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The Effect of Problem-Based Learning on Middle School Students' Environmental Literacy and Problem-Solving Skills

Gülsüm Gök[1]*, Gökçe Boncukçu[2]

[1]Department of Mathematics and Science Education, Faculty of Education, Mersin University, Mersin, Turkey
[2]Ministry of Education, Mehmet Akif Ortaokulu, Adana, Turkey

*Corresponding author: glsmgk@gmail.com

ABSTRACT This study investigates the impact of the problem-based learning (PBL) model on middle school students' environmental literacy and problem-solving skills. A quantitative research study was conducted using a quasi-experimental design for this aim. The sample comprises 114 8th-grade students from a public middle school in Şanlıurfa, Turkey. Four intact classes were randomly assigned to experimental and control groups and instructed in sustainable development using the PBL model and curriculum-based instruction, respectively. Data were collected through the Environmental Literacy Questionnaire and the Problem Solving Skill Test and analyzed using Mixed-Between-Within ANOVA (Mixed-ANOVA) to assess the effectiveness of the instructional methods. The results revealed that PBL was more effective in developing environmental attitudes than curriculum-based instruction. However, it did not produce the same effect on environmental behavior. Furthermore, it can be asserted that PBL significantly enhanced students' problem-solving skills in the experimental group, while the scores of students in the control group remained unchanged. The implications of these findings were discussed. Given its positive outcomes, PBL is recommended for cultivating students with the requisite skills to become responsible citizens who can take action on environmental issues.

Keywords: Problem-based learning, Environmental literacy, Problem-solving, Sustainable development, Middle school, Education for sustainable development

1. INTRODUCTION

In the present century, indiscriminate consumption of natural resources, population increase, disrupted ecological balance, and other environmental issues have instilled concerns about the continuity of life. The globalization of environmental challenges and the apprehension regarding ecosystems have contributed to the importance of sustainability (Erten, 2003). In essence, sustainability conceptually denotes the perpetual preservation of life's continuity. Furthermore, sustainable development allows for the responsible utilization of natural resources while ensuring the satisfaction of the needs of future generations (McKeown, 2002; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2014). Concerning the current environmental problems, it is imperative to retain sustainable development to enable the resolutions within the framework of environmental education (Teksöz, Şahin, & Ertepınar, 2010).

The concept of environmental education emerged in conferences held in Stockholm, Belgrade, and Tbilisi. The United Nations Conference on the Human Environment in 1972 aimed to address concerns related to the environment and collectively seek solutions with various countries that participated from all over the world (Dadlı, 2017). Then, In 1975, the Belgrade International Workshop on Environmental Education aimed to establish a global community that collectively strives to resolve and prevent existing problems (Sağır, Arslan, & Cansaran, 2008). Later, The Tbilisi Declaration, prepared during the International Conference on Environmental Education in 1977 in Tbilisi, underscored the global significance of environmental education (Paul & Volk, 2002).

The importance of environmental education for achieving sustainable development was emphasized in the United Nations Conference on Environment and Development in 1992. Education for sustainable development was defined as "encompassing environmental education while placing it within the broader context of

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socio-cultural factors and socio-political issues such as equity, poverty, democracy, and quality of life" (UNESCO, 2004). Additionally, UNESCO stressed the need to find sustainable solutions to prevent future generations from facing environmental issues. In line with this, the period between 2005 and 2014 was declared the Decade of Education for Sustainable Development to ensure that future generations do not encounter environmental problems. In 2015, the United Nations Development Programme (UNDP) introduced the 2030 Agenda for Sustainable Development Goals (SDGs) with 17 main objectives that address ongoing environmental issues and political and economic challenges to be achieved within 15 years. Education for sustainable development plays a significant role in accomplishing these goals and building a more equitable, just, and sustainable world. The goal of education for sustainable development is to cultivate the necessary skills and knowledge that empower individuals to engage in critical self-reflection concerning their actions, considering their current and future impact on social, cultural, economic, and environmental dimensions, both at local and global levels (Tejedor et al., 2019).

