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Investigating Problem-Based Learning Model's Impact on High School Student's Critical Thinking Skills in Environmental Conservation Context

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ABSTRACT

In the educational context of the 21st century, where critical thinking and problem-solving are essential skills, the Problem-Based Learning (PBL) model offers numerous advantages. In contrast to traditional learning models that only focus on knowledge transfer, PBL encourages students to solve real environmental problems, promotes active learning, and encourages the development of critical thinking skills to solve complex global issues. Environmental issues such as global warming, pollution, and other issues require students' ability to integrate various information and analyze, synthesize, and formulate holistic and comprehensive solutions. This research discusses the implementation of the Problem-Based Learning (PBL) model and aims to determine its effect on students' critical thinking skills in discussions related to the environment. The type of research applied was a quasi-experiment with a non-equivalent control-group design pre-test and post-test and the experimental class subjects were 29 and the control class was 32 students as a result of cluster random sampling. Data were collected in the form of essay tests and observations and then analyzed to determine significant differences using the t-test. The results of this study show that there is a significant difference in critical thinking skills with a value of $p = 0.004 < \alpha\ 0.05$ between the experimental class and the control class, where the experimental class gets a higher score of 71 compared to the control class of 61. If learning involves interdisciplinary and abstract material such as environmental topics and aims to develop students' critical thinking skills, the PBL model can be a teacher's choice in implementing learning.

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1. Introduction

The occurrence of environmental damage and the issue of unsustainable development are becoming increasingly serious topics discussed by the public. Based on the Global Risk Report 2023 published by the World Economic Forum, six types of environmental risks dominate in the next few decades such as natural disasters and extreme weather events, failure to mitigate climate change, large-scale environmental damages, and natural resource crises (World Economic Forum, 2023).

The younger generation, especially students, plays an important role in critically understanding and acting on these issues to build a sustainable future (Ariffin & Ng, 2020; Piscitelli & D'Uggento, 2022). However, student involvement in efforts to prevent environmental damage is still very low, students are not used to protecting the environment without direction from the teacher; likewise, teachers still have low motivation to develop the character of environmental awareness, lack of appropriate learning materials, and rely on traditional learning models (Marques & Xavier, 2020; Purwanti et al., 2019). The formation of environmental awareness is part of character education but is largely ignored by students (Khoiri et al., 2021). Lack of knowledge of environmental management is the reason for the low critical thinking skills and environmental awareness of students on environmental issues (Ahmadi et al., 2018).

Teaching students about environmental education so far has several challenges, one of which is the need to integrate environment-related learning in an interdisciplinary and experiential approach (Butler, 2022). This is because by accommodating this, students become more aware of the practical benefits and understanding beyond theoretical concepts. This is due to the limited learning resources that are integrated with environmental insights (Kamilah & Fikroh, 2022). Geography learning in schools is often still done with conventional models such as lectures and assignments (Handoko & Hamidi, 2023; Somantri & Ridwana, 2021). The model has limitations so an effective learning model is needed to deliver complex topics such as the environment and sustainable development, one of which is by utilizing the Problem-Based Learning model (Ali, 2019). The use of the Problem-Based Learning model is recommended to achieve competencies in Education for Sustainable Development (ESD) consisting of systems thinking, anticipatory thinking, ability to work on complex

problems, critical thinking and analysis, empathy and change of perspective, strategic action, and tolerance for ambiguity and uncertainty (Lozano et al., 2017; Riess et al., 2022; Tejedor et al., 2019). Meanwhile, conventional learning models such as lectures and assignments tend to be passive and only focus as much as possible on conveying information to students (Wicaksono & Widiyaningrum, 2020). This results in students only understanding the basic concepts but having difficulty applying them in the context of real life, students are also easily bored and learning feels monotonous (Nuralawiah et al., 2021).

Problems in learning related to complex topics such as the environment and sustainable development can be overcome with student-centered learning activities (Parry & Metzger, 2023). This follows the concept of 21st-century learning which emphasizes that learning is directed to be more student-oriented than the teacher (Artama et al., 2023; Islam et al., 2022; Ramalingam et al., 2021). One of the learning models in question is Problem-Based Learning (PBL) (Suwastini et al., 2021). The PBL model encourages students to actively solve real problems so that students will learn to collaborate and create effectively with teachers and fellow friends to find solutions to problems (Nisa & Wulandari, 2019). In its application to learning related to environmental conservation, students are given real problems that occur around them, such as environmental pollution, resource scarcity, and other similar issues (Baan, 2023). By focusing on real problems and accompanied by student-focused learning steps, the PBL model can increase students' understanding of environmental problems and encourage them to find sustainable solutions based on the needs of the local environment (Rachman et al., 2021). Furthermore, integrating environmental problems such as sustainable development issues with the PBL model will provide students with a holistic perspective on managing the environment wisely and encourage them to apply their knowledge to address environmental problems (Hsieh, 2020). The problems presented are ill-structured, messy, and untidy so that students can develop and apply their knowledge flexibly and responsively in complex and real situations (Smith et al., 2022). Some studies state that the learning approach using this model is in line with the principles of the 2013 Curriculum and the Merdeka Curriculum, which prioritize active student participation in the learning process (Aryanti et al., 2023; Rinasari & Sriyanto, 2022).

