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Research Paper

Enhancing Students' Knowledge of Environmental Pollution by Problem-Based Learning: An Experimental Study of High School Students

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Abstract
Based on the 2022 PISA report, the science performance of Indonesian students still tends to be low, namely at level 2 which indicates a lack of understanding of environmental phenomena, evaluating scientific evidence and making decisions related to various environmental issues. This condition has become a dilemma during the problem of global environmental damage. Therefore, learning is needed that can build the concept of the environment well. The study aimed to investigate the influence of the PBL model on student outcomes using a quasi-experiment method involving control class and experiment class. Each of the class contains 30 students. The learning outcomes of the two classes were in the form of pre-test and post-test scores, and then the gain score was calculated for further analysis. The measurement data was then analyzed using the t-test with the help of SPSS 27.0. The results of the study show that the PBL model has a significant effect on student learning outcomes. The average gain score of the experimental class was 42.73, while the control class was 28.86. The results of the analysis using an independent sample t-test showed the difference ρ-level value of .01. The ρ-level value is less than .05 (ρ< .05). These results show that students' knowledge can be improved through the PBL model.

Keywords *environmental education, problem-based learning, quasi-experiment method*

INTRODUCTION

Education is the most important thing to instill an attitude of caring for the environment in every generation so that it can form a collective consciousness to save the earth from damage. Experts from various parts of the world realize that in curriculum practice, students must be equipped with a variety of knowledge to be able to understand the importance of preserving the environment (Ardoin et al., 2020; Damoah et al., 2024). The aim is an effort to build collective awareness, which can finally give birth to real action in realizing a comfortable and sustainable environment. However, the results of the study show that the level of students' understanding of environmental pollution is still low (Fetiana et al., 2022; Kurniawan et al., 2024; Merritt et al., 2024; van de Wetering et al., 2022). Not only that, but based on the results of the 2022 PISA study, it was recorded that the science achievements of Indonesian students are still below level 2 (OECD, 2023). The PISA report emphasizes that students with low science performance tend to be less able to understand environmental phenomena, evaluate scientific evidence, and make decisions related to various environmental problems.

One way that can be used to improve students' understanding of the environment is to build concepts appropriately in a learning (Çibukçiu, 2025; Do et al., 2023; Xiong et al., 2025) This is in line with constructivist theory, which emphasizes that students can build their knowledge independently (Taber, 2024; Tsai et al., 2023). Therefore, in learning, teachers must be able to develop successful students' knowledge and experience. This is because teachers who are able to understand students' knowledge and experience will be able to build ideas from students. Overcoming these problems, it is necessary to choose the right learning model (Purnama, 2022). One of the learning models that is in line with constructivism theory is the PBL or p*roblem-based learning model* (Akcay & Benek, 2024;

Wijnia et al., 2024). The learning model can explore students' knowledge to be able to solve the problems that have been given (Chung et al., 2016).

Initially, PBL was developed only for medical students based at McMaster Medical School in Canada, then expanded to medical schools in the UK (Neville et al., 2019) After experiencing great success, PBL is applied to learning in various fields including geography, science, and education (Servant-Miklos et al., 2019) Researchers believe that PBL is a student-centered learning model that uses problems as a starting point in learning (Trullàs et al., 2022) The objectives of the learning model include 1) building a knowledge base, 2) developing the ability to solve problems, 3) teaching effective collaboration, and 4) providing the skills necessary to become successful lifelong learners (Chung et al., 2016; Trullàs et al., 2022). With this goal, students can work effectively with friends in a team to solve problems so that they can develop their abilities (Wang, 2022).

In PBL, students are positioned as learners who play the role of adults, working in small teams to explore problems until they complete problem solving (McLean et al., 2006) In addition, PBL also has advantages, namely: 1) focusing on students to become independent learners who are directly actively involved in group learning, and 2) helping students develop skills in reasoning and thinking when looking for data or information to get a solution to an authentic problem (Yu & Zin, 2022). Therefore, PBL is very suitable for learning about environmental issues that are authentic (Gök & Boncukçu, 2023).