Awareness of the importance of environmental issues and sustainability can be developed in individuals with well-developed problem-solving skills and environmental literacy. Problem-solving is the skill of thinking, analyzing to comprehend a problem and progressing through stages to formulate a solution. The most effective method to enhance students' problem-solving abilities involves integrating problem-solving techniques into educational tasks and exercises and allowing them to explore a problem (Goldschmidt & Smolkov, 2006; Seechaliao, 2017; Snyder & Snyder, 2008). Moreover, environmentally literate individuals are conscious of the limitations of natural resources, strive to use renewable energy sources, exhibit a specific sensitivity to environmental issues, and actively engage in environmental activities (Clacherty, 1992). Orr (1990) defines environmentally literate individuals as those who understand the impact of technological and social activities on the environment and can make decisions that favor the environment. The widespread cultivation of environmentally literate individuals, which is among the fundamental goals of environmental education, is also crucial for the future of education for sustainable development by understanding how natural systems operate in the world and how humans impact these systems because environmentally literate individuals can demonstrate the necessary sensitivity towards sustainable development (Teksöz et al., 2010). Within this context, environmental literacy is not limited to individuals possessing theoretical knowledge about the environment but also involves translating existing knowledge and skills into action (behavior) (Morrone, Mancl, & Carr, 2001). Some studies in the literature have aimed to determine students' environmental literacy levels at various levels of education, from primary school to higher education. These studies have examined different sub-dimensions such as environmental knowledge and skills, attitudes and behaviors towards the environment, and emotional tendencies (Kablan, 2019; Pe'er, Goldman, & Yavetz, 2007; Şahin, 2015; Timur, Timur, and Yılmaz, 2012; Yılmaz, 2019). Generally, cognitive and emotional dimensions are found to be at moderate to high levels, while the behavioral dimension tends to be lower. Variables such as gender and the environmental context in which individuals live have also been found to influence the existing levels. Additionally, although not abundant in number, studies involving non-classroom practices, argumentation, project-based learning, and similar methods have shown positive effects on environmental literacy (Benzer, 2010; Fettahlıoğlu, 2012; Karakaya, 2016; Kışoğlu, 2009; Yucasu, 2015).

The problem-based learning (PBL) model can be utilized in raising environmentally literate individuals with an education on the issue of sustainable development. Indeed, Maclean and Pavlova (2017) state that PBL stands out as a fundamental learning approach that should be employed to enhance the efficiency of environmental education. The PBL model is a teaching model based on a constructivist approach. PBL incorporates three main components: a problem situation as a stimulus for learning, the presence of a facilitating teacher, and collaborative group work (Dolmans, De Grave, Wolfhagen, & Van Der Vleuten, 2005). The problems upon which the learning process will be centered are real-life problems, which are ill-structured, complex, and open-ended open-ended. The PBL process starts when the student groups meet with the ill-structured problem scenario. Then, they illustrate the problem and generate the hypotheses for conceivable solutions. They seek more information to learn collaboratively and search various sources, such as the internet, books, or asking experts. At least, they evaluate the problem and the learning process and share their solution with other groups. The teacher's role is to guide students who take responsibility for their learning during the problem-solving process. This model was first applied in medical education. Then, it spread to various fields such as science, mathematics, engineering, architecture, and information technologies. In Education studies working with various age groups illustrate evidence of the effectiveness of PBL in cognitive processes like knowledge development and long-term retention, and higher-order thinking (Araz & Sungur, 2007; Liu, Liu, Pan, Zou & Li, 2019), affective skills such as motivation and attitude (Yew & Goh, 2016; Belland, Gu, Kim, Jaden Turner, & Mark Weiss, 2019; Liu et al., 2019), and skills as critical thinking and problem-solving skills (Musthofa, Prasetyo, & Purnomo, 2019). However, it is still essential to conduct more rigorous controlled experimental investigations to understand the effectiveness of PBL on middle school grades and the mechanisms behind how PBL works (Yew & Goh, 2016).

