out with a one-group pretest-posttest weak experimental design. The sample of the study consisted of 31 pre-service teachers attending biology, science, and chemistry education departments. As the data collection tool, the environmental literacy scale including knowledge, attitude, behaviour and awareness dimensions was applied to the sample group as a pre-test and post-test. The study lasted for 11 weeks in total, including training on microcontroller sets, STEM-based environmental education and application of tests. During the environmental education, the participants were divided into groups of 4-5 and the studies were carried out with the station technique. In the stations, a research problem about air, water, soil, light and noise pollution was posed to the participants. They were expected to propose a solution using microcontroller sets. At the end of the research, a statistically significant difference was determined between the pre-test and post-test scores of the pre-service teachers from the environmental literacy scale. Accordingly, it was concluded that STEM-based environmental education improved pre-service teachers' environmental literacy. Based on these results, it is recommended that experimental/ quasi-experimental studies investigating the effectiveness of STEM-based environmental education and studies determining the advantages and disadvantages of STEM based environmental education using microcontroller sets should be carried out.

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Introduction

Throughout their existence, human beings have been engaged in constant interactions with the environment, wherein they have both been influenced by their surroundings and, in turn, exerted an impact on the environment through their actions. This dynamic interaction, particularly amplified during the industrial revolution, has disrupted the delicate balance within ecosystems and led to the degradation of natural life. Consequently, the habitats for various organisms have been rapidly diminishing, and environmental pollution has become a pervasive issue (Sahin, Unlu, & Unlu, 2016).

In response to the escalating global effects of environmental pollution and the consequential challenges it poses, numerous countries have increasingly recognized the crucial importance of environmental education. This recognition stems from the need to cultivate environmentally responsible behaviors among citizens and address the imperative of safeguarding the environment (Unal & Dimiski, 1998; 1999).

Environmental education plays a crucial role in fostering environmental awareness and promoting responsible behavior towards our surrounding ecosystem, both at the individual and societal levels. Its primary objective is to shift the perspective of society from viewing the environment as a mere functioning machine to adopting an environment-centered outlook. By doing so, it is anticipated that the prevalence of environmental issues will diminish, and a conscientious society that understands its responsibilities towards the environment will emerge. Consequently, educational institutions aspire to cultivate environmental literacy among all individuals as one of their key objectives. To achieve this goal, the initial step involves enhancing the existing levels of environmental literacy, encompassing knowledge, attitudes, behaviors, and interests, through effective environmental education initiatives (Artun, Uzunoz, & Akbas, 2013; Teksoz, Sahin, & Ertepinar, 2010).

The most important goal of environmental education programs is environmental literacy (Akilli & Genc, 2015; Teksoz, Sahin & Ertepinar, 2010). Environmentally literate individuals are individuals who have learned basic concepts, acquired the necessary skills against environmental problems, have a sense of belonging to nature, voluntarily participate in environmental protection activities, are aware of their responsibilities, engage in activities to improve the environment, and have sensitive consumption habits and lifestyle (Artun, Uzunoz, & Akbas, 2013). The concept of environmental literacy was first used by C. Roth. According to Roth, environmental literacy consists of individuals' knowledge, understanding, attitudes and observable behaviors related to the environment (Roth, 1992). Environmental literacy can also be briefly expressed as the ability of an individual to transform what he/she knows about the environment in which he/she lives into behavior. Determining the variables affecting environmental literacy and knowing the ways to improve environmental literacy is important for raising individuals with a high level of environmental literacy. Environmentally literate individuals are not only individuals who have knowledge and sensitivity about the environment but also individuals who can recognize environmental problems and take part in their solution (Bozdogan, Sahinpinar & Karatekin, 2023).

In order for individuals to take part in the solution of environmental problems, environmental education should be carried out in a different way from traditional approaches that provide information to the individual (Kısoglu, 2009). Especially if we assume that interdisciplinary activities are at the forefront of solving environmental problems, it is important that environmental education also provides opportunities for interdisciplinary interactions. In addition, teachers should also provide environmental education in schools in a way that allows

interdisciplinary interactions (Chunteng, 2004). In this context, STEM approach can be utilized for an effective environmental education that will improve individuals' environmental literacy.

