RESEARCH ARTICLE

The effectiveness of STEM Project-Based Learning in improving students' environmental literacy abilities

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Abstract: This study aimed to determine the difference in environmental literacy skills between the Project-Based Learning (PjBL) learning model and STEM-based PjBL. This research is quantitative research with a quasi-experimental method. The research design used is a non-equivalent pretest-posttest control group design. The dependent variable in this study is environmental literacy skills. The population in this study were all grade X students of State Senior High School (SHS) 7 of Surakarta in the 2023/2024 academic year. The sampling technique used was cluster random, tenth grade (X) A and B. A class consists of 36 students, as a control, using the PjBL model whereas as many as 35 students in B class is an experimental group was learned using the STEM-PjBL model. The data collection technique was carried out using pretest and posttest on the research sample. Data analysis technique using ANCOVA test. Instrument validation techniques using validity tests and reliability tests. The test results using ANCOVA have a significance value of <0.05, indicating differences in students' environmental literacy skills between the implementation of PjBL and STEM-PjBL. These results show that implementing the STEM-PjBL model was superior compared to PjBL only. It can be seen from the difference in learning outcomes of the control class, within the pretest and posttest, which showed an increase of 10.16%. In comparison, the experimental class results showed an increase of 16.94%. STEM-PjBL also helps students to be able to improve their environmental literacy skills in terms of knowledge, cognitive skills, attitudes, and behavior toward environmental problems.

Keywords: environmental literacy skills; environmental pollution; project-based learning; STEM

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Introduction

Environmental destruction is an increasingly worrying global issue with serious impacts on human health and various ecosystems (Amoah & Addoah, 2021; Sadhu et al., 2018). The current environmental problems are also very complex, starting from land, water, and air pollution. Pollution in various areas is mainly caused by urbanization and industrialization (Sarker et al., 2021). The factory industry contributes a lot of waste in the form of toxic pollution fumes released into the air (Deckanio et al., 2023), dangerous liquid waste that causes river pollution, and huge amounts of residual waste. Urbanization in Indonesia is also experiencing a significant increase, which can indirectly cause air pollution and household waste. Domestic waste deposits waste sourced from daily community activities, both organic and non-organic waste (Mahyudin & Herlintama, 2023; Pangestu et al., 2017).

The results of interviews with high school teachers in Surakarta and analysis of student learning outcomes show that the majority of students do not have an adequate level of environmental awareness, namely only around 60%. Most students are less aware of the importance of environmental problems and their impact on daily life. Education to instill self-awareness regarding the threat of environmental problems is very necessary to form the character of students who care about the surrounding environment (Kaya & Elster, 2018; Masturoh & Ridlo, 2020).

Implementation of the *Kurikulum Merdeka* is a means of increasing student participation in the learning process. Apart from that, this curriculum is also designed to increase students' freedom to choose

subjects and learning projects in the hope of increasing their learning motivation. This flexibility allows for a learning process that is relevant to real life and encourages students to be more creative and solve problems. In addition, this curriculum emphasizes character development and 21st century competencies such as critical thinking, collaboration, communication, and environmental literacy to face global challenges.

Students often have a limited understanding of environmental issues and how to overcome them, making it difficult to plan a clean and effective environment (Koyama & Watanabe, 2023). Students' environmental literacy skills can be improved to be more aware and proactive in protecting the environment. Environmental literacy is an individual's skill in recognizing and analyzing the condition of the surrounding environment well (Cole, 2019). One learning model that provides opportunities for student participation is Project Based Learning (PjBL). The PjBL model guides students to discuss and collaborate in studying and understanding environmental issues and dealing with problems in the environment by formulating solutions (Indranuddin et al., 2024; Ramadhana et al., 2022).

STEM-PjBL is an educational model that merges Science, Technology, Engineering, and Mathematics (STEM) with project-oriented tasks (Alkautsar et al., 2023; Muttaqiin, 2023). STEM-PjBL is characterized by an Engineering Design Process (EDP), the implementation of EDP involves a cycle that starts with defining the problem, learning scientific concepts, planning solutions, trying out the solutions that have been made, and making decisions (Tank et al., 2018). The PjBL-STEM syntax includes (1) reflection, (2) research, (3) discovery, (4) application, and (5) communication (Laboy-Rush, 2011).

Amid global climate change and increasingly pressing environmental problems, students need to have a strong understanding of these problems so they can play an active role in responding to these challenges (Ekene & Oluoch-Suleh, 2015; Siew & Ambo, 2018). Previous research examining the effect of applying STEM-PjBL on students' environmental literacy skills is still very limited, especially in the context of teaching environmental pollution material (Alkautsar et al., 2023; Indranuddin et al., 2024). Based on the background description, several problems can be seen, including students still having difficulty in overcoming environmental problems, designing real solutions, and students' lack of motivation in learning about the environment. Environmental pollution problems if they do not see its direct relevance to everyday life. The formulation of the problem in this research is whether there are differences in environmental literacy skills in environmental pollution material for the class. This research aims to determine differences in environmental literacy skills regarding environmental pollution in class.