Additionally, in the literature, a limited number of studies have prepared an ill-structured problem within the framework of sustainable development and provided evidence of its impact on students' especially environmental literacy as well as other skills and knowledge (Febriasari & Supriatna, 2017). Moreover, developing authentic problems with proven effectiveness in sustainable development and other environmental issues for students is essential for environmental education (Ural & Dadli, 2020). Therefore, this study examines the effect of a problem-based learning model on 8th-grade students' environmental literacy and problem-solving skills in the context of Sustainable Development. In this aim, the following research questions were investigated:

1) Is there a significant effect of the Problem-Based Learning (PBL) model in the context of Sustainable Development on 8th-grade students' environmental literacy?

2) Is there a significant effect of the Problem-Based Learning (PBL) model in the context of Sustainable Development on 8th-grade students' problem-solving skills?

2. METHOD

2.1 Research Design

This study conducted the pretest-posttest control group quasi-experimental design (McMillan, 2000). Four intact classes with similar academic achievement averages in the Science course were randomly assigned as the experimental and control groups. Two classes were designated experimental groups, while the others were assigned control groups. In the experimental group, students learned about sustainable development using the Problem-Based Learning (PBL) method. In contrast, students in the control group received instruction through a method prepared following the curriculum and textbook. Before and after the treatment, both groups were measured for students' environmental literacy and problem-solving skills. Figure 1 represents the process of the experimental design.

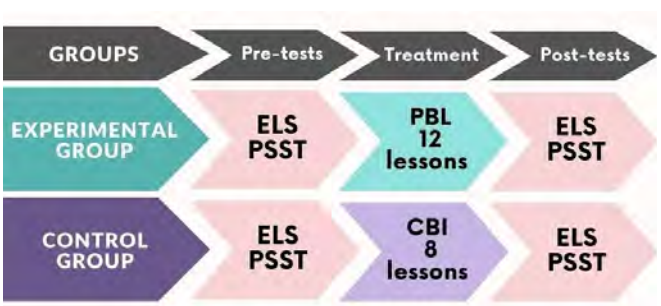

Figure 1 The experimental design of the research

2.2 Participants

The study participants were determined using the convenient sampling method for ease of access (Fraenkel & Wallen, 2012). The research study group consists of 114 8th-grade students who attended a middle school affiliated with the Ministry of Education in the city center of Viranşehir district in Şanlıurfa during the 2018-2019 academic year. The age range of the students is between 13 and 14 years old. Generally, the students were from middle-income families. There were 61 students in the experimental group (22 females and 39 males) and 53 in the control group (28 females and 25 males) sections.

2.3 Data Collection Tools

Environmental Literacy Scale for Middle School Students

The participants' environmental literacy was determined through the Environmental Literacy Scale for Middle School Students (ELS), developed by Yavuz, Kıyıcı, and Yiğit (2014). The scale covers 20 items on a 5-point Likert scale ranging from 'strongly agree' to 'strongly disagree'. Additionally, the scale comprises two dimensions: environmental attitude (10 items) and environmental behavior (10 items). The minimum score that can be obtained from the scale is 20, while the maximum score is 100. The scale's reliability was determined through Cronbach's alpha coefficient and reported as .84 for the total scale, while they were .82 (environmental behavior) and .79 (environmental attitude) for the dimensions. The Cronbach's alpha values obtained from this study were ranged between .81 and .90.

The Problem-Solving Skills Test

The researcher developed the Problem-Solving Skills Test (PSST) based on the example case scenario named 'Asuvan Dam' from Şenel's study (2010). Four open-ended questions were formulated for students to demonstrate their problem-solving skills related to this case. These questions encompass various stages of problem-solving, including problem identification, problem delimitation, explanation of the underlying causes of the problem, and the ability to provide various solutions. Expert opinions were sought for the problem and the subsequent questions, and the final version of the test was developed based on the feedback received. Additionally, ten middle school-grade students were piloted to assess the clarity of the text.

Scoring for the Problem Solving Skills Test was conducted using the Problem Solving and Performance Skill Grading Rubric developed by Lynch and Wolcott (2003) and adapted into Turkish by Sungur (2004). According to this rubric, the possible scores obtained per question from the test range between 0 and 5. For students to achieve a perfect score on this test, their skills must be at a sufficient level in various aspects of problem-solving: problem identification, overall approach to the problem, ability to organize information, ability to interpret information, and the capability to present different alternatives for solving the problem.