STEM is a teaching approach that consists of the initials of Science, Technology, Engineering and Mathematics and means that there is a transition between these disciplines. STEM education aims to enable students to apply their theoretical knowledge in daily life, to provide interdisciplinary integrity, and to gain skills as well as knowledge (Ayar, Cavas & Gurcan, 2020). One of the most important factors in the implementation of STEM education is the integration of technology and engineering knowledge into daily life problems. With STEM education, students recognize problems and develop solutions (Bybee, 2010). By using environmental problems during STEM activities, individuals can also gain skills in generating solutions to environmental problems.

STEM constitutes the education strategy of many countries. Because it is accepted that in the future, individuals who are trained in STEM education and who have learned different disciplines as a whole will be needed. In other words, integrating STEM education into courses is of great importance for the next generation (Cepni & Ormanci, 2018). If environmental education is presented with an interdisciplinary perspective with STEM, more effective teaching will be realized. At this point, individuals are expected to gain skills on how to cope with environmental problems. The version of STEM approach evaluated together with the environment is called Environmental→STEM (E→STEM) (Fraser, Gupta, Flinner, Rank & Ardalan, 2013). Since environmental problems will be approached by considering the STEM approach in the E→STEM approach, it creates more environmental awareness in individuals (Helvaci & Helvaci, 2019). For this reason, the newest approach preferred in environmental education is the use of STEM activities during environmental education (Candan-Helvaci, 2021).

In the review of the literature, it can be seen that the studies in which the environment and STEM activities are part of the study can be divided into two different groups. One is the studies using STEM approach to develop participants' skills called STEM skills (Candan-Helvaci, 2021) such as creativity, engineering design skills, innovation skills, and problem solving skills (e.g. Koculu & Girgin, 2022; Kulegel & Topsakal, 2021; Ozcakir-Sumen & Calisici, 2016). In these studies, environment-related contexts are used as everyday problems. The development of STEM skills or 21st-century skills is the main objective of this group of studies. Another study group is the studies in which the STEM approach is used in the learning environment planned to provide environmental education to the participants (e.g. Koculu & Girgin, 2022; Tadena & Salic-Hairulla, 2019; Wahyuni, Arrohman, Wilujeng, Widowati & Suyanta, 2022; Widowati, Purwanto & Akbar, 2021). The main objective of this study group is to provide environmental education to the participants in a student-centred environment. The interdisciplinary approach is taken into account. E→STEM represents a STEM approach that focuses on environmental education (Candan Helvaci, 2021; Fraser et al., 2013). Since this research is a study in which STEM activities were used to improve the environmental literacy of pre-service teachers, it is an example of the second group of studies.

Studies using STEM approach in environmental education are not common in literature (Sungur-Gul, Saylan-Kirmizigul & Ates, 2022). These studies examined the effects of STEM-based environmental education on participants' environmental competence, environmental attitude, or environmental awareness. For example, the effect of a 3-week environmental education programme, which was carried out using the E→STEM approach, on the environmental awareness of primary school students was investigated. According to the results

of the study, it was found that students' attitudes, behaviour and knowledge towards the environment, which are the sub-dimensions of environmental awareness, improved. It was also found that even in short-term E→STEM activities, students' environmentally friendly behaviours increased (Helvaci & Helvaci, 2019). Candan-Helvaci (2022) also investigated the effect of environmental education supported by the E→STEM approach on the level of environmental awareness of pre-service teachers. In the six-week study, pre-service teachers were asked to design E→STEM activities suitable for the primary education programme. At the end of the study, it was found that the environmental awareness of the participants had increased. Similarly, Koculu and Girgin (2022) conducted a 4-week E→STEM activity with primary school students to raise awareness about soil pollution, acid rain and sustainable agricultural practices. At the end of the study, the students' environmental awareness was found to have improved. Tadena and Salic-Hairulla (2019) also found that students' environmental awareness increased after environmental education, including STEM activities, with eighth-grade students.