Method

This research uses a quantitative approach, which is based on the philosophy of positivism or methods used to examine samples and certain populations, data collection using research instruments, quantitative data analysis, and as a hypothesis tester that has been applied (Sugiyono, 2015). The type of research is quasi-experimental with a non-equivalent pretest-posttest control group design to investigate the effectiveness of STEM- PjBL implementation in improving students' environmental literacy skills on environmental pollution material. The research design consisted of two classes, class A as a control class and X B as an experimental class. The layout of the research plan can be found in Table 1.

Table 1. Research design

Class group	Pretest	Independent Variable	Posttest
STEM-PjBL	P1	X1	P2
Project Based Learning	P1	X2	P2

Information:
P1: Implementation of a pretest of environmental literacy skills
P2: Implementation of the posttest on environmental literacy skills
X1: Implementation of learning by teaching STEM-PjBL
X2: Implementation of PjBL learning without being STEM

The research population is a generalization area of both subjects and objects that have certain characteristics that have been determined by the researcher (Sugiyono, 2015). The population in this study were all grade X students of public high schools in Surakarta in the 2023/2024 academic year, consisting of 10 classes. The research was conducted in February - March 2024.

The samples used in this study were students with a total of 72 students divided into two classes, X A and X B, which were randomly selected using the cluster random sampling technique. This research was conducted with class X B given treatment, namely by applying STEM-based PjBL while class X A as a

control (only using PjBL). All samples used environmental pollution material. The research sample is presented in Table 2.

Table 2. The sample class

Class Sample	Treatment	Number of Students
X A	Control class with PjBL learning model	36
X B	Treatment class with STEM-PjBL model	35

Sample determination was carried out using the cluster random sampling technique. This technique is a sample selection technique that is carried out randomly per class and not individually, namely from 10 classes taken so that two classes are obtained to be used in research. The class selection was carried out using two tests, namely homogeneity and normality. The data used in calculating these two tests is the last daily assessment data for biology material. The normality test using Kolmogorov-Smirnov shows that the five classes have a normal distribution, including XA, XB, XD, XE, and XG with the significances are 0,102, 0,109, 0,139, 0,106, and 0,134 respectively. Furthermore, the Levene test shows Sig. (0.096) > 0.05 so that the entire population has a homogeneous variance. The results of the prerequisite test were then used to test class equality using SPSS 27 to determine one class as the control group (XA) and the other class as the treatment group (XB).

The data-gathering methods involved examinations and observations. For this study, pretest and posttest evaluations were employed. The pretest was administered to students before any intervention to gauge their environmental literacy levels. Following the intervention, students underwent a posttest to evaluate their environmental literacy skills. There were 20 multiple-choice questions with five Likert scales used to test students' abilities. The test instrument used the modified Middle School Environment Literacy Survey/Instrument (MSELS/I) by Nastoulas et al (2017). The indicators studied were four indicators of students' environmental literacy skills according to Hollweg et al (2011), i.e. knowledge, attitude, cognitive skills, and behavior. The observation technique of this research is to understand and assess whether the implementation of the STEM-PjBL model is going well or not. Observations are made by observers and then reported using a validated observation sheet.

The validity of this research uses the Rasch Model. This validity test was conducted using Winstep software. According to Boone et al (2014), the items are proven valid if they have at least two of the criteria 0.5 < MNSQ < 1.5, -2.0 < ZTSD < +2.0, and or 0.4 < CORR < 0.85. Based on the validity test, shows that all items are declared valid. Reliability criteria according to Arikunto (2013) are presented in Table 3. The reliability test in this study used the Rasch Model. The results of the reliability test showed that the Item Reliability value (0.65) > 0.65 so that all the items were declared reliable.

Table 3. Reliability criteria

Reliability Index	Criterion Interpretation
0.80 – 1.00	Very High
0.60 – 0.79	High
0.0 – 0.59	Medium
0.20 – 0.39	Low
< 0.20	Very Low

Hypothesis testing in this study is by utilizing the ANCOVA analysis test. ANCOVA technique is an analytical test technique to determine the difference between two treatment groups in the presence of covariates with a significance level of 0.05. Ho states that there is no difference and H. there is a difference in improving students' environmental literacy skills with the application of the STEM-based PjBL model. If the test result is sig. > 0.05 then Ho is accepted so that there is no difference in improving students' environmental literacy skills with the application of the STEM-based PjBL model. However, if sig. <0.05 then H_1 is accepted so that there is a difference in improving students' environmental literacy skills with the application of the STEM-based PjBL model. Before hypothesis testing, normality and homogeneity tests were conducted. The normality test that will be applied in this study is the Shapiro-Wilk test. Normal data is data with sig. > 0.05. The homogeneity criteria in this study used Levene's Test. If the data obtained has a significance value > 0.05 then it is considered homogeneous.