2.4 Treatment

The content of Sustainable Development was taught using the PBL model in the experimental group classes and the Curriculum-Based Instruction (CBI) in the control group classes. The related content, Sustainable Development, was a part of the 8th-grade Energy Transformations and Environmental Science unit. The study's second author conducted the applications in experimental and control groups.

Control Group

In the control group, students were instructed in Sustainable Development through Curriculum-Based Instruction (CBI) for two weeks, consisting of 8 lessons. During the courses, videos emphasizing the importance of conservation, photographs depicting examples of non-renewable energy consumption in daily life leading to environmental degradation, and guiding questions for discussions were used. Subsequently, the teacher used an expository approach to address examples of conservation and environmental issues found in the textbook in detail. Group work was conducted on an activity related to ways to use natural resources efficiently. Students made presentations on topics such as deforestation, air pollution, and the decrease in species diversity. The presentations varied in format, including posters, slides, and displays, and all groups prepared their work based on the science textbook. In the following weeks, the topic of Sustainable Development continued with a focus on recycling, and it was completed through lectures, question-answer sessions, and discussion methods.

Experimental Group

In the experimental groups, the process involving the PBL model was completed over three weeks, consisting of 12 lessons. During this process, students were challenged with an ill-structured problem to solve collaboratively while using technology effectively.

Ill-structured Problem

This study utilized a problem scenario called "Mysterious Island," encompassing ten chapters. The researchers developed the scenario, and opinions were sought from four experts, two of whom were doctoral-level faculty members, while the other two were science teachers. Necessary revisions were made based on their feedback. The scenario revolves around a scientific team's shipwreck on a mysterious island in the ocean, where they investigate the reasons behind the drought and collapse on the island by tracing the traces of the civilization that once existed there. Information provided to students in each new section is designed to help shape their previous ideas and hypotheses. Through scientific findings, tables, and graphics included in the scenario, the goal is for students to grasp the importance of sustainable development by the end of the process and to make generalizations and inferences from the island scale to the world. The problem scenario and implementation details can be accessed from Boncukçu and Gök's study (2023).

Collaborative Learning

Initially, students were placed in groups of five, with roles assigned such as writer, reader, and various roles representing scientists in the scenario. Starting from the first section, each group engaged with the problem and formulated hypotheses for the solution. As the sections progressed, students shaped their identified problems and developed hypotheses, conducted individual and group research outside of school, and attempted to generate solutions through group discussions. Throughout the process, they filled out a KWLH table containing headings such as "What we know?, What we need to know?, Learned., and How we learnt it?" The teacher encouraged students to think critically, conduct research from reliable sources, understand the problem, and formulate hypotheses through group discussions. At the end of the process, a lesson was held where students presented their learning progression and proposed solutions. A discussion environment was created during this lesson to facilitate knowledge exchange among all groups.

Effective Technology Use

Throughout the process, students used the internet to research and gather more information about the data and evidence provided in the scenario. Some of the groups created their presentations and posters using presentation software as well as web-based design environments. In the final lesson, an online meeting through the internet was established with an environmental engineer, allowing students to ask questions about the topic and gain insights into the importance of sustainable development for the future of the world and life.

2.5 Data Analysis

Statistical analysis in the study was conducted using Mixed Between-Within Analysis of Variance (Mixed-ANOVA). This analysis is used because it combines between-group and within-group variables within a single analysis. It is suitable to be applied in pretest-posttest control group quasi-experimental designs. It tests whether there are main effects for each independent variable and whether the interaction between the two variables is significant (Pallant, 2020). The SPSS 21 package program analyzed the data, and the statistical significance level of the research was set at .05. In the analysis, the variable "group" represented the comparison between the experimental and control groups' scores, reflecting the between-group differences. Additionally, the variable "time" signified the comparison within each group, comparing the pre-test and post-test scores to assess within-group changes.

As follow-up analyses, pairwise comparisons were conducted extensively to examine the differences within and between groups. Pairwise comparisons between groups were performed to determine whether there were differences between the experimental and control groups concerning problem-solving scores and environmental literacy dimensions, environmental attitude, and environmental behavior scores. Additionally, changes within each group from pre-test to post-test were interpreted using within-group pairwise comparisons. The Bonferroni adjustment was applied to lower the risk of Type I errors that may arise when conducting multiple analyses on a dataset.