Winarni, Karpudewan, Karyadı, and Gumono (2022) focused on environmental literacy in their study. The study conducted with primary students focused on the life cycle topic. As a result of the study in which the STEM approach was applied, it was found that students' environmental literacy increased. Similarly, Wahyuni et al. (2022) conducted STEM-based environmental education with secondary school students. As a result of the study, it was found that students' environmental literacy levels improved.

As mentioned above, when reviewing the literature on environmental literacy, it has been found that education that aims to raise awareness and/or provide information on the topic is often implemented, but STEM-based education that aims to question the existence of environmental problems or how to solve environmental problems is less common (Tadena & Hairulla, 2019; Koculu & Girgin, 2022; Wahyuni et al., 2022). Therefore, this research serves to fill the knowledge gap (Miles, 2017) that is missing in the literature. Environmental problems are not an area that concerns only one discipline, such as biology or chemistry. On the contrary, understanding environmental problems and proposing appropriate solutions can be achieved through an interdisciplinary approach. In order to understand environmental problems, it is necessary to know the ecology and the balances in the ecosystem, as well as to make measurements that reveal the existence of problems.

Similarly, solutions to environmental problems require knowledge from different disciplines (such as biology, chemistry, geology and zoology) or innovative and nature-friendly designs. In this study, pre-service teachers made nature-friendly designs to highlight the existence of environmental problems or to propose solutions. They also learned about the environment during the design process. Since the STEM approach allows the combination of different disciplines, this study conducted STEM-based environmental education and used microcontroller sets to enable participants to realise designs and integrate technology (Coskun & Ozkaya, 2020). Microcontroller sets are tools that facilitate the integration of technology in STEM approaches (Benitti, 2012). Demirci (2023) conducted a STEM activity with pre-service teachers using microcontroller sets. In the study, pre-service teachers were asked to design a lamp to prevent light pollution using the Arduino sets. There are almost no studies using microcontroller sets in environmental education. Another originality of this research is the use of microcontrollers in environmental education.

In this context, the aim of the study is to determine the effect of STEM-based environmental education using microcontroller sets related to environmental problems on pre-service teachers'

environmental literacy. The study aimed to answer the question "What is the effect of STEM-based environmental education with Ardunio sets on the environmental literacy of pre-service teachers?

Method

Research design

One-group pretest-posttest weak experimental design, a quantitative research method, was used in the study. In the one-group pretest-posttest weak experimental design, the effect of the researched object is tested as a result of a study with a single group (Wallen & Fraenkel, 2001). The data on the topic under investigation were obtained using the same sample and measurement instrument as the pretest before the application and the posttest after the application. As the sample consisted of a group of appropriately and purposefully selected students studying at a state university, a weak experimental design was used as the design. This is the limitation of this research.

The sample

The sample of the study consisted of 31 pre-service teachers who are studying in the biology, science and chemistry education departments of a state university in Ankara in the spring semester of 2021-2022. The sampling process was carried out according to the convenience and purposive sampling methods. Participants were identified through an online form inviting them to participate in the study, which was published on the website of the chemistry, biology, and science education departments of the respective university. The participation of the pre-service teachers in this study was completely voluntary. The distribution of pre-service teachers participating in the study according to departments is presented in Table 1.

Table 1. Distribution of the sample group based on departments

Departments	f	%
Chemistry	24	77.5
Biology	5	16.1
Science	2	6.4

Ethical declaration

This research is derived from the first author's master's thesis in the field of chemistry education under the supervision of the second and third authors. The study was conducted with the ethical approval of Gazi University Ethics Committee dated 23.12.2020 and number E.137842. It was also supported by Gazi University Scientific Research Projects Department with permission number SYL-2021-6953.

Data Collection Tool

The environmental literacy scale developed by Kısoglu (2009), which consists of (i) knowledge, (ii) attitude, (iii) behaviour and (iv) awareness dimensions, was used as the data collection tool with permission from the author. There are a total of 61 questions in the test. There are 20 multiple-choice questions in the knowledge dimension. The knowledge dimension score was determined by coding the answer to each question as 1 if correct and 0 if incorrect. For this study, the knowledge dimension's reliability coefficient (α) was calculated to be 0.71.