PBL is central to learning because in this model, students can conduct investigative activities naturally, think broadly, and make decisions about the knowledge they know (Anggraeni et al., 2023; Putri et al., 2023; Rafiq et al., 2023). In this model, students can express their knowledge and exchange ideas with other students. Solving environmental issues requires problem-solving solutions that consider various aspects (Timothy, 2021). As with the problem of environmental pollution that requires a wide variety of views to be summarized in one comprehensive problem-solving (Hidayanti et al., 2023). One of the problems that needs to be solved by teachers is how to overcome the problem of waste that is mounting in the school environment (Nisa et al., 2025). In the educational environment, students need to be involved in solving these problems in real life, so that students must be trained to jointly solve problems until then (Handayani & Widodo, 2024). Through this research, a solution is sought to provide a knowledge base for students to be able to understand environmental phenomena, as well as the scientific evidence that is evaluated (van de Wetering et al., 2022). Therefore, this study focuses on the PBL model experiment and its influence on students' knowledge of environmental pollution issues (Cahyadini et al., 2024) and students can also build the knowledge they already have to be developed in solving problems that occur in the real world (Nicholus et al., 2023; Wijnia et al., 2024).

PBL is an active learning model that leads to greater understanding and competency achievement (Lara-Bercial et al., 2024) The learning model is not designed for the purpose of knowledge retention for self-interest (Servant-Miklos, 2019) PBL also has a huge influence on students, because in this model, students are required to think naturally and make decisions about a problem faced in real life (Lee, 2025) Other opinions also outline that PBL aims to build a knowledge base, develop problem-solving skills, teach effective collaboration, and provide the skills necessary to become successful lifelong learners (Smith et al., 2022; Zamiri & Esmaeili, 2024)

LITERATURE REVIEW

A learning model is a plan of sequential learning steps that guides classroom teaching, aligned with the chosen strategy and directly influencing competencies, learning objectives, student tasks, and learning outcomes (Spatioti et al., 2022). Therefore, a learning model must be designed as effectively as possible to support successful student learning. One promising model is problem-based learning (PBL), where students engage with real-world problems through investigation, collaboration, and reflection. Empirical evidence shows that PBL can foster critical thinking, deeper conceptual understanding, and learner autonomy — yet results vary depending on content area, context, and implementation. The literature notably lacks robust studies examining PBL's impact on students' knowledge about environmental pollution issues. Accordingly, this study addresses that gap by investigating how a PBL model influences students' understanding of environmental pollution phenomena.

Problem-based learning is a learning model that uses problems as a starting point to acquire new knowledge, where students use authentic problems to learn the content of the lesson, and

conversely, students also learn special skills to solve problems using means in the form of lesson content (Nurwidodo et al., 2025). On the other hand, it is known that the essence of problem-based learning is to present authentic and meaningful problems to students that can serve as a stepping stone for investigation and investigation (Smith et al., 2022) Thus, the use of authentic problems in PBL model learning is the starting point for acquiring new knowledge, while the acquisition of this knowledge is carried out by conducting investigations and investigations.

PBL is a student-centered learning model that uses problem solving in starting to learn. PBL is a learning model developed from *a* problem-solving learning strategy by exploring students' knowledge and ability to solve problems in the real world, so the use of this model is very suitable for use in subject matter topics that are abstract but related to everyday phenomena (Surur et al., 2020). The existence of problems in these phenomena will be thought about by students and then confirmed through existing theories to solve and find solutions to solve the problem. This is in line with Dewey's opinion that in general, a person learns by starting to think when he feels a problem, then trying to clarify the problem at hand to determine the right solution to the problem (López et al., 2024)