The necessary assumptions for mixed ANOVA were preliminarily tested for each analysis (Pallant, 2020). Skewness and kurtosis coefficients of the data (-3 to +3 range) indicated that the distributions were normal. Homogeneity of variances was assumed for both pre-test and post-test scores of all variables ($p > .05$). Moreover, the significance values for the Box Test of Equality of Covariance Matrices table were found to be ranging from .03 to .05 ($p > .001$).

3. RESULT AND DISCUSSION

3.1 Findings Regarding the Environmental Attitude Dimension of ELS

The results obtained through mixed-ANOVA for environmental attitude scores are presented in Table 1.

The interaction of the two independent variables (time and group) appeared to be statistically significant ($F = 5.64$, $p < .05$, Wilk's $\Lambda = .95$, Partial $\eta^2 = .05$), indicating a moderate effect size (Cohen, 1988). Since the interaction effect is significant, it is not reasonable to interpret the main effects of the independent variables. Therefore, pairwise comparisons were conducted as recommended for further analysis (Pallant, 2020). The result of the pairwise comparison conducted to compare the differences between the pre-test and post-test scores within each group are presented in Table 2.

As seen in Table 2, there is not a statistically significant mean difference between the pre-test ($\bar{X}$=4.24, SD = .94) and post-test ($\bar{X}$=4.50, SD =.70) scores of the experimental group for environmental attitude dimension (p=.07, η^2=.03). Similarly, in the control group, there is no significant difference between the pre-test ($\bar{X}$=4.28, SD =.79) and post-test ($\bar{X}$=4.05, SD =.97) scores for this dimension (p=.14, η^2=.02). Considering the differences in means over time, it can be concluded that both of the interventions in the experimental group and the control group caused a small effect on improving the environmental attitude towards environment scores of students.

The results of pairwise comparisons comparing the pre-test and post-test scores between the groups are presented in Table 2. There is no significant mean difference between the pre-test scores of the experimental group ($\bar{X}$=4.24) and the control group ($\bar{X}$=4.28) (p=.82, η^2 =.00), indicating a low effect size. However, a statistically significant mean difference was observed between the post-test environmental attitude scores of the experimental group ($\bar{X}$=4.50), and the control group ($\bar{X}$=4.05) (p=.01, η^2=.07), indicating a moderate effect size.

Figure 2 presents the change over time in the mean score for both groups. As seen in the graph, while the students in the experimental group showed an increase in environmental attitude scores, the control group scores decreased. However, these differences were not statistically

Table 1 Mixed-ANOVA results for environmental attitude scores

	Wilk's Λ	F	p	η2
Interaction (Time x Group)	.95	5.54	.02*	.05
Time	1.0	0.3	.87	.00
Group		2.74	.10	.02

* p < .05

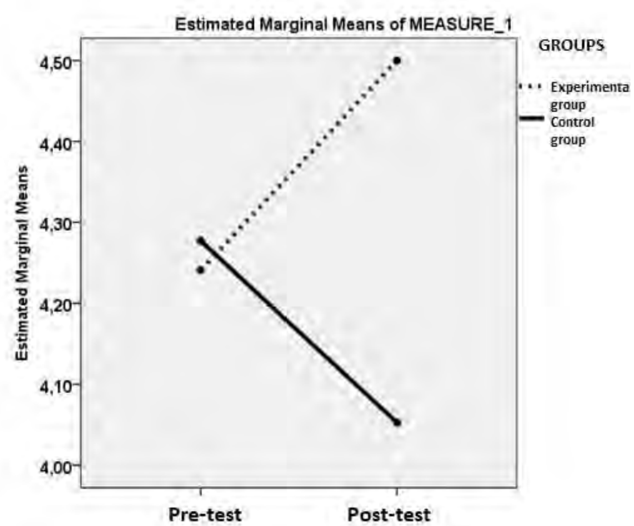

Figure 2 The changes in the mean scores of student's environmental attitudes in groups

Table 2 Pairwise comparisons between and within groups on environmental attitude scores