There are 18 5' Likert-type questions in the attitude dimension. The reliability coefficient of this dimension of the scale for this study was calculated as (α) 0.74. There are 20 3-point Likert-type questions in the behaviour dimension. This dimension's reliability coefficient (α) was calculated to be 0.74. There are 3 Likert-type questions in the awareness dimension. This dimension's reliability coefficient (α) was calculated to be 0.82. The scale was administered to the participants as a pre-test before the environmental education and as a post-test after the environmental education.

Research process

The research was carried out in four stages. In the first stage of the research, training was provided on microcontroller sets (digital sensors) that pre-service teachers will use in the design creation process. Arduino sets were used as the microcontroller sets. The training lasted for 4 weeks. It included training on the parts of the sets, how to use them and how to write/find code. In the second phase, the Environmental Literacy Scale was administered to the participants as a pre-test.

In the third phase of the study, STEM-based environmental education was carried out over a five-week period. The participants were divided into groups of 4-5 and the studies were carried out using the station technique. The stations were based on the inquiry research approach. Each station focused on a different environmental issue. In the stations, the participants were given a problem related to air, water, soil, light, and noise pollution and the digital sets (digital sensors in Arduino sets) to be used. The participants were expected to identify the environmental problem and propose to solve the problem based on the researched problem. Meanwhile, the participants conducted research from various sources (textbooks, articles, internet searches, and so on) to produce solutions to the research question. After determining their solutions, the participants were asked to design a material using Arduino sets. The participants collected data on the factors that cause environmental problems with the materials they designed and, if necessary, classified the data by drawing graphs and creating tables. The research was completed after reporting the data obtained.

The activities carried out at the stations were as follows:

Air Station

The aim of this activity is to determine the relationship between air quality and CO_2 level in the air. At the beginning, the working group was given a scenario about the problem of air pollution. The scenario given is briefly as follows: "Mrs. H woke up in the morning with headache and weakness and went to the hospital. Her tests were clean. When she returned home, she realised that the house was stuffy. She knew that her headache and weakness could be caused by this. H, who could not realise that the house was stuffy without going outside, thought how good it would be to have a system that measures air values at home." Then, the study group was asked the research problem: "How do you think such a device could be made? How are the air quality and CO_2 values in the places you are in? What could be the reasons affecting these values? " was asked as a research question. The study group was asked to determine the problem situation and to do research on the problem situation. Arduino Uno set, CO_2 sensor and air quality sensor were given to the study group. Within the scope of the aim, a material was designed by using Arduino sets (Figure 1). With the help of the designed material, measurements were taken from various environments (smoking environment, car park, classroom and open air). As a result of the measurements, a relationship between air quality and CO_2 level in the air was determined.