Results and Discussion

Environmental literacy abilities were measured using a literacy ability test with indicators proposed by (McBeth & Volk, 2010). The test was carried out for 60 minutes with 20 multiple-choice items and a 20-item Likert scale questionnaire. Categorization of environmental literacy skills using environmental literacy skills categories according to McBeth et al (2011) is segmented into low (0-20), medium (21-40),

and high (41-60) ranges categories. Data from measuring students' environmental literacy abilities in the control class using the PjBL model and its categorization are presented in Figure 1.

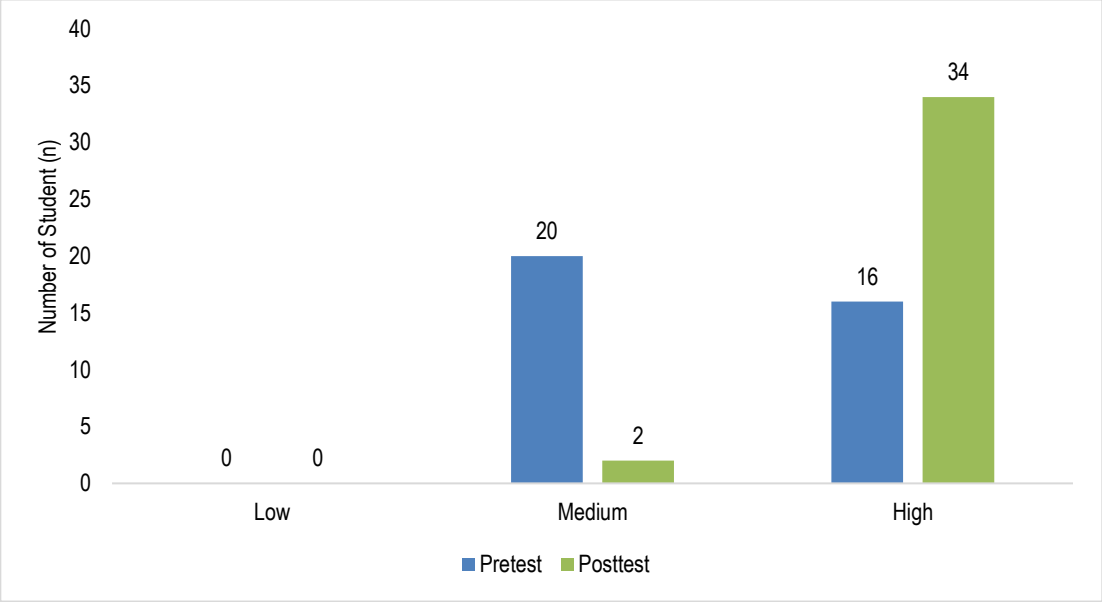


Figure 1. Pretest and posttest scores on environmental literacy in control class (XA)

Based on Figure 1, the pretest results show that 20 students have moderate environmental literacy skills and 16 students have high environmental literacy skills. Posttest data shows that there are no students with low literacy skills, as many as two students have moderate environmental literacy skills and 34 students have high environmental literacy skills. The data on the results of measuring students' environmental literacy skills in the experimental class using the STEM-PjBL model are presented in Figure 2.