In everyday life, the ability to think critically is essential for preserving the environment (Ristanto et al., 2022). In actual practice, students can apply critical thinking skills in terms of evaluating the impact of pollution on the surrounding environment and planning rational and feasible solutions, such as conducting recycling programs or campaigns to reduce the use of plastic. In addition, they can also be given case studies of environmental disasters where they will analyze the factors that contribute to the occurrence of the disaster and can plan solutions to prevent the same occurrence in the future. These case-based learning activities and real-life problems encourage students to understand more deeply about environmental issues and think critically about their actions that can contribute to the preservation and sustainability of the environment (Ichinose, 2024). Critical thinking is not only used by students in classroom learning but also implemented outside of school as an effort to realize environmental sustainability (Faize & Akhtar, 2020). Therefore, environmental care attitudes and students' ability to think critically are closely related, where students' environmental care attitudes can be developed by training students to be able to find solutions to environmental problems, analyze problems in-depth, and be able to understand problems more comprehensively (Amin et al., 2020).

The occurrence of environmental damage is caused by a lack of awareness of the environment (Rindha, 2020). To overcome this, one of the ways that can be done is to take actions that ensure environmental sustainability (Arı & Yılmaz, 2017). One way is to develop students' environmental care attitudes (Nurhidayati et al., 2022). Developing students' concern for the surrounding environment can be done through integration between subjects with materials related to environmental education (Anilia et al., 2023; Sukma et al., 2020). For example, in the subject of geography, the discussion of the environment is a representation of the application of environmental education for students (Rahman et al., 2022; Sumarmi et al., 2023). An attitude of caring for the environment is an action that is realized by preserving, preventing, and repairing environmental damage (Anilia et al., 2023; Arifin et al., 2023; Warni et al., 2022). Environmental attitudes are formed from three factors, namely knowledge about environmental issues (cognitive), sentiments about environmental issues (affective), and the tendency to act on environmental issues (conative) (Abun et al., 2019; Mustafa et al., 2021; Quoquab & Mohammad, 2020).

Based on observations and interviews with geography teachers at MAN 1 Malang, triggering questions in the initial learning process tend not to cover the indicators of critical thinking skills. Teacher-student interaction is limited so that students only understand the basic concepts of the material being taught. In addition, the learning model applied still focuses on delivering material intensely to students. In line with research from Cendikia et al., (2023) who stated that the reality of geography learning in class only requires students to memorize and understand the concepts of the material taught in class. As a result, students were able to answer the question, but it was not accompanied by comprehensive scientific reasoning.

An interview with one of the geography teachers was conducted regarding the learning model in the classroom, the teacher stated that the school has tried to implement a student-oriented learning model, but it has not been fully implemented, considering that teachers are still accustomed to teaching with a lecture model. As stated by Nurmalasari et al., (2022) and Putri et al., (2022) this model results in students' critical thinking skills becoming less honed, because students are not accustomed to being active, creative, and critical in receiving information and solving a problem.

The research gap addressed in this study is that the application of student-oriented learning models, such as the Problem-Based Learning (PBL) model is still few and limited in terms of its application, especially in geography learning. The practice of geography learning in reality is more often done in a lecture format, which emphasizes memorization rather than honing students' critical thinking abilities and other skills. This research gap is both significant and essential to address because critical thinking is an essential skill for students to understand and solve complex environmental problems. By addressing this research gap, this study aims to demonstrate the effectiveness of the PBL model in improving students' critical thinking skills, which therefore contributes to providing valuable insights into geography learning.

Not many studies discuss the effect of the PBL model on high school students' critical thinking skills in geography subjects, especially in the environmental conservation context. Research subjects related to this research topic are also still dominated by the subject domain of elementary, junior high, and university students. For example, research from Amin et al., (2020) discusses the effect of PBL on critical thinking skills and environmental care attitudes, but with the subject of university students enrolled in Social Studies Education. The same was also the case in Selamat, (2023) research which emphasized the implementation of the PBL contextual model in junior high school students. In addition, given that the issue of environmental conservation and sustainable development is an essential topic for students to understand along with the increasingly real and many problems about it (Pozo-Muñoz et al., 2023). Environmental problems and sustainable development are issues that need to be understood and solved by students by understanding the problem firsthand. Recognizing that there is a gap in effectively integrating an understanding of environmental conservation with 21st-century competencies such as critical thinking, especially at the high school level, student-centered learning models such as PBL provide the potential to close or reduce this gap. Concerning this, the PBL model has the potential to accommodate this comprehensively (Affolderbach, 2022). Therefore, this study aims to determine how the PBL model affects students' critical thinking skills with the hope that the application of PBL can better influence students' critical thinking skills so that they can increase significantly, especially for students at The Adiwiyata School, MAN 1 Malang.

When integrated with geography learning practices, the PBL model offers significant potential in enhancing students' critical thinking skills, notably when applied to contemporary environmental issues such as global warming or pollution. Teachers can develop engaging and reflective learning environments by incorporating real-world contexts in lesson plans. Learning using this model helps develop analytical and problem-solving skills and encourages students to be proactive and take responsibility for solving often complex environmental problems. Hence, the PBL model can bridge the gap between theoretical concepts and understanding with practical applications in the real world, making learning more relevant and impactful.

2. Method

This study used a quasi-experimental method with two groups of research subjects which became experimental and control groups. A quasi-experiment aims to evaluate the effect of an intervention to demonstrate intervention-outcome causality (Harris et al., 2006). The use of quasi-experiments is due to the presence of external variables that cannot all be controlled so that the changes that occur are not entirely due to the influence of the treatment. The experimental design in the form of a non-equivalent control group design – pre and post-test was implemented in this study to determine the effect before and after the application of the PBL model on the critical thinking skills of students between control and experimental groups. This design was chosen because (1) it excels in efficiency and practicality of implementation so as not to disrupt the normal flow of learning activities at school, (2) it allows for a comparison of control and experimental groups to assess the effectiveness of the intervention, (3) strengthening the interpretation of research results, and (4) strengthening the research design by utilizing a pre-test to reduce bias (Handley et al., 2018). The Non-equivalent control group design – pre and post-test is described in Table 1.