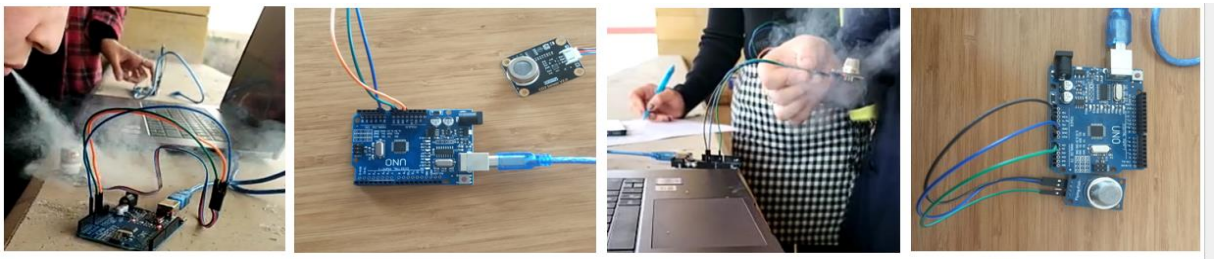

Figure 1. Some photos of air pollution station

Water station

The aim of the water pollution activity is to compare the pollution levels of water from different sources by analysing samples taken from different water sources in terms of pH and dissolved oxygen content. For this purpose, a scenario was given to the study group. The given scenario is briefly as follows: " W went on a picnic with her family. W's brother wanted to leave the fruits in the artificial lake to keep them cold. W told her brother not to do this because she thought the water might be dirty. Her brother thought that the water looked clean and there would be no problem. The two siblings, who had a difference of opinion, decided to investigate this situation when they came home." At the end of the scenario, the question "How do you think it can be understood whether a water is drinkable or not?" was posed as the research problem. The study group was asked to determine the problem situation and conduct research. Then Arduino Uno set, Dissolved Oxygen and pH Sensor were given. A material was designed for the purpose (Figure 2). Measurements were made with samples taken from a lake, pool and tap water. In addition, the ready TDS meter and odour analysis available in the laboratory were also used. As a result, differences in pH, dissolved oxygen, TDS and odour were detected in the samples and comparisons were made about water pollution.

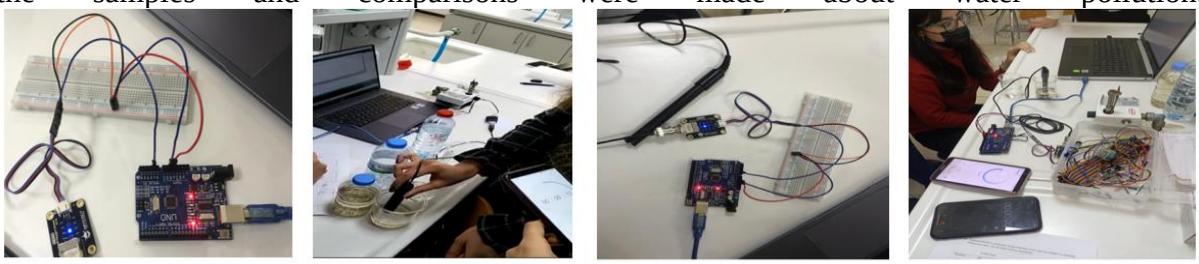

Figure 2. Some photos of Water Pollution Station

Agricultural Station

The aim of the soil pollution activity is to design a material to control and facilitate agricultural activities. Within the scope of this purpose, a scenario was given to the study group. The scenario given is briefly as follows: "Mr. S, who is engaged in agriculture, notices that the yield of the peppers he grows has decreased. He thinks that the reason for this may be the chemical fertiliser he has recently started to use. Mr. S decides to investigate how chemical fertiliser changes the structure of the soil (pH and moisture etc.)." At the end of the scenario, the question "What do you think is the effect of the chemical fertiliser used by Mr. S in agriculture on the pH and moisture values of the soil?" was posed as the research problem. The working group was asked to determine the problem situation and conduct research. Then, Arduino Uno set, pH and moisture sensor were given to the group. With the designed material, pH measurements were taken with soil samples with and without chemical fertiliser (Figure 3).

As a result, the soil in which chemical fertiliser was used turned into an acidic environment in terms of pH and yellowing and drying of the plant was observed.

