

## EFFECTIVENESS OF PROBLEM-BASED LEARNING ON STUDENTS' CRITICAL THINKING SKILLS TO SUPPORT ESD

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### Article Info

Received: 18 May 2025

Accepted: 09 August 2025

Publication: 24 August 2025

### Abstract :

This research is proposed to determine the effectiveness of problem-based learning on students' critical thinking skills, especially on physics material about alternative energy and its role in supporting ESD. The design used in this research is a quasi-experimental design with a non-equivalent control group design. The sample is class X E as the experimental class and then class X D as the control class at SMAN 14 Bandar Lampung. The test instrument has a value from Cronbach's Alpha of 0.862. The result of the average N-Gain was 0.63 with a moderate category, while the average N-Gain of critical thinking skills in the control class was 0.41 with a moderate category. This shows that the indicators of critical thinking skills increased significantly; the significance value was  $0.000 < 0.05$ , so it can be concluded that there is a significant difference between the average n-gain of critical thinking skills of students in the experimental class and the control class. The novelty of this research lies in its contribution to integrating Problem-Based Learning (PBL) with Education for Sustainable Development (ESD). By utilizing real-world sustainability issues as learning contexts, the study aims to enhance students' critical thinking skills in a meaningful and relevant manner. The findings have practical implications for educators in designing instructional strategies to increase critical thinking and sustainability awareness. Theoretically, this research supports the role of PBL as an effective pedagogical approach for 21st-century education with the goals of sustainable development.

Keywords: Critical Thinking Skills, ESD, Problem-Based Learning

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## INTRODUCTION

Education plays an important role in preparing the young generations to have a good understanding of global issues, so good soft skills and hard skills are needed to find a solution for those issues (Abera, 2023). Critical thinking skills are one of the skills in the 21<sup>st</sup> century that can give a good understanding to the young generation to evaluate something objectively and make a good decision in problem-solving (Sahidu et al., 2020).

21st-century skills require teachers to focus on learning carried out by students, including in terms of communication, collaboration, creativity, and innovation, as well as critical thinking and problem solving (Nirbita et al., 2018). Critical thinking skills are one of the 21st-century skills that can provide understanding to the younger generation to evaluate something objectively and make the right decisions to solve problems (Husaini et al., 2023). Critical thinking skills play a crucial role in supporting the role of science education in addressing global challenges and issues, such as energy and sustainability (Santos, 2017).

Critical thinking skills are one of the 21st-century skills that can provide understanding to the younger generation to evaluate something objectively and make the right decisions to solve problems (Anisa et al., 2021). Demands of global issues like an energy crisis and sustainability issues require education to make students have a good understanding of the material that leads to the goals of sustainable development (Malik, 2018). Critical thinking skills support the role of science education in global challenges and issues, such as energy and sustainability (Carmona 2023).

The sustainability, which is called the Sustainable Development Goals (SDGs) (Purnamasari & Hanifah, 2021) SDGs have 17 goals that cover various aspects of global development (Sorooshian, 2024). One aspect to achieve the SDGs is through an educational approach (Akinsemolu & Onyeaka, 2025). An educational approach carried out with the principle of sustainable development is needed to create a world without having to sacrifice (Husaini et al., 2023). The educational approach to sustainable development is known as Education for Sustainable Development (ESD) (Ariska et al., 2024).

Alternative energy material is very appropriate because that's relevant to sustainability issues and global efforts to reduce dependence on fossil fuels, which are limited and increasingly depleted (Wang & Azam, 2024). The use of energy such as solar, wind, and biomass energy provides a sustainable solution to reduce dependence on fossil fuels and reduce negative impacts on the environment (Utami & Syam, 2022). According to a global report, Indonesia currently contributes around 30% of carbon emissions from the energy sector. The use of these environmentally unfriendly energy sources must be immediately reduced and replaced by more environmentally friendly and renewable energy sources (Silitonga and Ibrahim, 2020). The importance of delivering this material is that teachers are expected to be able to guide students to critically understand the concept of physics and its relevance to solving problems in everyday life, and demand a more innovative and interactive approach in the learning process (Sari et al., 2023).