The basic principle in PBL is learning that begins with the problem that is asked. Problem-based learning addresses complex problems that occur in the real world to explore students' knowledge, where students will discuss in small groups to communicate and integrate information (Hmelo-Silver, 2004; Schmidt et al., 2011) Problems are the key to PBL. Problem-giving prioritizes complex problems that occur in the real world, including problems related to the environment, so that these problems can be integrated with information obtained by students to communicate in groups. In problem-based learning, the problem situation raised in learning must be able to meet five important criteria, namely 1) the situation is authentic; 2) the problem can create mystery; this means that the problem presented requires alternative solutions because the problem cannot be solved by simple solutions; 3) the problem must be meaningful and in accordance with the student's level of intellectual development; 4) the problem must be broad to provide an opportunity for teachers to meet their instructional objectives; and 5) the problem must be beneficial to students (Loyens et al., 2020; Smith et al., 2022) Thus, the five principles can be used as a reference in formulating a problem as an initial study in the problem-based learning model.

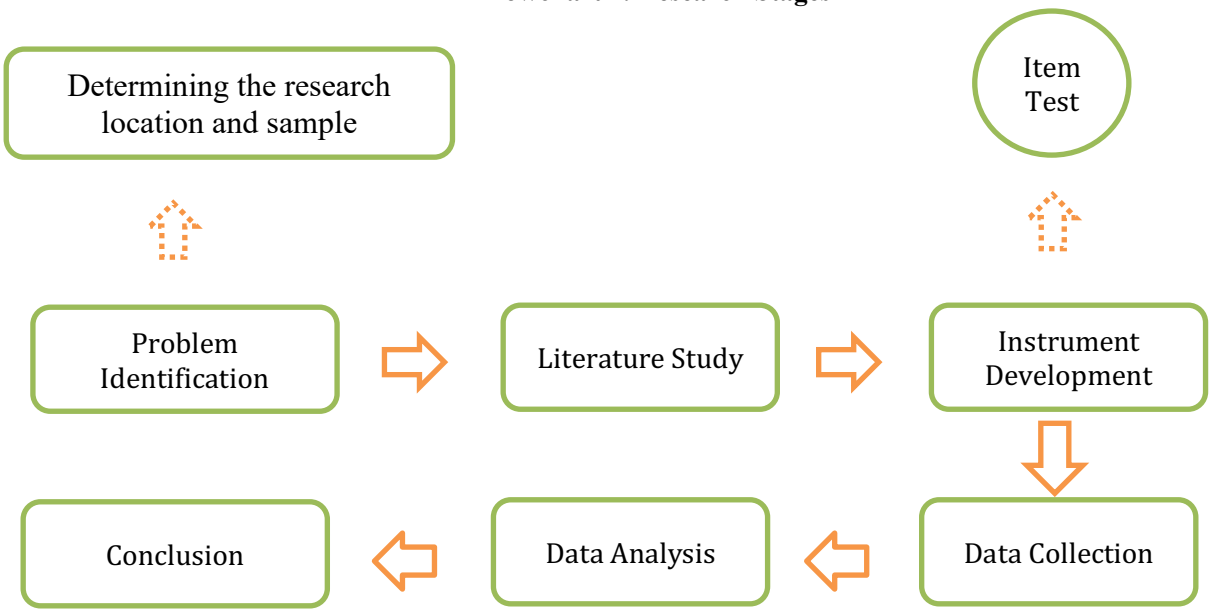
To organize the problem, teachers can conduct demonstrations, present phenomena, or conduct experiments (Smith et al., 2022). In this learning, the teacher is no longer the only source of learning, but the teacher in this case only plays the role of a facilitator (Sormunen et al., 2020). In this context, the teacher presents various problems in real life, then facilitates investigation and dialogue. Thus, the use of this model is appropriately used to create active, student-centered learning.

Problem-based learning has five learning syntax, namely: 1) orienting students to problems, 2) organizing students to learn, 3) guiding individual and group investigations, 4) presenting the results of the work, and 5) evaluating and analyzing problem-solving processes (Tan & Tee, 2021). Experts say that PBL can be implemented well if the five syntax have included activities to achieve all the learning objectives that have been set (Tan & Tee, 2021) It is known that one of the advantages of implementing the five syntax of PBL is that it can provide opportunities for students to interact with each other, collaborate in solving problems, and provide freedom to propose problem-solving ideas (Lestari et al., 2019) This means the model emphasizes the quality of interaction to solve problems that can help students in improving learning outcomes.