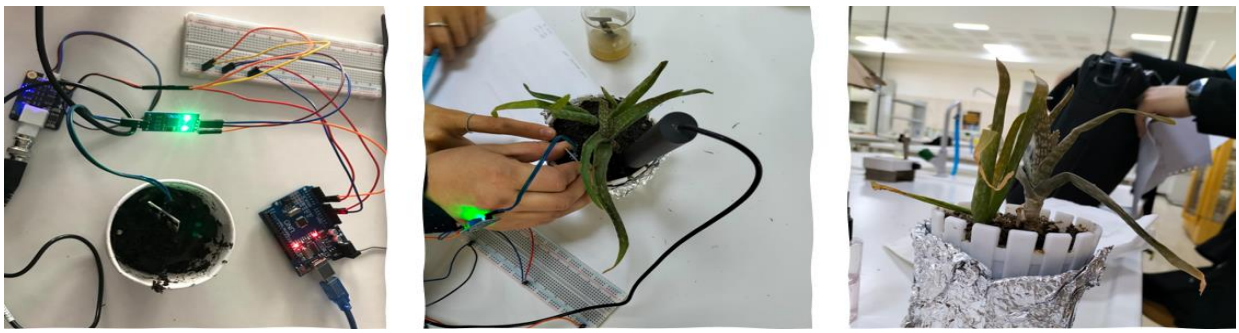

Figure 3. Some photos of Agricultural Station

Light Station

The aim of the light pollution activity is to raise awareness of the effects of light on sleep quality and the design of a night light to reduce unnecessary use of light. For this purpose, the study group was given a scenario. The scenario is briefly as follows: "L, who chose science for the project, wanted to work on light pollution. There could be both light pollution and adverse effects on human health if people left their night lights on while they slept. So L decided to design a night light". At the end of the scenario, the question "How do you think L can design a night light to prevent unnecessary use of light? The study group was asked to identify the problem situation and conduct research. After that, the Arduino Uno kit and the pulse sensor were given to the group. As a result, a lamp system was designed that can be switched off according to the pulse level during sleep and switched on when waking up (Figure 4).

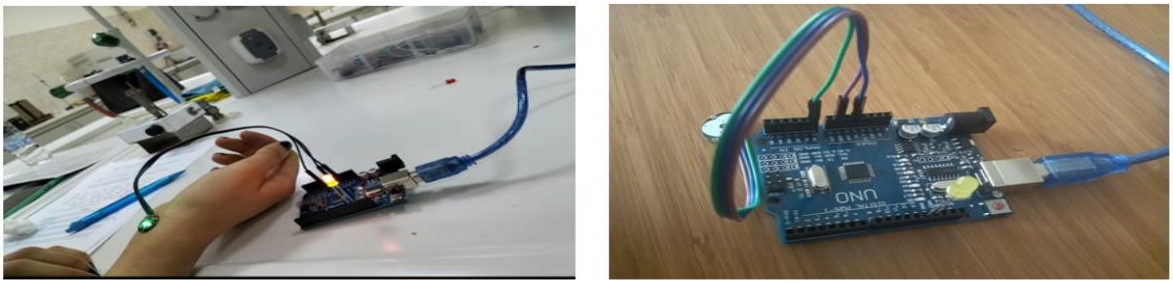

Figure 4. Some photos of Light Station

Sound station

The aim of the noise pollution activity is to determine the relationship between noise level and pulse rate in order to raise awareness of the discomfort caused by noise to living things. In order to do this, a scenario has been given to the study group. The scenario is briefly as follows "N, who used to live in a quiet place, moved to a megacity to study. Since the dormitory he moved to was in a central place, the traffic and music sounds did not stop day and night. He could not sleep at night and could not concentrate during the day. Feeling unwell, N decided to "investigate the effects of noise on humans". At the end of the scenario, the question "What kind of physiological changes do you think noise exposure can cause in humans? The working group was asked to identify the problem situation and conduct research. The group

was then given an Arduino Uno kit and a pulse sensor. The material was designed. Since the sound sensor designed for Arduino could not make accurate measurements, the sound level was measured simultaneously with the pulse sensor using the 'Arduino Science Journal' application, which can be easily downloaded to the phone (Figure 5). As a result of the measurements taken in different environments, it was found that the pulse value increased as the noise increased, and the pulse level became normal as the noise decreased.

Figure 5. Some photos of Sound Station

In the final phase of the study, the Environmental Literacy Scale was administered again as a post-test. The study lasted for 11 weeks and included all the stages.

Data analysis

Non-parametric statistical analysis was used in the analysis of pre-tests and post-tests because the scale used consisted of Likert-type questions and some of the data did not show a normal distribution (Turan, Simsek, & Aslan, 2015). IBM SPSS 26.0 (Statistical Package for Social Science for Personal Computers) program was used for statistical analysis. The Wilcoxon signed-rank test was used to determine the differences between the dimensions of the environmental literacy scale. The necessary assumptions for the analyses were checked.

Findings

In the study conducted to determine the effect of STEM-based environmental education on the environmental literacy levels of pre-service teachers, the Environmental Literacy Scale was used as a pre and post-test. The scores on the Environmental Literacy Scale before and after the STEM-based environmental education were analysed using SPSS. The results of the analysis are presented in Table 2.