However, in reality, the student's critical thinking ability, specifically in terms of critical thinking skills, is low. This is evidenced by the results of research conducted by Wijayanti & Siswanto (2020) with the results of students' critical thinking being classified as low, namely 46.97% and in the research of Ekamilasari & Pursitasari (2021) which showed that students' critical thinking skills are in the low category with an average score of 28.68%. Students' weak critical thinking skills have an impact on their awareness of sustainability issues, which are still classified as moderate, with a total mean of 3.65. This suggests that students are not yet sufficiently critical to analyze real-life sustainability problems effectively.

The results of preliminary research conducted by researchers through interviews with one of the physics teachers at SHS 14 Bandar Lampung showed that physics learning, especially the material on alternative energy, has explained the concept of the material in general, but still does not adequately address the role of education for sustainable development (ESD). Teaching material used in the learning is the PowerPoint and implementation with a cooperative model supported by books from the library as teaching materials, which causes low understanding and critical thinking skills of students regarding alternative energy material to support the role of ESD (Wahyuni et al., 2024).

The solution from the problem-based learning model is very good for improving students' critical thinking skills (Arends, 2012) because the basic principle of the problem-based learning model uses actual problems to deepen students' understanding (Siagian et al., 2023). Hutagalung et al., (2023) in their research, they said that in problem-based learning, students' critical thinking skills are truly optimized through teamwork, so that students are able to optimize their thinking skills well. The implementation of problem-based learning in its application must also be supported by relevant teaching materials and optimal implementation (Purba et al., 2023)

The results of research indicate that the problem-based learning model has been widely applied to the improvement of students' critical thinking skills, but there are still few that specifically teach alternative energy materials to support the role of ESD. The materials provided are still general and less specific in discussing the problems of the energy crisis, global challenges, and sustainability issues, a topic that is not only scientific but also requires critical thinking skills to understand. This research is also relevant and new because it links formal education with global demands, supporting the role of education in sustainable development.

## **RESEARCH METHOD**

### ***Research Design***

This research was conducted in the even semester of the 2024/2025 academic year at SHS 14 Bandar Lampung, which is located in the Kemiling District, Bandar Lampung, and uses a quantitative research design. This research was conducted at grade X D as the control class and X E as the experimental class, with adjustments to the physics learning schedule at the school.

### ***Research Target/Subject***

The population of this research consisted of all grade X students of SHS 14 Bandar Lampung. The sampling technique used was purposive. The sample was obtained by considering the abilities of students who were almost the same in previous learning outcomes, so that the sample for this study was grade X E as the experimental class and grade X D as the control class.

### ***Research Procedure***

The research procedure consists of three stages. The first stage is the preparation stage, which involves conducting a literature review on the topic to be discussed, carrying out preliminary research to determine the population and research sample, preparing the research instruments, and testing these instruments. The second stage is the implementation and data collection phase, involving two classes: an experimental class that receives treatment in the form of problem-based learning, and a control class that receives no treatment. The final stage involves processing and analyzing the data, followed by drawing conclusions based on the analysis results.

### ***Instruments and Data Collection Techniques***

This research employs written test questions as an assessment instrument to measure students' thinking skills on alternative energy topics, with a focus on the role of energy in the energy crisis and global challenges related to sustainability. The instrument was developed using critical thinking skill indicators, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation, according to (Facione, 2013). The test consists of 10 descriptive questions contextualized around alternative energy, emphasizing problem-solving, energy management, and support for the role of Education for Sustainable Development (ESD). This instrument was administered during both the pretest and post-test. Before use, the research instrument was tested on a sample to ensure its quality. It was validated through a validity test (Arikunto, 2011) and a reliability test (Rosidin, 2017) to ensure its effectiveness in supporting the research hypothesis. The instrument is expected to demonstrate an improvement in students' critical thinking skills after the implementation of the problem-based learning model in the context of alternative energy.

The data collection technique in this study involves the use of tests to measure students' critical thinking skills on alternative energy topics, focusing on the role of energy in addressing energy crises and global challenges related to sustainability. The test is administered twice: before the learning process (pretest) and after the learning process is completed (post-test). This test is given to all students in both the experimental and control classes.