Table 1. Non-equivalent Control Group Design – Pre and Post-test

Group	Pre-test	Treatment	Post-test
Experiment	T_1	X	T_2
Control	T_3	-	T_4

Description:

T_1, T_2 : Pre and Post-test of the experimental group before and after learning using the PBL model
T_3, T_4 : Pre and Post-test of the control group before and after learning using the conventional model
X : Learning in the experimental group using the Problem-Based Learning (PBL) model
- : Learning in the control group using the conventional (lecture-based) model

Meanwhile, the purpose of this study is to answer the following research questions (RQ):

RQ Is there an effect of the Problem-Based Learning model on students' critical thinking skills?

The research subjects consisted of 11th-grade students of MAN 1 Malang in the 2023/2024 academic year who chose the Social Studies specialization. Subject determination using cluster random sampling. In this research, class XI – G (n = 32; Male = 16; Female = 16) and XI – H (n = 29; Male = 5; Female = 24) selected as research subjects, with n_{total} = 61. Class XI – G became the control group while XI – H became the experimental group after a random drawing using a coin (Siedlecki, 2020). Determining the two classes to be experimental or controlled using coin-based randomization ensures that the determination is unbiased and random, which is standard practice in experimental research to maintain internal validity and prevent selection bias (Peepliwal, 2024). In this study, data was collected in two forms, namely in the form of six open-ended essay questions about the environment which were adjusted to the Competency-Achievement Indicators (IPK) on Environment and Population material following the Merdeka Curriculum. The essay questions are tailored to the six indicators of critical thinking skills from (Facione & Facione, 2013). Data were analyzed using several stages of testing, consisting of instrument tests (validity and reliability test), preliminary tests (normality and homogeneity test), and hypothesis tests using Independent sample t-test, with a significance value of 5% and 95% confidence level. Therefore, the hypotheses in this study are:

H_0 There is no statistically significant difference in critical thinking between experimental and control group students.

H_1 There is a statistically significant difference in critical thinking skills between experimental and control group students.

After students finished working on the essay test questions and questionnaires during the pre-test and post-test, students' answers were scored based on the scoring guidelines. After that, student scores for each indicator of critical thinking ability were determined using the following formula 1:

$$AV = \frac{R}{MS} \times 100\% \qquad (1)$$

Description:

AV Acquisition value
R Score of each indicator
MS Maximum score

Critical thinking skills score data was analyzed after researchers obtained the pre-test and post-test scores of both groups. The classification of critical thinking skills scores according to Bashith & Amin, (2017); Isro et al., (2021); Solikhin & Fauziah, (2021) is presented in Table 2.

Table 2. Critical Thinking Skills Score and Classification

Interval Value	Classification
$80 < X \leq 100$	Very Critical
$60 < X \leq 80$	Critical
$40 < X \leq 60$	Moderately Critical
$20 < X \leq 40$	Slightly Critical
$0 < X \leq 20$	Not Critical

3. Results and Discussion

Geography learning in schools plays an important role in promoting students' understanding of the environment and their critical thinking skills to find solutions to environmental problems that are often complex and interdisciplinary. Therefore, critical thinking skills are important to develop because students will analyze and interpret geographic data, plan comprehensive solutions and decisions, and ultimately be able to solve problems efficiently and effectively. This emphasizes that a learning model that can foster students' critical thinking skills is highly needed.

In the context of application in this study, the PBL model was applied to the experimental class to put students in an active learning situation by solving problems related to environmental issues. In learning in the experimental class, the teacher encouraged students to be able to collaborate and communicate well to produce solutions to real environmental issues. Meanwhile, in the learning carried out in the control class, the teacher taught only with the lecture model as usual with the teacher as the main role in providing material and students as recipients of the lesson material.

In its implementation in this study, the PBL model was applied to the experimental class by giving students real problems in the form of case studies related to environmental problems, which they would solve collaboratively in groups. The role of the teacher in this experimental class is as a facilitator, who only plays a role in directing students during the discussion and reflection process, and does not intervene and dominate every student activity. Meanwhile, the control class applied a lecture-based learning model where the teacher only focused on providing material directly to students, and the teacher expected students to understand and memorize the material presented with minimal interaction and discussion. To assess how well the students understood the material presented, both classes were given students worksheets (LKPD) related to the material and case studies previously done in the learning process.

This research was conducted during four meetings in geography learning held at MAN 1 Malang from April 22nd to May 22nd, 2024. Researchers applied the Problem-Based Learning model in the experimental class and the lecture-based teaching model in the control class.

The main objective of this research is to see the effectiveness of the PBL model in terms of improving students' critical thinking skills in learning geography, especially on materials related to the environment. The existence of this research plays a significant role because this research can address the gap in current geography learning practices by integrating PBL models to develop students' critical thinking skills, which are also very important to understanding and making solutions to environmental problems that are often complex and require diverse perspectives. Data from the pre-test and post-test essay results on students' critical thinking skills are explained in Table 3.