Table 2. Pre- and post-test analysis results of the sub-dimensions of the Environmental Literacy Scale

		N	X	SS	min	max	p
Pre- Tests	Knowledge	31	9.38	3.00	5.00	15.00	**.625**
	Attitude	31	73.45	12.93	30.00	87.00	**.000**
	Behaviour	31	43.09	4.42	33.00	52.00	**.669**
	Awareness	31	10.83	1.67	8.00	15.00	**.100**
	Total	31	136.84	14.22	85.00	152.00	**.000**
Post-Tests	Knowledge	31	11.00	2.22	6.00	15.00	**.443**
	Attitude	31	78.64	13.23	19.00	108.00	**.000**
	Behaviour	31	46.48	4.68	38.00	56.00	**.681**
	Awareness	31	12.03	1.51	7.00	14.00	**.001**
	Total	31	148.09	14.72	93.00	176.00	**.002**

When the pre-post test analysis results given in Table 2 are examined, it is seen that the scores of some dimensions do not show normal distribution ($p<0.05$). Therefore, a nonparametric Wilcoxon signed-rank test analysis was applied. Table 3 shows the results obtained from the Wilcoxon signed-ranks test regarding whether there is a significant difference between the pre-post test scores obtained from the environmental literacy scale.

Table 3. Wilcoxon signed-rank test analysis results

Sub-dimensions	**Pre-post test**	**N**	**Mean rank**	**Sum of rank**	**z**	**p**
Knowledge	Negative ranks	4	11.75	47.00	3.29*	**.001**
	Positive ranks	22	13.82	304.00		
	Ties	5	-	-		
Attitude	Negative ranks	9	12.56	113.00	2.46*	**.014**
	Positive ranks	21	16.76	352.00		
	Ties	1	-	-		
Behaviour	Negative ranks	9	13.44	121.00	2.29*	**.022**
	Positive ranks	21	16.38	344.00		
	Ties	1	-	-		
Awareness	Negative ranks	3	9.50	28.50	3.67*	**.000**
	Positive ranks	22	13.48	296.50		
	Ties	6	-	-		
Total	Negative ranks	8	6.75	54.00	3.80*	**.000**
	Positive ranks	23	19.22	442.00		
	Ties	0	-	-		

*Based on negative ranks

According to Table 3, when the total score and sub-dimensions of environmental literacy were examined, it was determined that there was a significant difference between the pre-test and post-test scores of the pre-service teachers who received environmental education ($z=3.29$, $p<0.05$ for knowledge dimension; $z=2.46$, $p<0.05$ for attitude dimension; $z=2.29$, $p<0.05$ for behaviour sub-dimension; $z=3.67$, $p<0.05$ for perception sub-dimension and $z=3.8$, $p<0.05$ for total score of environmental literacy). When the rank averages and sums of the difference scores are taken into consideration, it is seen that this difference is positive ranks; in other words, in favour of the post-test. According to the results of the analysis, it can be concluded that the environmental education increased the environmental literacy level of pre-service teachers, which includes knowledge, attitude, behaviour and perception sub-dimensions related to environmental issues. In other words, it was determined that STEM-oriented environmental education with pre-service teachers was effective in improving pre-service teachers' environmental literacy.

Discussion and Conclusion

Comparing the pre-test and post-test scores of pre-service teachers from the environmental literacy scale, which includes knowledge, attitude, behaviour and awareness sub-dimensions, it is seen that there is a difference favouring the post-test (Table 3). Accordingly, it was found that STEM-based environmental education positively influenced the environmental literacy of pre-service teachers.

Environmental literacy is an individual's ability to understand environmental issues (Eren, 2020). It is considered one of the 21st-century skills needed for sustainable development (Maurer & Bogner, 2020). In order to prevent environmental problems, improving the environmental literacy of individuals is seen as an important step. In this context, the environmental literacy of pre-service teachers has been improved through STEM-based

environmental education, which aims to recognize environmental problems and generate solutions to them. In this context, STEM-based environmental education with the aim of recognising environmental problems and generating solutions to them has improved the environmental literacy levels of pre-service teachers. A review of the literature shows that similar results are obtained from studies on STEM-based environmental practices to support the findings of this study (Kulegel, 2020). Wahyuni et al. (2022) designed an environmental activity according to the STEM approach and investigated the effect of this activity on the environmental literacy of 7th-grade students. An environmental literacy test was used as a data collection tool. As a result, it was found that the prepared activity had an impact on the students' environmental literacy.