**Data analysis technique**

In this research, the Kolmogorov-Smirnov test was used with SPSS 25.0 to examine the normality of the data. The N-Gain was calculated using the N-Gain formula to determine the difference between pretest and post-test scores. Hypothesis testing was conducted using the Independent Samples T-Test to determine whether there was a significant difference in the mean scores between two unrelated groups. This was followed by an effect size test to measure the magnitude or significance of the difference in the average N-Gain between the groups.

**RESULTS AND DISCUSSION**

This research was conducted at SHS 14 Bandar Lampung, with the sample used in this study being class X E as the experimental class and X D as the control class, determined using a purposive sampling technique. This study used a descriptive test technique to determine students' critical thinking skills, namely a pretest given before the application of the problem-based learning model on alternative energy material in the experimental class and the cooperative learning model in the control class, then a post-test was given after the learning activities had been carried out in each class. The following are quantitative data from the research results in Table 1.

Table 1. Result of Quantitative Data

Parametric Statistic	Control Class		Eksperimen Class	
	Pretest	Post-test	Pretest	Post-test
Number of Sample (N)	36	36	36	36
Lower Score	5	27,5	7,5	42,5
Highest Score	62,5	87,5	52,5	95
Maximum Score	100	100	100	100
Mean	21,6	53,3	21,6	71,4

The results of the data analysis are presented in the form of inferential statistical data, including normality tests, homogeneity tests, N-Gain calculations, and hypothesis testing using the Independent Samples T-Test. The detailed results of the analysis can be found in Tables 2 to 5.

Table 2. Result of Normality Test

Class	Kolmogrov Smirnov		
	Statistic	Df	Sig.
Experiment	0,125	36	0,170
Control	0,108	36	0,200

Table 3. Result of Homogeneity Test

Levene Statistic	df 1	Df 2	Sig.	Interpretation
0,103	1	70	0,750	Homogen

Table 4. Result of N-Gain

Class	Score			Category
	Score Max	Score Min	Mean	
Experiment	0,91	0,32	0,63	Sedang
Control	0,76	0,17	0,41	Sedang

Table 5. Result of Independent Sample T-Test

Levene's Test for Equality of Variances	T-test for Equality of Means
Equal variances assumed	Sig. 2-tailed 0,000

Table 2 presents the results of the normality test using a parametric approach, which determines whether an Independent Samples T-Test can be conducted based on the assumption of normal data distribution. The normality test was performed using SPSS 25 with the Kolmogorov-Smirnov method, as the sample size in this study exceeds 50 participants. The results indicate that the significance value (Sig.) for the N-Gain in the experimental class is 0.170, and in the control class is 0.200. Since both significance values are greater than 0.05, the null hypothesis ( $H_0$ ) is accepted, indicating that the data in both classes are normally distributed. The results of the homogeneity test in this study are presented in Table 3. It can be seen that the sig value obtained is 0.750, so the sig value  $> 0.05$ . Therefore, the N-Gain data from the pretest and post-test in both the experimental and control classes can be considered homogeneous.

Based on the N-Gain calculation results presented in Table 4, the experimental class achieved an average N-Gain of 0.63, while the control class obtained an average N-Gain of 0.41. The results of the hypothesis testing are shown in Table 5, using the Independent Samples T-Test, which yielded a significance value (Sig.) of 0.000 ( $< 0.05$ ). Therefore, the null hypothesis ( $H_0$ ) is rejected and the alternative hypothesis ( $H_1$ ) is accepted, indicating a significant difference in the average N-Gain between the experimental class that implemented the Problem-Based Learning (PBL) model and the control class that used the cooperative learning model. As there is a significant difference in the average N-Gain between the two groups, it can be concluded that  $H_1$  is accepted.

Based on the quantitative data presented in Table 4 regarding students' critical thinking skills, it is shown that the average post-test score in the experimental class (71.4) is higher than that in the control class (53.3). This difference is also reflected in the average N-Gain of critical thinking skills between the two groups, as presented in Table 1.