Groups	Comparison	Mean Difference	Standard Error	p	η2
Within Groups	EG (pre-test – post-test)	-.26	.14	.07	.03
	CG (pre-test – post-test)	.23	.15	.14	.02
Between Groups	Pre-test (EG – CG)	-.04	.1	.82	.00
	Post-test (EG – CG)	.45	.16	.01*	.07

* p < .05 (Bonferroni adjustment applied)

significant. On the other hand, this change over time has led to a statistically significant difference between the post-test scores of the groups. That is, it has been observed that students who continued with the PBL model showed positive improvements in their environmental literacy attitudes. Students examined various environmental issues throughout the scenario while identifying problems and proposing solutions. Towards the end of the scenario, they had the opportunity to learn about sustainable development by comparing the island's experiences with those of the world. In the scenario's conclusion, discussions were held about individual and collective actions needed to protect the world from the challenges the island faced. This may have contributed to students internalizing environmental issues and fostering positive environmental attitudes.

Consequently, it can be concluded that the PBL model positively impacted students' environmental attitudes. Enhancing students' environmental attitudes occurs as they encounter real-life problems in these issues (Bergman, 2016). According to Amin, Utaya, Bachri, Sumarmi, and Susilo (2020), PBL fosters students' environmental attitude as the problem-solving process in PBL motivates students to show concern for their environment. Through such processes, students recognize their responsibility to preserve the environment (Wesnawa, Christiawan, & Suarmanayasa, 2017). PBL compels students to deal directly with environmental problems, fostering a deeper connection to the environment as they witness its disruption and the potential impact on living things, thereby elevating their environmental attitude (Roshayanti, Candra Wicaksono, & Budi Minarti, 2019).

Moreover, continuously solving problems enhances their environmental attitudes (Zecha, 2010). These results are similar to other constructivist approaches. Coertjens, Boeve-de Pauw, De Maeyer, and Petegem (2010) state that schools adopting a constructivist approach to teaching science tend to have students with greater environmental awareness, and engaging in environmental learning activities is connected to students developing more pro-environmental attitudes. Similarly, various studies have reported evidence of significant development in students' environmental attitudes due to environmental education with a constructivist approach (Ajiboye & Olatundun, 2010; Benzer, 2010; Bögeholz, 2006; Carrier, 2009; Dienno & Hilton, 2005; Kadji Beltran, Barker, & Rager, 2001).

3.2 Findings Regarding the Environmental Behavior Dimension of ELS

The mixed-ANOVA results for environmental behavior scores are presented in Table 3.

As seen in Table 3, the results indicated no statistically significant interaction between time and groups $F = .02$, $p > .05$, Wilk's $\Lambda = 1.0$ Partial $\eta^2 = .00$. Moreover, the main effect of time was not statistically significant, indicating no difference between pre-test and post-test scores, $F = 2.5$, $p > .05$, Wilk's $\Lambda = .98$, Partial $\eta^2 = .02$. Similarly, the main effect of the group was not statistically significant, meaning there was no difference between groups $F = .14$, $p > .05$, Partial $\eta^2 = .00$.

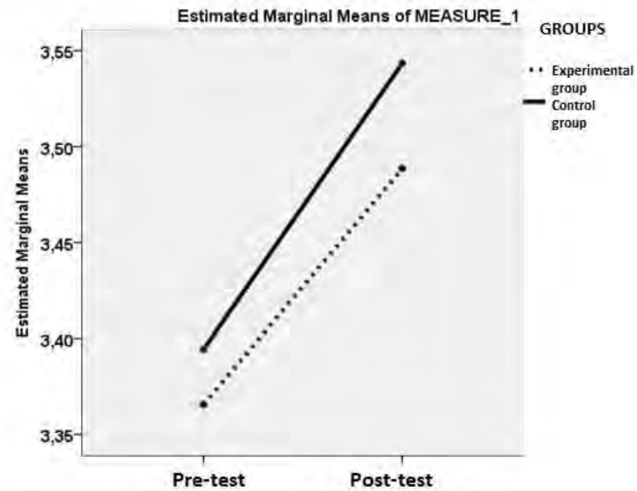

Figure 3 The changes in the mean scores of student's environmental behavior in groups