The first dimension of environmental literacy is knowledge. Knowledge about environmental issues is a prerequisite for environmentally responsible behaviour (Disinger, 2001). It is thought that STEM-based education has an important impact on pre-service teachers' knowledge of the environment. In order for the problems that are presented to the learners during STEM-based education to be more meaningful, the problems should be real-life problems. In this way, students will be able to apply theories, laws, models or principles related to science to the real world. From this point of view, STEM-based education provides learners with the opportunity to carry out context-based learning (Tadena & Salic-Hairulla, 2019). In the STEM-based education that was carried out in this study, the problems that were given to the pre-service teachers are problems that are related to the environment and are intertwined with everyday life. In order to solve these problems, they carried out investigations and research using environmental resources. They also worked collaboratively in groups. They may have gained more knowledge about environmental issues as a result of this education.

The second dimension of environmental literacy is attitude. The attitudes of pre-service teachers towards the environment were improved by STEM-based environmental education. The reason for this may be that the activities used in the education emphasized how the activities have an impact on other living beings in the ecosystem, including human beings. In this way, the pre-service teachers may have become more aware of environmental problems. Similar to the results of this study, Demir (2021) found that STEM activities had a positive effect on the attitudes of students towards the environment in his study with primary school students. The same result was also found by Calisici (2018). Moreover, Yildirim (2018) investigated the attitudes and sensitivities of pre-service teachers towards the environment and their commitment to nature as a result of STEM-based activities. As a result of STEM-based practices, it was found that the attitudes and sensitivity of pre-service teachers towards the environment increased after the education and had a positive effect on their commitment to the environment.

The behavioral dimension is another dimension of environmental literacy. Studies on environmental education have generally focused on improving the knowledge and attitudes of individuals, while the development of positive behaviors towards the environment has been less targeted (Erbasan & Erkol, 2020; Guven & Aydogdu, 2012; Hick & Holden, 1995). However, in this study, STEM-based environmental education improved pre-service teachers' positive behaviour towards the environment. This may be because, during the activities, pre-service teachers proposed and designed solutions to environmental problems. In other words, during the activities, the pre-service teachers were asked to take action by making designs to solve pollution or environmental problems.

The final dimension of environmental literacy is environmental awareness. Environmental

awareness expresses an individual's interest in environmental issues and problems (Kısoglu, 2009). According to the results of the study regarding the awareness dimension, pre-service teachers' interest in environmental problems increased. Integrating different environmental problems, such as light pollution, noise pollution, or the harmful effects of fertilisers, into STEM-based environmental education, other than the usual environmental problems, may have increased pre-service teachers' interest in environmental problems. Similarly, Dogru (2020) found that STEM activities with waste materials had a positive effect on middle school students' environmental awareness. In the study, Helvaci and Helvaci (2019), aimed to determine the environmental awareness of the participants by preparing E→STEM-based activities. As a result of the study, positive changes in environmental awareness were found. Tadena and Salic-Hairulla (2019) investigated the effect of STEM-based environmental education on the environmental awareness of 8th-grade students. As a result of the study, it was determined that environmental education improved students' environmental awareness.

Considering the procedure and results of this research, several suggestions can be given to researchers. Firstly, as the results of this study show, the use of STEM-based environmental education can make a significant contribution to the development of individuals in environmental issues. For this reason, it is suggested that studies investigating the effects of STEM-based environmental education on other environmental variables (awareness, attitude, behaviour...) should be conducted. In addition, in this study, STEM-based environmental education was carried out with only one group of pre-service teachers. It is suggested that experimental/quasi-experimental studies should be carried out with primary and secondary school students to determine the change in environmental literacy levels. In this way, additional findings can be obtained about the effectiveness of approaches that allow interdisciplinary interaction. Finally, STEM activities in the study were carried out with microcontroller sets. However, these sets are not easy to use. For this reason, it is also necessary to determine the advantages and disadvantages of using such digital sensors in STEM activities. Carrying out studies to overcome this deficiency may provide enlightening results about the use of these controller sets.

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