The results of hypothesis testing using the Independent Sample T-test in Table 5 show that there is a difference in the average n-gain of students' critical thinking skills between the control and experimental classes. The achievement of students' critical thinking indicators can be seen based on the average n-gain on each critical thinking indicator shown in Figure 1.

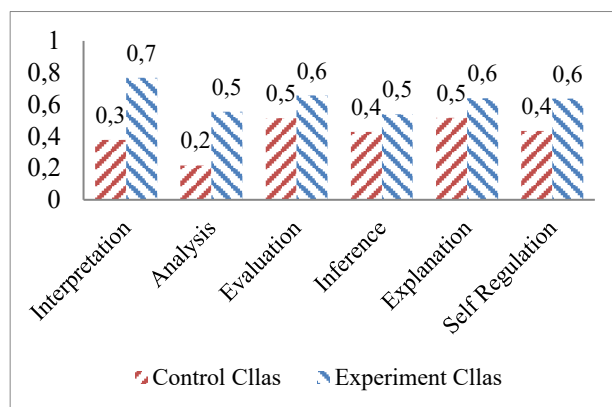


Figure 1. N-Gain Graph of Critical Thinking Skills Indicator Achievement

Figure 1 shows that there is an increase in students' critical thinking skills in each of its indicators. The first indicator of critical thinking skills is evident in the significant increase in critical thinking skills observed in the experimental class compared to the control class, with a notable difference in values between the two classes, specifically 0.389. This is because, during the learning process in the experimental class, students were engaged in preliminary activities as part of the PBL

phase, specifically the orientation to a problem. This orientation involved the use of texts, images, or videos related to real-life phenomena (Widayati & Sofwan, 2025).

According to Aprina et al (2024), at the problem orientation stage, students are focused on solving and interpreting a problem individually or in groups with a critical approach to find solutions, and according to them, critical thinking skills are needed to make it easier to solve problems. This is also supported by the application of constructivist learning theory, where students are provided with opportunities to apply their thinking skills by directly engaging with real-world phenomena (Suparlan, 2019). The learning process is not merely about memorization, but also involves the active construction of knowledge through individual effort (Abdjul, 2019). The understanding related to this theory views learning as a process constructed through students' independent acquisition of knowledge. The improvement of this indicator during implementation is closely linked to teaching methods that emphasize student-centered learning (Dewi & Fauziati, 2021). Constructivist theory is a part of the explanation that explains how students who are individuals can adapt and improve their knowledge (Mokalu et al., 2022).

In the analysis, evaluation, and inference indicators, the experimental class experienced a fairly high increase compared to the control class. This was due to the PBL phase, namely the implementation of the investigation. Students conducted investigations by examining and analyzing opinions from information to find a solution to the problems given (Wijaya et al., 2018). According to (Sari et al., 2021) explained that critical thinking skills can be trained and developed through a structured approach, emphasizing the importance of providing appropriate guidance to support students in carrying out the investigation process, thereby enhancing their critical thinking abilities.

The explanation indicator showed improvement in the experimental class because, during the PBL phase, specifically the stage of developing and presenting the results, students were trained to design a product or solution in response to the given problem, and subsequently present their work to other groups in front of the class.(Karan, E. Brown, 2022). According to Mustakim et al., (2023) Through the process of developing and presenting the results of the work, students are encouraged to think analytically, creatively, and critically, which in turn improves their critical thinking skills.

The last critical thinking skill indicator that showed improvement in both classes was the self-regulation indicator; this increase can be attributed to the fact that students in the experimental class were trained to be more independent in solving problems. Self-regulation skills are students' skills to regulate themselves during the learning process, including planning, setting goals, evaluating progress, and making decisions based on the results of the evaluation (Rodiyah, 2022). Aprina et al. (2024) in their research stated that PBL learning requires students to engage in active self-regulation and fosters the development of this skill in each individual. This enables students to better control and direct their thinking processes when solving the problems presented to them.

Based on Figure 1, it can be seen that there are 6 indicators of critical thinking skills of students in the experimental class that have increased. The interpretation indicator has increased in the high category, while the other five indicators, namely analysis, evaluation, inference, explanation and self-regulation have increased in the moderate category.