Table 3. Pre-test and Post-test Results on Critical Thinking Skills

Data	Pretest		Posttest	
	Experiment	Control	Experiment	Control
Students (n)	29	32	29	32
Highest Score	71	96	92	96
Lowest Score	46	29	42	42
Average Score	61	65	71	61

In Table 3, it can be seen that the average pre-test score is higher in the control class (65) than in the experimental class (61). However, the post-test value showed a significant increase in the experimental class (71) and a decrease in the control class (61). This change is important because it shows the effectiveness of the PBL model in improving critical thinking skills. The decrease in scores in the control class shows that learning using the lecture model is less effective in improving or maintaining students' critical thinking skills.

On the other hand, the significant increase in the experimental class shows that PBL encourages students to be more deeply involved during learning activities, which is better for developing their critical thinking skills.

The increase in post-test scores in the experimental class was caused by a more active learning situation, supported by learning that focused on active problem-solving as well - which is the learning process of the PBL model. Such learning activities can improve students' critical thinking skills so that they perform better in the post-test. Meanwhile, it can be seen in Table 3 that the highest score in the control class remains the same, which indicates that the application of the lecture-based learning model in the control class does not provide equal opportunities for students to develop their critical thinking skills compared to the experimental class.

Table 3 also shows that the post-test scores of both classes show the same lowest score for both classes, this is because some students still have difficulty understanding the material presented even though they are given different learning models. The similarity of the lowest scores for both classes can be interpreted that some students who experience these difficulties need to be given special attention to help them perform better. Students who have difficulty understanding this material also have trouble following the learning activities in each learning model that researchers do.

From the information above, it can be concluded that the average post-test score of the experimental class is greater than the control class. The classification of critical thinking ability criteria consists of five levels consisting of uncritical, less/slightly critical, moderately critical, critical, and very critical. The description of critical thinking skills for both classes is presented in Figure 1 and Figure 2.

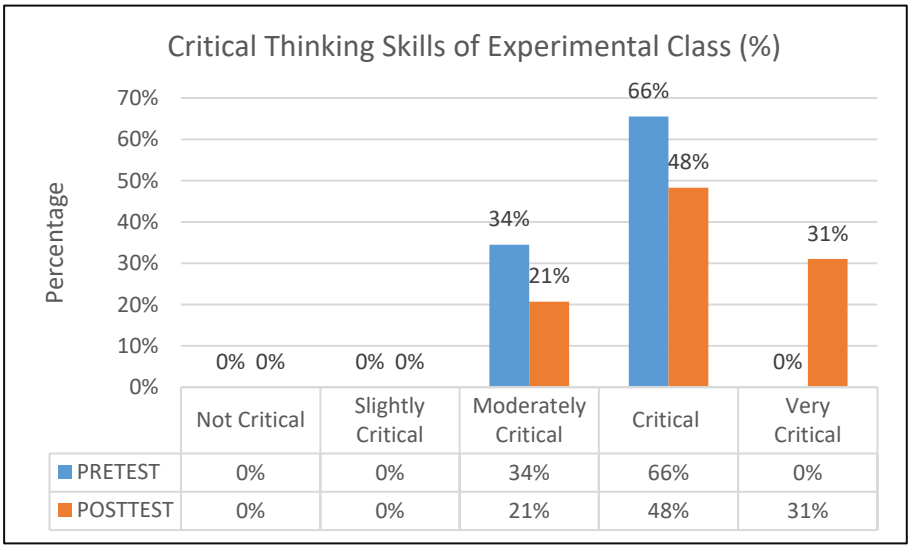

Figure 1. Distribution of Critical Thinking Skills Level of the Experimental Class

Figure 1 shows the classification of students' critical thinking skills in the experimental class during the pre-test and post-test sessions. There are no students who are in the uncritical or less critical classification. In the moderately critical classification, the percentage of students decreased from 34% in the pre-test to 21% in the post-test. In the critical classification, there was a decrease from 66% to 48%. However, there was a significant increase in the very critical classification from 0% to 31% in the post-test.

The increase in the percentage of students in the very critical category can be attributed to learning activities and active problem solving which is the essence of the Problem-Based Learning model. Learning steps in the PBL model that focus on active problem solving among students encourage them to understand more deeply the material and problems given, think critically and objectively, and at the same time collaborate and communicate both with the teacher and other students so that they can improve their ability to think critically (Samadun & Dwikoranto, 2022). In Figure 1, it can also be seen that there is a decrease in the percentage of students who are in the critical and moderately critical categories, which can be explained that some students can improve their critical thinking skills to a very critical level.

Meanwhile, it can also be seen that there are no students categorized at the not critical and slightly/less critical levels, indicating that the PBL model is at least able to improve students' critical thinking skills to a moderate level. These results show that the PBL model demonstrates the ability to develop learning situations for the better even for students who have learning difficulties, this model encourages them to engage in learning and development (Meek, 2020).

Factors that contribute to changes in students' critical thinking skills are one of them in the form of learning stages in the PBL model which emphasizes the ability to solve problems, apart from the collaboration between students which can increase understanding of the problems being faced. In addition, the role of the teacher during the implementation of learning helps students to clarify ideas and thought processes thereby improving critical thinking skills. This is reinforced by the statement from Diquito et al., (2024) that the role of teachers in learning using PBL models is to assist students in identifying problems, providing a supportive learning environment, assessing students' learning progress during the PBL process, and encouraging students to reflect on what strategies are working well and what still need improvement.