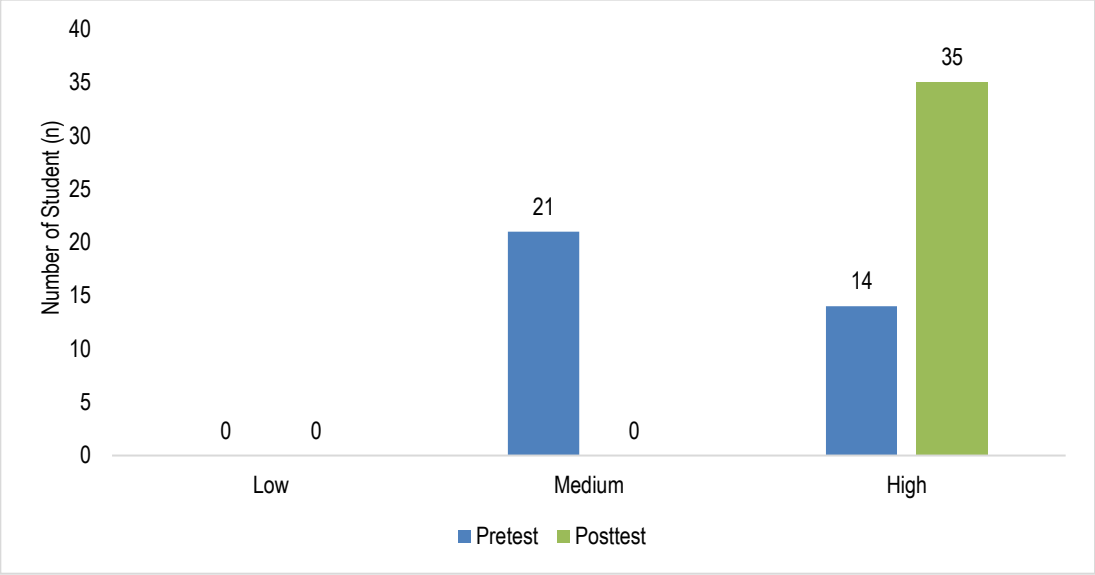


Figure 2. Pretest and Posttest Scores for Experimental Class (XB) Environmental Literacy Ability with STEM-PjBL

Based on the pretest results, 21 students had moderate environmental literacy skills and 14 students had high environmental literacy skills. Posttest data showed that there were no students who had low or moderate environmental literacy skills, while all 35 experimental class students had high environmental

literacy skills. Key elements of environmental literacy abilities encompass knowledge, cognitive skills, attitude, and behavior.

The sample in this study consisted of two classes, namely the PjBL control class and the STEM-PjBL experimental class. The calculation of the pretest data distribution of environmental literacy skills is shown in Table 4. The distribution of environmental literacy post-test data is shown in Table 5.

Table 4. Distribution of student pretest scores

	Control Class (PjBL)	Experimental Class (STEM-PjBL)
Mean	72.06	71.66
Standard Deviation	5.860	5.308
Median	72.00	72.00
N	36	35

Table 5. Distribution of student posttest scores

	Control Class (PjBL)	Experimental Class (STEM-PjBL)
Mean	82.22	88.60
Standard Deviation	7.140	2.953
Median	83.50	89.00
N	36	35

Comparisons on each aspect of environmental literacy skills were made by comparing pretest and posttest scores in each class based on Mcbeth et al (2008) scoring. The maximum score of each aspect is 60, so the comparison can be done by simplifying each score result by dividing by 10. The average difference of each aspect in each class is presented in Figure 3.

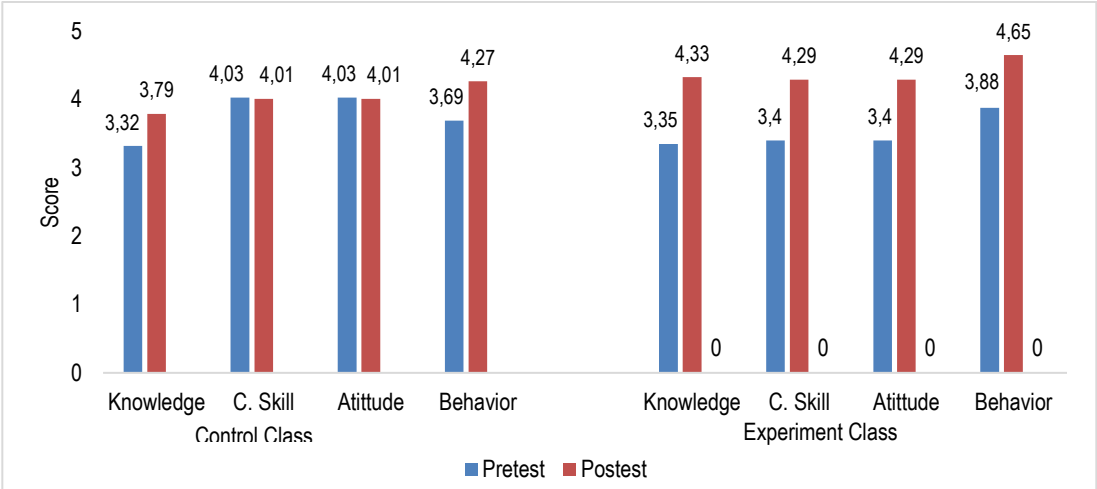


Figure 3. Average of each aspect of students' environmental literacy abilities in the control class (PjBL) and experimental class (STEM-PjBL)

Based on Figure 3, the pretest results show that the average environmental literacy ability of students in the Knowledge aspect in the control class is 3.89 while the experimental class is 4.02. The posttest results increased where the average in the control class was 4.55 while the experimental class was 5.19. In the Cognitive Skill aspect, the control class was 4.83 while the experimental class was 4.07. The post-test results decreased slightly in the control class by 4.81. However, the experimental class experienced an increase of 5.41. The pretest on the Attitude aspect in the control class was 4.42 while the experimental class was 4.69. As for the post-test results, the average increase in the control class was 5.12 while in the experimental class, it was 5.57. The pretest results on the Behavior aspect of the control class were 4.08 while the experimental class was 4.45. As for the posttest results, there was an increase in the value in the control class of 5.20 while in the experimental class of 5.35.