Based on the results of the analysis of the increase in n-gain achievement in each indicator of critical thinking skills, it was found that learning activities in the PBL model were able to support the increase in critical thinking skills of students quite significantly. Based on the results of the effect size test, the Cohen's d value was 1.361 with a large category. This shows that the problem-based learning model in the experimental class is very effective in terms of students' critical thinking skills in alternative energy material, where the presentation of the material is directed towards sustainable life (sustainability) (Agusti et al., 2019).

A significant improvement in students' critical thinking skills was observed following the implementation of Problem-Based Learning (PBL), supported by teaching materials in the form of PBL-based student worksheets (LKPD) that focused on sustainability issues (Yuliandriati et al., 2019). The first stage of learning for students is problem orientation. Students are given a phenomenon in LKPD related to everyday life in an alternative material.



Figure 2. Process from Create Project

At the development and presentation stage, students produced a simple project that utilized alternative energy as a solution to the formulated problem. Their work demonstrated how such solutions could contribute to reducing the negative impacts of conventional energy use, as exemplified by the creation of a basic hydroelectric power plant, as shown in Figure 2.

The activities at this stage are intended to improve students' understanding of ESD, which aims to identify and find solutions to problems related to the environment and sustainability (Paul & Elder, 2014). This is confirmed by research by Rahmawati et al., (2021) which states that ESD can be integrated into physics learning, which can direct students so that they can contribute actively and creatively to preserving the surrounding environment. Furthermore, students in each group make presentations of the products they have designed as solutions to the problems given (Ismail et al, 2018). The indicator of critical thinking skills practiced at this stage is explanation, related to how students are able to explain and express the solutions they get from a particular process.

The implementation of learning in the experimental class showed active participation and involvement from students (Rahmi, 2024). This is because the process of problem-based learning requires students to be active and critical in solving a problem both individually and in groups. Research from Nirmayani & Suastra, (2023) states that the use of the problem-based learning model is able to solve problems and have the skills to participate actively in groups.

According to (Widya & Marwa, 2025) the involvement of students at each stage of learning that is applied with a focus on alternative energy material on the role of ESD can stimulate students to improve their critical thinking skills in terms of understanding and interpreting the meaning of information, analyzing, explaining, concluding and evaluating a problem-solving process to find solutions to the problems given and focusing on supporting the roles of education in sustainable development (ESD).

## CONCLUSION

Based on the results of the study, literature review, testing, and analysis of research data, it can be concluded that the PBL model is quite effective and has a major influence on improving students' critical thinking skills in alternative energy material, regarding the role of alternative energy as an environmentally friendly alternative energy solution, and supporting the role of ESD. This is indicated by the difference in the average n-gain of students' critical thinking skills in the experimental class, which is higher than the control class, which is 0.633, with a moderate category. This increase is supported by the results of the effect size test with a Cohen's d value of 1.325 in a large category. This increase is caused by PBL activities that support the improvement of students' critical thinking skills.

This study has shown that the Problem-Based Learning (PBL) model is effective in enhancing students' critical thinking skills on the topic of alternative energy, thereby supporting the role of Education for Sustainable Development (ESD). However, this research was limited to a specific subject, educational level, and a relatively short duration of implementation. Therefore, it is recommended that future research explore the long-term effects of PBL across a broader range of science topics and educational contexts. Further studies could also incorporate other 21st-century

skills, such as collaboration, communication, and creativity, to provide a more comprehensive understanding of how PBL contributes to sustainable education.

## ACKNOWLEDGMENTS

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This study has shown that the Problem-Based Learning (PBL) model is effective in enhancing students' critical thinking skills on the topic of alternative energy, thereby supporting the role of Education for Sustainable Development (ESD). However, this research was limited to a specific subject, educational level, and a relatively short implementation duration. Therefore, it is recommended that future research explore the long-term effects of PBL across a broader range of science topics and educational contexts. Further studies could also incorporate other 21st-century skills, such as collaboration, communication, and creativity, to provide a more comprehensive understanding of how PBL contributes to sustainable education.

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