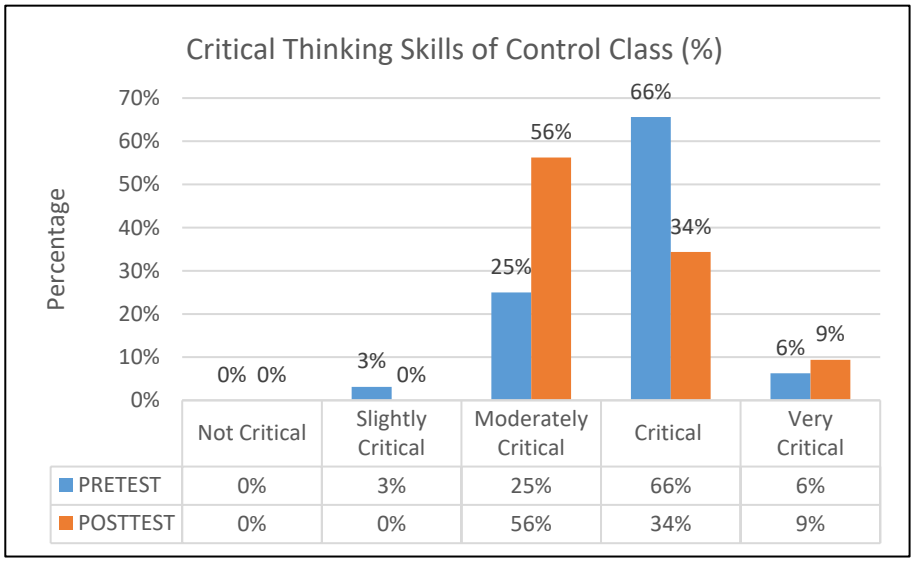

Figure 2. Distribution of Critical Thinking Skills Level of the Control Class

Figure 2 shows the classification of students' critical thinking skills in the control class during the pre-test and post-test sessions. In the slightly/less critical classification, there was a decrease from 3% in the pre-test to 0% in the post-test. In the moderately critical classification, the percentage of students increased from 25% in the pre-test to 56% in the post-test. In the critical classification, there was a decrease from 66% to 34%. In the highly critical classification, the percentage of students increased from 6% in the pre-test to 9% in the post-test.

The increase in the percentage of students in the moderately critical category in the control class can be further examined as an effect of the application of the lecture-based learning model, which helps students understand basic concepts related to the problems presented to them. However, it can be seen in Figure 2 that it does not have a big influence on developing students' critical thinking skills at higher levels - such as at the critical and very critical levels.

In contrast, the experimental class showed a significant increase in critical thinking skills in higher-order categories, such as critical and very critical, compared to the control class. An example is in the very critical category which has a notable increase. This is because in the learning model applied in the experimental class, the PBL, students are encouraged to contribute actively such as communicating among friends and teachers, collaborating, criticizing information before trusting it, and trying to be creative in the solutions that are planned to solve problems (Palwe, 2022). Learning activities like this will make it much easier to develop student's critical thinking skills than learning that emphasizes teachers who control all learning activities from beginning to end.

Factors that contribute to the difference between the experimental and control classes can also be attributed to the nature of the two learning models, in the PBL model students are accommodated to solve problems in a structured manner and encouraged to cooperate with their friends and be given feedback by the teacher during the learning process. On the other hand, learning activities in the control class, which was given a learning model in the form of lectures only, were certainly passive and ultimately did not provide enough space for students to develop their critical thinking skills. This is consistent with the findings of Usman et al., (2024) that students who are in a student-centered learning environment, such as PBL, have stronger critical thinking skills than teacher-centered learning environments, such as lecture-based learning because the PBL model always involves students in from the beginning to the end of learning activities.

Analysis of the pre-test and post-test results showed that implementing the Problem-Based Learning (PBL) model in the experimental class significantly increased students' critical thinking skills. This result is in line with the initial objective of this research, which is to test if the PBL model can be an effective pedagogical model to improve students' critical thinking skills in the context of environmental conservation. The observed improvement, as indicated in the post-test results, supports the hypothesis that PBL is more effective than lecture-based learning models. Furthermore, the findings have practical implications for learning practices, suggesting that integrating PBL into the curriculum can equip students with skills essential for solving complex environmental problems.

Comparing the two figures, it can be seen that critical thinking skills in the experimental class experienced a higher growth than in the control class. This is corroborated by the average value for both classes, where the experimental class received a value of 71 while the control class was 61. The data obtained from the instrument requires a prerequisite test with the aim of knowing its feasibility before being tested with further methods. The prerequisite test consists of normality and homogeneity tests. Below is a description of the test results.

The implementation of prerequisite tests is essential and relevant because it ensures the validity of the research results. The normality test, as the name suggests, is intended to determine whether the data distribution shows an approximate normal distribution. This is very crucial because many statistical test methods assume, including the Independent sample t-test, that the data is normally distributed, so by ensuring that the data is normally distributed, the statistical tests being applied produce reliable information (Ghasemi & Zahediasl, 2012).

Furthermore, the implementation of the homogeneity test is equally important, the homogeneity test is required to determine whether the variance of each class is the same. This is highly crucial because if the variance of the two classes is not the same, it will result in wrong conclusions when comparing the two classes. As stated by Koning, (2014), the inconsistency in the homogeneity test (i.e. the presence of heterogeneity) will cause the statistical test to be invalid, reduce the confidence interval range, and reduce the precision estimator. The homogeneity test also ensures that if there are differences in the control and experimental classes, this is due to the effect of the intervention, not the variance in the data. Therefore, these two tests were run to improve the quality and credibility of the research results by ensuring that the data explained met the assumptions for valid statistical tests. The following is a description of the test results.