Figure 3 shows that the mean environmental behavior scores of students in the experimental group increased slightly from the pre-test ($\bar{X}$=3.37, SD =.76) to the post-test ($\bar{X}$=3.49, SD =.64). Likewise, a slight difference was observed in the pre-test ($\bar{X}$=3.39, SD =.85) and post-test ($\bar{X}$=3.54, SD =.75) scores of the control group students. Considering the relatively short duration of this study and the fact that behavioral changes often require more time to become evident, it can be concluded that this model may not have had the intended impact on students' behavior. Additionally, since students were introduced to PBL for the first time, they may have mainly concentrated on enhancing their knowledge and skills during the application. Environmental behavior is human responses to environmental problems (Abun & Agout, 2017). Dealing with problems will trigger increasing awareness and attitude, leading to acting and taking responsibility. In this context, Erten (2003) pointed out that in environmental education, increases in knowledge initially influence emotional skills, and the development of these emotional skills over time can lead to changes in behavior. Considering today's environmental problems and the future consequences that will be faced, encouraging

Table 3 Mixed-ANOVA results for environmental behavior scores

	Wilk's Λ	F	p	η2
Interaction (Time x Group)	1.0	.02	.88	.00
Time	.98	2.50	.12	.02
Group		.14	.71	.00

individuals and communities to adopt positive environmental behaviors is now of greater importance than before (Abun & Agout, 2017). As seen in Figure 3, both groups indicated an increase in their environmental behavior scores. Education brings knowledge and awareness, leading individuals to prioritize social well-being and adopt more environmentally conscious behavior (Meyer, 2015).

3.3 Findings Regarding the Problem Solving Skills

The Miedx-ANOVA results investigating the effect of treatment on students' problem-solving skills are shown in Table 4.

The results indicated a statistically significant interaction effect of time and group variables on problem-solving skills scores with a high effect size (F = 37.1, p < .05, Wilk's Λ = .75, η^2 = .25). Since there was a significant interaction effect, the main effects were not interpreted. Follow-up analyses were conducted to investigate between- and within-group comparisons for mean scores (Pallant, 2020). The pairwise comparison results are shown in Table 5.

The pairwise comparison revealed that there is a statistically significant mean difference between the pre-test ($\bar{X}$=2.67, SD = 1.63) and post-test ($\bar{X}$=5.0, SD =2.12) scores regarding experimental group students' problem-solving skills (p=.00, η^2=.46). On the other hand, there is no significant mean difference between the pre-test ($\bar{X}$=2.70, SD =1.72) and post-test ($\bar{X}$ =2.90, SD =1.46) scores of control group students' problem-solving skills (p=.16, η^2=.01). Considering the differences in means over time, it can be concluded that PBL in the experimental group caused a significant effect on improving students' problem-solving skills.

Between-group comparisons showed that there is no significant mean difference between the pre-test scores of the experimental group ($\bar{X}$ =2.67) and the control group ($\bar{X}$ =2.70) (p=.93, η^2 =.00). However, a statistically significant mean difference was observed between the post-test problem-solving skill scores of the experimental group ($\bar{X}$=5.00), and the control group ($\bar{X}$=2.90) (p=.00, η^2=.25), indicating a high effect size. The change in the mean scores over time for each group can be seen in Figure 4.

Table 4 Mixed-ANOVA results for problem-solving skill scores

	Wilk's Λ	F	p	η2
Interaction (Time x Group)	.75	37.1	.00*	.25
Time	.69	51.3	.00*	.31
Group		13.9	.00*	.11