This research uses the ANCOVA test at a significance level of 0.05. The covariance analysis technique is a linear model using a continuous dependent variable (quantitative) where the independent variable is categorical (qualitative). The ANCOVA test criteria are if $F_{count} < F_{table}$ and the sig value. > 0.05. The results of hypothesis testing using ANCOVA are presented in Table 6.

Table 6. ANCOVA test results

Source		ANCOVA Test		
		Sig.	Decision	Description
Environmental Literacy Ability	Learning Model	0,000	Sig. < 0,05	H_0 is rejected

The test results in Table 3 show that the significance level is <0.050. The conclusion of the test results is Ho is rejected, meaning that there is a difference in students' environmental literacy skills between the application of the PjBL learning model and STEM-PjBL. The conclusion obtained from the test is Ho is rejected, meaning that there is a significant difference in students' environmental literacy skills between the application of the PjBL model and STEM-PjBL. The difference is that the STEM-PjBL model can help students improve their environmental literacy skills, especially in the aspects of knowledge, cognitive abilities, attitudes, and behavior.

PjBL is one of the models that applies the student-centered method. The project applies real problems as a context so that students can learn and be able to improve their thinking skills in problem-solving efforts by doing project-based activities. Project-based learning is an innovative student-centered learning by places the teacher as a facilitator and motivator (Hira & Anderson, 2021; Taskiran, 2021). The PjBL learning syntax according to Zulyusri et al (2023) encompasses (1) Identifying the crucial aspects, (2) crafting a project plan, (3) establishing a timetable, (4) supervising both students and project advancement, (5) appraising the results, and (6) analyzing the overall experience.

(a) (b)

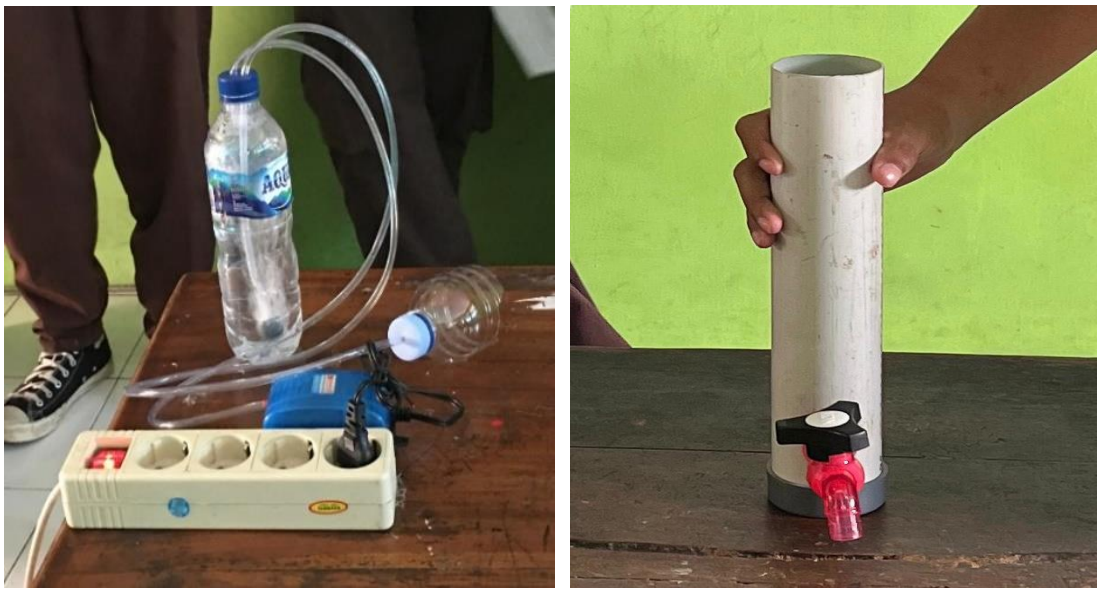
Figure 4. Example of control class project results, (a) Simple sound damper, (b) Simple water filtration

figure 4 is one of two projects made by students in class xa (control). sound-dampening devices can function to reduce or reduce the intensity of sounds and noise that occur. simple soundproofing devices can use simple materials such as egg cartons, foam, and so on. there are also passive and more complex sound absorption media, such as resonators, which minimize noise by converting it into resonator vibrations (sujon et al., 2021). meanwhile, water filtration is a tool that functions to filter or remove contaminants in water by using barriers or media, whether physical, chemical, or biological processes. water filtration can be created by detailing the construction of small-scale water filters using recycled aggregates (verma et al., 2024).