Table 4. Critical Thinking Skills Normality Test Results

Test of Normality						
	Kolmogorov – Smirnov			Shapiro – Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Critical Thinking Skills	.105	61	.092	.966	61	.084

Based on Table 4, the normality test of the experimental and control class critical thinking skills data for the Kolmogorov-Smirnov test is 0.092 and the Shapiro-Wilk is 0.084, based on these results it can be seen that 0.092 and 0.084 > α = 0.05 so it can be concluded that the data is normally distributed. From the results of the normality test above, it can be seen that the data follows a normal distribution, which allows researchers to conduct parametric statistical testing for more detailed data analysis.

Table 5. Critical Thinking Skills Homogeneity Test Results

Test of Homogeneity of Variances					
		Levene Statistic	df1	df2	Sig.
Critical Thinking Skills	Based on Mean	.002	1	61	.965

Referring to Table 5, the variance homogeneity test on the experimental and control class of critical thinking skills data shows that the sig. value = 0.965 > α = 0.05 with $F(1,59) = .002$, $p = .965$. Based on these results, it can be concluded that the data variability for both classes is homogeneous. The homogeneity test results show that the variability between the control and experimental classes is the same, which permits to compare of the two groups using the Independent Sample t-test. This same homogeneity test result is very important because it ensures that the observed difference in critical thinking ability between the two classes is more likely to be due to the treatment in the form of the PBL model given, rather than due to different variability in the groups. Given that the assumptions of normality and homogeneity of both classes are met, the Independent Sample t-test can be conducted. Table 6 below explains the results of the Independent Sample t-test (2-tailed) as hypothesis testing.

Table 6. Independent Sample t-test Results of Critical Thinking Skills

		Levene's Test for Equality of Variances				t-test for Equality of Means						
		Mean	SD	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI of the Difference	
											Lower	Upper
DV	1	71.38	13.65	.002	.965	2.98	59	.004	10.286	3.449	3.38	17.18
	2	61.09	13.26									

Table 6 shows that there is a significant difference ($t = 0.004 < \alpha = 0.05$) in the critical thinking skills of the experimental (1) and control (2) classes with (t (df) = 59, p = .004) values in the experimental class (M = 71.38, SD = 13.65) while the control class with values (M = 61.09, SD = 13.26). The magnitude of the difference in mean (Mean Difference = 10.286, 95% CI: 3.38 to 17.18) was significant. Therefore, H_1 is accepted and H_0 is rejected. It can be concluded that there is a significant difference in critical thinking skills before and after the application of the Problem-Based Learning model.

The average value (mean) of the two classes also shows a difference, where the experimental class value is 15.5% or 10.2 points higher (71.38) than the control class (61.09). The Independent Sample t-test results showed that there was a significant difference in critical thinking skills between the experimental and control classes, indicating that the Problem-Based Learning model is effective in improving critical thinking skills. The results of these findings indicate that the implementation of the PBL model in geography learning is capable of improving students' critical thinking skills, which are important in the process of academic pursuit as well as other life skills. In addition, the results of this t-test also show that PBL can be an effective learning model by supporting students to learn more deeply and hone their problem-solving skills better, which is also crucial in addressing complex environmental problems.

The Problem-Based Learning model has a syntax that is able to hone students' 21st-century competencies, these competencies, known as the 4Cs consist of competencies in communication, collaboration, critical thinking, and creativity. In the implementation of this research, the student worksheets (LKPD) given to students are done together in groups. Students discuss collaboratively so that they get information from various perspectives. This discussion activity to solve problems given by the teacher is a medium to develop a supportive learning environment, communication and socialization skills, and active problem-solving skills (Hill & Griswold, 2013; C. N. D. Putri et al., 2023). After that, students have the opportunity to present and evaluate together with their friends. This opens up opportunities for critical discussions that have an impact on students understanding of the material in-depth and finding solutions to problems. During the problem-solving process, students exchange perspectives and ideas, respect each other's opinions, reflect on their ideas, and ultimately formulate a comprehensive problem-solution (Yu & Zin, 2023). These activities are the basis of scientific inquiry which encourages students to think critically. The main difference between the Problem-Based Learning model applied in the experimental class compared to the conventional learning model in the form of lectures applied in the control class is that the implementation of learning becomes more interactive between students-students and student-teachers.

Based observations carried out during the learning process at MAN 1 Malang, it shows that the application of a lecture-based learning model has a negative impact on students' critical thinking skills. When the pre-test session was conducted, the experimental class received a score of 61 while the control class was 65. After implementing the Problem-Based Learning model, the post-test score in the experimental class increased to 71, while the control class only increased to 65.

The main difference between the Problem-Based Learning model applied in the experimental class and the lecture or conventional model in the control class is how intense the interaction between students and their friends and with the teacher as a facilitator in learning. The conventional learning model - which is conducted in the form of lectures and places the teacher as the main source of information in learning provides obstacles to students to practice critical, creative, collaborative, and communicative thinking skills (Tian, 2021). Contrary to the PBL learning model which is based on active learning where students from the beginning to the end of learning are involved in the problem-solving process, discuss their ideas and perspectives together, and from there create comprehensive solutions, and therefore improve their critical thinking skills.