* p < .05

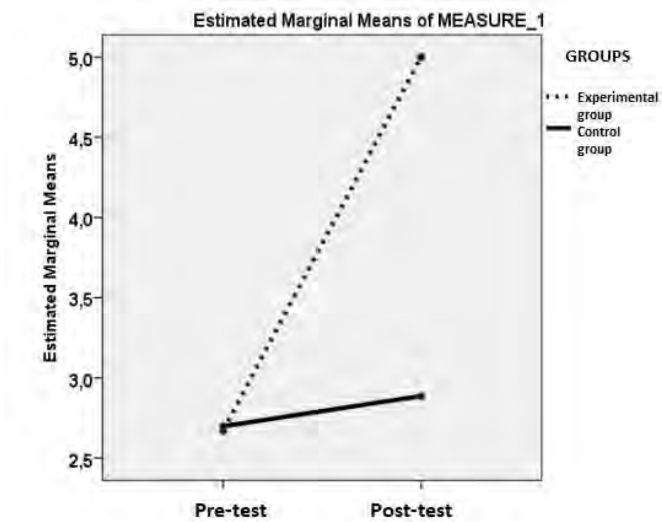

Figure 4 The changes in the mean scores of student's problem-solving skills test in groups

As seen in the graph, while the students in the experimental group showed a significant difference and development in the problem-solving scores, the control group scores did not change. In the PBL model, the problems students work on are ill-structured, meaning they have a complex structure with no clear and single answer that can generate different meanings, ideas, and solution proposals. This complexity allows for different interpretations, ideas, and possible solutions. Moreover, PBL creates an environment where students can engage in the analysis of real-life problems. They learn to identify the necessary information, pick the proper problem-solving method, and develop a problem-solving understanding (Kalaycı, 2001). Challenging students with a problem to solve provides them an environment for learning as they analyze, synthesize, design, and evaluate information (Bath, Smith*, Stein, & Swann, 2004). This study has allowed students to become familiar with the steps they need to take when faced with a problem and has contributed to the development of their problem-solving skills. Allowing students to understand the structure of a problem, choose

Table 5 Pairwise comparisons between and within groups on problem-solving skill scores

Groups	Comparison	Mean Difference	Standard Error	p	η2
Within Groups	EG (pre-test – post-test)	-2.33	.24	.00*	.46
	CG (pre-test – post-test)	-.19	.26	.16	.01
Between Groups	Pre-test (EG – CG)	-.03	.31	.93	.00
	Post-test (EG – CG)	2.11	.35	.00*	.25

* p < .05 (Bonferroni adjustment applied)

a method for its solution, and interpret the findings facilitates their ability to use the same skills when faced with a similar situation (Üstündağ & Beşoluk, 2012). The studies conducted in the literature also support the effectiveness of PBL as a method for enhancing problem-solving skills (Aktı Aslan, 2019; Argaw, Haile, Ayalew, & Kuma, 2017; Gibbings, Lidstone, & Bruce, 2008; Orrill, 2002; Özcan, 2013; Reynolds & Hancock, 2010).

4. CONCLUSION

This study revealed that implementing sustainable development concepts through the PBL model enhances students' environmental literacy and problem-solving skills. Based on the findings, it can be concluded that the PBL model was more effective in instilling environmental attitudes than curriculum-based instruction. However, it did not have the same effect on the environmental behavior. It is suggested that more studies be conducted to investigate the change in the student's behavior. Moreover, the PBL model improved the problem-solving skills of the experimental group students, while the scores of the control group students remained unchanged. Considering its positive effects, PBL should be implemented in classrooms to enhance students' environmental literacy and problem-solving skills, thus fostering their awareness of and responsibility for sustainable development. Additionally, it may be beneficial for classroom environments to be technologically equipped with resources that enable students to conduct research and communicate with experts. Adjusting the classroom setting to focus on PBL may produce more positive outcomes.

On the other hand, the study has several limitations. First, implementing a learning activity centered around ill-problems is time-consuming compared to the traditional methods. The teachers and researchers need to consider this in planning the implementation. Spending more time dealing with environmental issues may lead to better outcomes for the experimental groups. Moreover, the PBL process requires a teacher's expertise for effective facilitation, guidance, and feedback. Training about this model may be suggested for the pre-service and in-service teachers. The final limitation of the study is that the results are specific to 8th-grade middle school students in public schools. Future research could investigate the effects of PBL on students with different characteristics.

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Abbreviations

PBL, Problem-Based Learning; CBI, Curriculum-Based Instruction; ELS, Environmental Literacy Scale for Secondary School Students; PSST, Problem-Solving Skills Test; SDGs, Sustainable Development Goals; UNDP, United Nations Development Programme.