RESEARCH METHOD

This study was designed using a quasi-experiment with cluster sampling that involved an experimental class and a control class at one high school in Jombang district, East Java, Indonesia. Where learning outcomes are bound variables while the PBL model is an independent variable. The learning outcomes obtained in this study are in the form of pre-test and post-test scores, which are then calculated as N-Gain scores for further analysis. The subjects of this study were students in two classes, namely: 1) 22 students in the experimental class participated in learning using the PBL model, and 2) 22 students in the control class who used conventional learning through discussion and lecture methods. Here is the flowchart of this study.

Flowchart 1. Research Stages



The data collection technique uses a valid and reliable test to find out student learning outcomes. The instrument has 5 items, then to test the validity of its contents, the instrument is reviewed by three experts. Then the instrument was caried out to the field for pilot test with 60 participants. After that, using SPSS 22 collected data, the validity of the question was tested by looking for the Pearson Correlation value and the Cronbach Alpha reliability value. Here are the results of the validity and reliability, shown at Table 1 and 2.

Table 1. The validity of instrument

Item Test	Pearson Correlation (r)	Interpretation
Item 1	0.614	Valid
Item 2	0.737	Valid
Item 3	0.619	Valid
Item 4	0.745	Valid
Item 5	0.726	Valid

Table 2. The reliability of instrument

Variable	Cronbach's alpha coefficient	Interpretation
Instrument test	0.723	Reliable

The pre-test and post-test results are then taken separately to get a gain score. The gain score calculation is used to obtain quantitative data that informs the achievement of student learning outcomes after being given treatment. This study aims to determine the influence of PBL on student learning outcomes. Based on the type of existing research variables, the data analysis technique used is the t-test.

FINDINGS AND DISCUSSION

Based on student learning outcome data consisting of the average score of pre-tests post-test, and N-Gain score, it was found that the average score of the initial ability of students in the experimental class was 49.09 and the control class was 49.32. The data showed that the average pre-

test scores for the experimental class and the control class were relatively the same. Meanwhile, the average score of the post-test score in the experimental class was 84.32 and the control class was 78.18. The data showed that the average post-test score for the experimental class was higher than that of the control class. The average N-Gain score in the measurement in the experimental class was 0.736 and in the control class it was 0.565. The data showed that the N-Gain of the experimental class was higher than in the control class. After obtaining the N-Gain value, a statistical test was then carried out with SPSS 22, starting from the normality and homogeneity test. The following is the case in Table 3.

Tabel 3. Results of the Normality Test

Class	Shapiro-Wilk test			Conclusion
	Data	Statistics	Sig.	
Class Experiment	N-Gain	0.98	0.91	Normal
Class Control	N-Gain	0.95	0.77	Normal

From the results of the normality test Shapiro-Wilk test (N<50) which was carried out separately between the experimental and control classes. Produced experimental class data W= 0.98, sig.= 0.91 and control class W= 0.95, sig.= 0.77. Referring to the p> value of 0.05, it indicates that the data is normally distributed. Furthermore, Table 4 shows the results of the homogeneity test through the Levene test.

Tabel 4. Results of the Homogeneity Tets

Class	Data	F	Sig.	Interpretation
Experiment and control	N-gain	3.622	0.064	Homogeneous

Based on Table 4, the results of the Levene homogeneity test show F= 3.622, sig. = 0.064, p= >0.05 This signifies the variance between the experimental class and the homogeneous control, so that the t-test assumption is met. The following are the results of the independent sample t-test in Table 5.

Tabel 5. Results of the Independent sample t-test

Data	t	df	Sig. 2-tailed	Interpretation
N-gain	2.75	42	0.009	significant difference

The results of the analysis of the t-test results are t= 2.75, df= 42, and sig. 2-tailed= 0.009, p= ≤ 0.05. This shows that there is a significant difference between the score gain of the experimental class and the control class, meaning that problem-based learning influences student learning outcomes.