Learning that emphasizes learners or what is known as student-centered learning provides opportunities for students to develop their competencies. This student-centered learning approach prioritizes students' interests and needs in the learning process. Therefore, in contrast to teacher-centered learning, this approach emphasizes student collaboration and engagement tailored to the learning objectives (Kerimbayev et al., 2023). Problem-Based Learning, as the name implies, is a process that emphasizes the exposure of contextual and real-life problems as learning and problem-solving materials for students. The Problem-Based Learning (PBL) model enables students to collaborate and resolve problems together so that they can learn and criticize the variety of ideas and ideas expressed by their friends, this causes learning to be more meaningful and improves their critical thinking skills. According to Cayetano-Jiménez et al., (2024), the PBL model has been proven to improve critical thinking skills and other 21st-century competencies such as communication, collaboration, and creativity. It is intended that students can understand problems, find solutions to problems, conclude problems, and devise solutions to problems holistically and comprehensively. The advantages of PBL are in line with the results of this study, which showed a significant increase in the critical thinking skills of students in the experimental class compared to students in the control class.

During the research implementation process, the researcher provides problems about the environment that are messy, untidy, and ill-structured in the student's worksheets that are done by students. The problems presented are related to the problem of microplastic waste in rivers, industrial waste pollution in rivers, and the problem of pollution of community water resources due to mining activities. The problems presented in the student's worksheet and in the test session are open-ended, so students will be more free to express their opinions, which is important in assessing students' critical thinking skills (Sato, 2022).

Based on observations during geography learning at MAN 1 Malang, the application of learning using conventional models in the form of lectures, has an impact on the learning outcomes of students' critical thinking skills, when the pre-test is conducted, it shows that the achievement is not optimal. Conventional learning with this lecture-based model is commonly used, especially in geography learning in the classroom (Handoko & Hamidi, 2023). In the pre-test session, the experimental class scored 61 while the control class scored 65. Meanwhile, when the intervention of the learning model in the form of Problem-Based Learning was carried out, the learning outcomes of experimental class students, which were initially 61 during the pre-test, increased above the control class value, which was 71, an increase of 10 points or 16 percent from the pre-test value. Meanwhile, the control class scored 65, only an increase of 4 points or 6 percent compared to the score in the pre-test session.

The t-test results showed that there was a significant difference between the experimental and control classes in terms of critical thinking skills, with a p-value of 0.004. This indicates that the PBL model has a positive effect on students' critical thinking skills. In a practical way, this means that the application of the PBL model in learning activities can improve the quality of students in terms of thinking critically about a real problem that occurs around them, which is a very crucial thing in dealing with complex 21st-century problems.

Furthermore, the significant improvement observed in the experimental class demonstrates the practical relevance of applying the PBL model in a learning environment where critical thinking and problem-solving skills are necessary to solve many of today's global environmental problems. These results are in line with the objectives of this study and support the hypothesis that PBL is more effective in developing critical thinking skills than the traditional lecture-based learning model.

The post-test score in the control class given a lecture-based learning model which is lower than the experimental class further emphasizes that teacher-centered learning is not optimal and several problems arise in it, especially in current learning that emphasize 21st-century competencies, the 4Cs. This is supported by the statement from Jiann-Wen & Liao (2024) that some of the problems in the lecture-based model such as problems in the long span of student attention, passive learning, and lack of opportunities for students to hone their criticality and creativity. The learning model which is implemented only using the lecture or lecture-based method is also criticized because it results in a lack of student motivation and interest in the material provided by the teacher (Chueh & Kao, 2024). Based on the evidence above, it can be seen that if a teacher wants to deliver material that is abstract, broad, requires integration between scientific disciplines, complex, and hone students' 21st-century competencies, a student-centered learning model such as Problem-Based Learning (PBL) is a better choice compared to conventional lecture-based models.

On the other hand, the implementation of this student-centered learning model indicates that the Problem-Based Learning model influences improving students' critical thinking abilities. As stated by Nisa & Wulandari (2019) the PBL model encourages students to participate actively, collaboratively, and effectively in solving real problems. Even though students solve problems together in groups, in the PBL model students also learn to be independent in finding solutions to a problem so that their ability in self-directed learning, understanding a problem in-depth, working together in groups, and their ability to solve practical problems can be honed

(Jiann-Wen & Liao, 2024). This learning model is also in accordance with the characteristics of Environmental and Sustainable Development (ESD) material, which is closely related to students and current environmental problems which are messy, untidy, and ill-structured (Smith et al., 2022).

To find out whether the implementation of the PBL model has a statistically significant effect, and not just due to mere coincidence before and after the intervention, the Independent Sample t-test was carried out. Based on the results of the Independent Sample t-test on critical thinking skills, there is a significant difference between the control and experimental classes, with a significance value of 0.004 (with $\alpha = 0.05$, 95% *CI*). Based on these results, it can be seen that the Problem-Based Learning model has a positive impact on improving students' critical thinking abilities.

The results of this study are supported by the findings of, Amin et al., (2020), and Anggraeni et al., (2023) which have shown that learning models based on real problems, such as PBL, are capable of significantly improving students' critical thinking skills. In the context of this study, the application of the PBL model which emphasizes reflection and active problem-solving activities directly contributes to the improvement of critical thinking skills, as shown in the significant increase in this study. This is consistent with studies that underline the effectiveness of PBL in linking theoretical knowledge and concepts with practical problem-solving in real-world contexts (Liu & Pásztor, 2022).