apart from that, the caring attitudes and behavior shown during problem analysis and project evaluation by students have increased, this is demonstrated by problem-solving abilities and the creation of good projects. the use of PjBL has a significant influence on students' active involvement and creativity in solving complex project problems by producing real products (Suciani et al., 2018). making projects can help students increase their active and creative role. PjBL helps students to improve their environmental literacy skills in terms of knowledge, cognitive skills, attitudes, and behavior toward environmental problems.

STEM-PjBL not only fosters problem-solving skills in students but also inspires them to design, create, and utilize technology, fostering the development of cognitive, emotional, and practical knowledge

(Ramadhana et al., 2022). the pjbl syntax according to Laboy-rush (2011) is reflection, research, discovery, application, and communication. STEM-based learning can equip students with the ability to utilize their knowledge to generate problem solutions to their environment using technology. in addition, this model encourages students to become active participants in learning, promoting problem-solving, critical thinking, collaboration, and communication skills (Maulana, 2020).



(a) (b)

Figure 5. Examples of experimental class project results, (a) Simple air filtration, (b) Simple water filtration

Figure 5 is one of the two projects made by students in class XB (experiment). An air filtration device is a device that works to reduce the amount of dirty air intensity around it, an example of air filtration can be a breathing apparatus. Simple air filtration devices can use simple materials such as aerators, bubble-breaking balls, hoses, and tubes or bottles. Accurate and comprehensive modeling of filtration will not only aid the creation of more efficient filters but also facilitate the production of engineered solutions, allowing for the customization of filters tailored to specific pollutants (Berry et al., 2023). Meanwhile, water filtration can be made with simple materials such as tubes or pipes, faucet stops, and filter materials such as palm fiber, charcoal, foam, gravel, and so on. This filter development details the construction of small-scale water filters with recycled materials (Verma et al., 2024).

The difference in learning outcomes after the pretest and posttest shows an increase in students' critical thinking skills from the initial average of 71.66 to 88.60 (an increase of 16.94%). The science aspect is obtained when students try to understand the problem and think of possible solutions that can be done. The technology aspect is shown by students' ability to choose modern technology-based materials and project design planning. The engineering aspect is done when students work on project prototypes until the project becomes a product. The mathematics aspect is shown by students being able to calculate the making of the project both the composition of the toolhole and the estimated materials to become a good product.

The syntax of STEM-PjBL can improve students' ability to understand, apply, and develop their knowledge, especially in the discovery stage, where students select the most suitable solution based on the results of group discussions that include the process of exploring various solution options. Through learning about the environment, students are expected to develop literacy and critical thinking skills by applying STEM principles (Borchardt et al., 2019; Kennedy & Odell, 2014).

Conclusion

Based on the findings of the study regarding the impact of implementing the STEM-PjBL approach on the environmental literacy proficiency of tenth-grade students in environmental pollution topics, it can be concluded that the PjBL-STEM model is more effective in improving students' environmental literacy skills than the PjBL model alone. This fact can be seen from the difference in learning outcomes of the control class pretest and posttest, which showed an increase in students' critical thinking skills from the initial average of 72.06 to 82.22 (an increase of 10.16%). The experimental class pretest and posttest

learning results showed an increase in students' critical thinking skills from the initial average of 71.66 to 88.60 (an increase of 16.94%). STEM-PjBL also helps students to be able to improve their environmental literacy skills in terms of knowledge, cognitive skills, attitudes, and behavior toward environmental problems.

For suggestions, teachers are advised to adopt instructional models that can enhance students' environmental literacy, such as the STEM-PjBL model, while schools should ensure the provision of optimal resources for both teachers and students to facilitate effective learning environments. However, it's important to acknowledge the limitations of this research, thus suggesting further investigation into the application of the STEM-PjBL model with broader scopes or in different contexts.

Conflicts of Interest

The author stated has no conflicts of interest in this paper.

Author Contributions

T. U. Pertiwi: analysis of data and writing—original draft preparation; **D. Oetomo:** review and validation; **B. Sugiharto:** methodology and review; **T. U. Pertiwi, D. Oetomo, and B. Sugiharto:** review and editing.