The influence of PBL on student learning outcomes can be explained through several arguments. First, PBL has a syntax that can lead students to organize problems. In this case, students are directly faced with the problem of garbage accumulation in the school environment caused by the students themselves. Therefore, students find it easier to understand the description of the problem given by the teacher. In this learning phase, students begin to think about how to solve the problems that have been raised. This is because, in general, a person learns by starting to think when they feel a problem, then people try to clarify the problem at hand to determine the right solution to the problem (Güner & Metacognitive, 2021; Zepeda & Nokes-Malach, 2023)

Second, PBL has a phase that directs teachers to guide students to conduct investigations both individually and in groups (Hmelo-Silver, 2004; Schmidt et al., 2011). In this study, students were invited to visit dump stations in the school environment to find out the conditions in that place. In this case, students conduct investigations by conducting observations and interviews to be able to construct knowledge (Lizier et al., 2018). Thus, students can directly conduct investigations about water, soil, air, and the impact of waste on the environment, as well as how to overcome the accumulation of waste. This is in line with the opinion of experts who state that education in schools is a larger mirror and classrooms will become laboratories for investigation and a place to address real-life problems (Stöhr & Adawi, 2018; Watson, 2020). In the other hand, the results shown in Table 5, indicate that after learning with the PBL model, students experience a significant increase in knowledge about environmental pollution. In this case, students can understand how to deal with

waste problems in the school environment. Starting from collection, to managing waste according to the category of waste.

Third, PBL also has a phase that can lead students to be able to analyze and evaluate the problem-solving process (Jumhur et al., 2024). At this learning stage, students are given the opportunity to be able to make presentations and have class discussions (Yew & Schmidt, 2012). Presentations are an opportunity for students to socialize and communicate the results of their findings (Dias-Oliveira et al., 2024). Meanwhile, class discussions can provide students with opportunities to exchange opinions about the right actions to overcome the accumulation of waste that occurs in the school environment. This is in line with the opinion of experts who revealed that through class discussions, students can exchange ideas and clarify each other to deepen the concepts being studied (Filho et al., 2024). In addition, these activities can also improve students' ability to argue with each other, test assumptions, and evaluate evidence to strengthen the construction of concepts being studied (Dolmans & Wilkerson, 2011; Zhao & Wang, 2022).

Empirically, the findings in this study are strengthened by several research results. First, PBL can improve the mastery of concepts, student activities, and student learning outcomes in biology subjects (Febrianti et al., 2025). The next finding stated that the learning model can challenge students' abilities as well as provide opportunities to explore new knowledge, help students transfer their knowledge to understand relevant real-life problems that can be applied in daily life (Yu & Zin, 2022), engage students in actively solving problems and demand high-level thinking skills (Surur et al., 2020), and make students play an active role in learning (Amanda, 2020). These findings strengthen the argument that PBL has an influence on student learning outcomes on the environmental topics raised in this study.

Another research that is in line with this research is the results of research (Ajai et al., 2013), that the value in the PBL model is higher than the conventional learning model. The results of the research on environmental conservation materials show the influence of PBL on student learning outcomes (Chen, 2024). This is because the problems presented are authentic, making problems a starting point in learning, and PBL has proven to be a student-centered learning that is suitable for use in learning to solve environmental problems (Biney, 2025).

CONCLUSION

The application of the PBL model has a significant effect on student learning outcomes in the main meter of environmental pollution. This happens at least because of three things, namely: 1) Increased understanding of how to deal with problems in the surrounding environment; 2) students can conduct investigations directly; and 3) the provision of opportunities to make presentations. Thus, the learning model is very important to be applied because it has an influence on learning outcomes. Therefore, teachers can implement the PBL model as a problem-solving learning model that is in accordance with basic competencies on the topic of environmental pollution. This is because the learning model is suitable for solving all problems that occur in real life.

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