The implementation of learning in the experimental class using the PBL model shows that students become more active and independent in solving problems given by the teacher. This is supported by research from Sartika et al., (2024) which states that the implementation of the PBL model will support students' ability to connect real problems with what they are learning, support collaboration between students, and train students' higher-order thinking skills. The teacher's role is as a facilitator by assisting students' needs regarding questions or material that they do not yet understand, but is not the main actor in learning. When working on the questions on the student worksheet, students use various sources of information, both from friends and teachers. After the student's worksheet (LKPD) task activities are completed, students have the opportunity to present their findings in front of the class, and together with the teacher and students reflect, evaluate, and correct if there are learning concepts that need to be improved. With learning activities that tend to focus on the construction of knowledge by students, PBL is considered effective in improving student understanding, critical thinking skills, individual and group performance, motivation, and student satisfaction (Kusumawardani & Aminatun, 2024; Lu, 2024). This is because if students formulate their own learning goals, they will learn how to be independent and assess themselves, and also learn how to work together in groups (Cássia Silva De Oliveira & Behnken, 2024).

In the control class, the teacher's focus in teaching was on delivering lecture-based material and students working on student worksheets without any presentation or reflection on learning. The lack of active interaction between teachers and students resulted in passive learning (Mariappan, 2023). In contrast to this, in the experimental class, the teacher applied the model and delivered the learning model in the form of Problem-Based Learning (PBL) and always assisted students during the problem-solving process by facilitating discussion and reflection between students. This causes students to be more active and independent in their learning.

Based on the explanation above, it can be seen that a learning model that is oriented and focused on students, especially Problem-Based Learning (PBL) has a significant influence in improving students' critical thinking abilities, this cannot be separated from the fact that students are faced with problems and are given freedom of opinion, collaboration, creativity, communication, and in-depth analysis of ideas and information to form comprehensive and holistic solutions to problems. For example, during the implementation of the PBL model in the experimental class, students were given worksheets containing questions related to case studies, such as hazardous waste pollution in rivers, local community innovations to reduce plastic waste in the sea, evaluation of steps to deal with environmental problems, and grouping the principles of conservation and sustainable development based on the case study given. During the implementation, students are supported to collaborate and discuss in groups, analyze ideas and arguments from various perspectives, and make presentations in front of the class. This learning process not only enhances their understanding of the topic but also hones their critical thinking skills as they learn to critically evaluate information and provide well-founded and rational solutions.

In addition, learning activities will be lively and interactive, students who have a passive tendency will be trained to express ideas and contribute to group work so that the ideas and solutions obtained as a result of learning are diverse and able to become solutions to the problems they face. For the implementation of learning using the PBL model to run well, teachers need to prepare problems that are appropriate to the context, prepare material or references that are appropriate to the problem and real to the students' environment, and provide

questions or problems that need to be answered by students in a representative manner based on the material that has been provided, delivered, or taught previously (Li et al., 2024).

4. Conclusion

This research found that the implementation of learning uses a student-centered approach, in this case, Problem-Based Learning (PBL) has a significant effect on increasing students' critical thinking abilities. The results of this study can be a recommendation for teachers to apply the PBL model in the learning process, especially on materials that are complex and require an interdisciplinary approach such as the environment and its problems. In the case of geography lesson planning, the results of this study can serve as a foundation for the development of geography lesson planning that is more adaptive and relevant to the needs of today's students. In addition, the results of this study also show that the PBL learning model has an important role in improving students' critical thinking skills, which also basically emphasizes the importance of having students' 21st-century skills developed.

The average score (mean) between these two classes shows a statistically significant difference, where the experimental class with the Problem-Based Learning (PBL) model got a higher average score of 71.38. In contrast, the control class with the lecture or lecture-based model got an average score of 61.3. The significant difference between the two classes can be seen from the results of the Independent Sample t-test with a significance value of $0.004 < \alpha = 0.05$. The lowest score in the pre-test session in the experimental class was 46 while the highest score was 71. In the post-test session, the experimental and control classes had the same lowest score of 42. The experimental class got the highest score of 92 while the control class was 96. Overall, there are differences in the average scores for the two classes.

The average score for the experimental and control classes in the pre-test session was 61 and 65 respectively, where the control class showed an average pre-test score that was 6% higher than the experimental class. When intervention in the form of a Problem-Based Learning (PBL) learning model was applied in the experimental class, the post-test score showed an increase of 42% to 71 compared to the pre-test session. Meanwhile, the control class where the lecture or lecture-based learning model was applied showed a decrease of 6% to 61 compared to the pre-test session. The standard deviation value for the experimental class shows a higher value of 13.65 compared to the control class of 13.26.

As stated in the results and discussion section, there was an increase in critical thinking skills in the experimental class compared to the control class because, in the implementation of the Problem-Based Learning (PBL) learning model, students became more active in constructing their ideas and knowledge, students also had the opportunity to hone their competencies. The core of the 21st century such as critical, creative, collaborative, and communicative thinking which are basic elements of critical thinking are developed.

Although this study has demonstrated the effectiveness of the PBL model in improving students' critical thinking skills, some limitations must be considered. For example, the study sample size was limited to 61 students, potentially limiting generalization to a wider population. In addition, the limited duration of the study may also be insufficient to fully evaluate the long-term impact of the PBL model, therefore, a longitudinal study may be needed. Researchers who are interested in continuing the results of this research can compare the differences in critical thinking abilities between the two classes in terms of gender distribution. Apart from that, researchers can increase the number of students or apply more than one student-centered learning model to gain new insights regarding the influence of various learning models on students' critical thinking abilities, especially in environmental materials in geography. Future researchers can also extend the duration of the study to gain deeper insight into the effects of the PBL model. Researchers can also add variables other than critical thinking skills, such as student engagement in learning, motivation, and other variables.

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