References

Alkautsar, S., Nuryady, M. M., Husamah, H., Wahyono, P., & Miharja, F. J. (2023). STEM-PjBL Worksheet: Ways to improve students' collaboration, creativity, and computational thinking. *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, *9*(2), 681–695. https://doi.org/10.33394/jk.v9i2.7587

Amoah, A., & Addoah, T. (2021). Does environmental knowledge drive pro-environmental behaviour in developing countries? Evidence from households in Ghana. *Environment, Development and Sustainability*, *23*(2), 2719–2738. https://doi.org/10.1007/s10668-020-00698-x

Arikunto, S. (2013). *Research procedure (A Practice Approach).* Rineka Cipta. https://opac.perpusnas.go.id/DetailOpac.aspx?id=801361

Berry, G., Beckman, I., & Cho, H. (2023). A comprehensive review of particle loading models of fibrous air filters. *Journal of Aerosol Science*, *167*(April 2022), 106078. https://doi.org/10.1016/j.jaerosci.2022.106078

Boone, W. J., Yale, M. S., & Staver, J. R. (2014). Rasch analysis in the human sciences. In *Rasch Analysis in the Human Sciences*. https://doi.org/10.1007/978-94-007-6857-4

Borchardt, R., Salcedo, T., & Bentley, M. (2019). Little intervention, big results: intentional integration of information literacy into an introductory-level biology lab course. *Journal of Biological Education*, *53*(4), 450–462. https://doi.org/10.1080/00219266.2018.1494029

Cole, L. B. (2019). Green building literacy: A framework for advancing green building education. *International Journal of STEM Education*, *6*(1). https://doi.org/10.1186/s40594-019-0171-6

Deckanio, A., Pratiwi, A. M., Ililiyun, D., Nuriyah, S., & Cahyani, T. D. (2023). Analisis dampak pencemaran limbah industri PT. S terhadap kehidupan masyarakat di Kabupaten Sidoarjo. *Jurnal Ilmiah Multidisiplin*, *1*(4), 141–151. https://jurnal.penerbitdaarulhuda.my.id/index.php/MAJIM/article /download/97/105

Ekene, O. G., & Oluoch-Suleh, E. (2015). Role of institutions of higher learning in enhancing sustainable development in Kenya. *Journal of Education and Practice*, *6*(16), 91–103. https://eric.ed.gov/?id =EJ1079963

Hira, A., & Anderson, E. (2021). Motivating online learning through project-based learning during the 2020 COVID-19 pandemic. *IAFOR Journal of Education*, *9*(2), 93–110. https://doi.org/10.22492/ije.9.2.06

Hollweg, K. ., Taylor, J. ., Bybee, R. ., Marcinkowski, T. ., McBeth, W. ., & Zoido, P. (2011). *Developing a framework for assessing environmental literacy*. North American Association for Environmental Education (NAAEE). https://naaee.org/sites/default/files/inline-files/devframewkassessenvlitonlineed.pdf%0A

Indranuddin, R. D., Susetyarini, E., & Miharja, F. J. (2024). Developing STEM-PjBL worksheet to lift students' critical, creative, and computational thinking skill. *Research and Development in Education (RaDEn)*, *4*(1), 85–101. https://doi.org/10.22219/raden.v4i1.27165

Kaya, V. H., & Elster, D. (2018). German students' environmental literacy in science education based

on PISA data. *Science Education International*, *29*(2), 75–87. https://doi.org/10.33828/sei.v29.i2.2

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246–258. https://eric.ed.gov/?id=EJ1044508

Koyama, D., & Watanabe, T. (2023). Why a dispositional view of ecological literacy is needed. *Teaching in Higher Education*, *28*(5), 1108–1117. https://doi.org/10.1080/13562517.2023.2198637

Laboy-Rush, D. (2011). *Integrated STEM education through project-based learning*. https://doi.org/10.51272/pmena.42.2020-381

Mahyudin, R. P., & Herlintama, S. A. (2023). Estimation of greenhouse gas emissions in waste management at Basirih Landfill Banjarmasin South Kalimantan Indonesia. *International Journal of Research and Review*, *10*(6), 629–636. https://doi.org/10.52403/ijrr.20230677

Masturoh, M., & Ridlo, S. (2020). Character building of environmental care on students in Sekolah Indonesia Kota Kinabalu (SIKK) Malaysia. *Journal of Biology Education*, *9*(2), 193–201. https://doi.org/10.15294/jbe.v9i2.39522

Maulana, M. (2020). Penerapan model project based learning berbasis stem pada pembelajaran fisika siapkan kemandirian belajar peserta didik. *Jurnal Teknodik*, 39–50. https://doi.org/10.32550/teknodik.v0i2.678

McBeth, B., Hungerford, H., Marcinkowski, T., Volk, T., Cifranick, K., Howell, J., & Meyers, R. (2011). National environmental literacy assessment, phase two: measuring the effectiveness of North American environmental education programs with respect to the parameters of environmental literacy. Final report. In *NOAA and NAAEE. Accessed November* (Vol. 28). https://www.noaa.gov/sites/default/files/legacy/document/2019/Jun/NELA_Phase_Two_Report_020711.pdf

Mcbeth, B., Hungerford, H., Marcinkowski, T., Volk, T., Meyers, R., Meyers, R., Potter, G., Schoedinger, S., & Day, B. (2008). *National Environmental Literacy Assessment Project : Year 1 , National Baseline Study of Middle Grades Students Final Research Report*. https://www.noaa.gov/sites/default/files/legacy/document/2019/Jun/Final_NELA_minus_MSELS_8-12-08.pdf

McBeth, W., & Volk, T. L. (2010). The national environmental literacy project: A baseline study of middle grade students in the United States. *Journal of Environmental Education*, *41*(1), 55–67. https://doi.org/10.1080/00958960903210031

Muttaqiin, A. (2023). Pendekatan STEM (Science, Technology, Engineering, Mathematics) pada pembelajaran IPA untuk melatih keterampilan Abad 21. *Jurnal Pendidikan Mipa*, *13*(1), 34–45. https://doi.org/10.37630/jpm.v13i1.819

Nastoulas, I., Marini, K., & Skanavis, C. (2017). Middle school students' environmental literacy assessment in Thessaloniki Greece. *Health and Environment Conference Proceedings*, *March*. https://www.researchgate.net/publication/317358717_Middle_School_Students%27_Environmental_Literacy_Assessment_in_Thessaloniki_Greece

Pangestu, R., Riani, E., & Effendi, H. (2017). Estimasi beban pencemaran point source dan limbah domestik di Sungai Kalibaru Timur Provinsi DKI Jakarta, Indonesia. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan*, *7*(3), 219–226. https://doi.org/10.29244/jpsl.7.3.219-226

Ramadhana, S. D., Norra, B. I., & Rasyida, N. (2022). Keefektifan perangkat pembelajaran daring dengan model PjBL-STEAM pada materi lingkungan untuk meningkatkan literasi lingkungan. *Jurnal Pendidikan (Teori Dan Praktik)*, *6*(2), 75–81. https://doi.org/10.26740/jp.v6n1.p75-81

Sadhu, S. D., Garg, M., & Kumar, A. (2018). Major environmental issues and new materials. In *New Polymer Nanocomposites for Environmental Remediation* (pp. 77–97). Elsevier. https://doi.org/10.1016/B978-0-12-811033-1.00004-4

Sarker, T. R., Pattnaik, F., Nanda, S., Dalai, A. K., Meda, V., & Naik, S. (2021). Hydrothermal pretreatment technologies for lignocellulosic biomass: A review of steam explosion and subcritical water hydrolysis. *Chemosphere*, *284*(June), 131372. https://doi.org/10.1016/j.chemosphere.2021.131372

Siew, N. M., & Ambo, N. (2018). Development and evaluation of an integrated project-based and stem teaching and learning module on enhancing scientific creativity among fifth graders. *Journal of Baltic Science Education*, *17*(6), 1017–1033. https://doi.org/10.33225/jbse/18.17.1017

Suciani, T., Lasmanawati, E., & Rahmawati, Y. (2018). Pemahaman model pembelajaran sebagai kesiapan praktik pengalaman lapangan (ppl) mahasiswa program studi pendidikan tata boga. *Media Pendidikan, Gizi, Dan Kuliner*, *7*(1), 76–81. https://doi.org/10.17509/boga.v7i1.11599

Sugiyono. (2015). *Metode Penelitian Pendidikan*. Alfabeta. https://opac.perpusnas.go.id/Detail

Opac.aspx?id=853411

Sujon, M. A. S., Islam, A., & Nadimpalli, V. K. (2021). Damping and sound absorption properties of polymer matrix composites: A review. *Polymer Testing*, *104*, 107388. https://doi.org/10.1016/j.polymertesting.2021.107388

Taskiran, A. (2021). Project-based online learning experiences of pre-service teachers. *Journal of Educational Technology and Online Learning*, *4*(3). https://doi.org/10.31681/jetol.977159

Verma, A., Yalem, R., & Saini, G. (2024). Use of recycled aggregates as filter support and filter media for decentralized water filtration systems. *Journal of Engineering Research (Kuwait)*, *October*. https://doi.org/10.1016/j.jer.2023.10.016

Zulyusri, Z., Elfira, I., Lufri, L., & Santosa, T. A. (2023). Literature study: Utilization of the PjBL model in science education to improve creativity and critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 133–143. https://doi.org/10.29303/jppipa.v9i1.2555