The Effect of the PBL-STEM on Students' Critical Thinking Skills

Robi Awaludin, Aripin, & Yanti Sofi Makiyah*
Physics Education Study Program, University of Siliwangi, Indonesia
*Corresponding Author: yanti.sofi@unsil.ac.id

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Abstract - *The low level of students' critical thinking skills is one of the main challenges in education, often caused by a lack of variety in instructional models. To address this issue, the researcher implemented the Problem-Based Learning model integrated with Science, Technology, Engineering, and Mathematics (PBL-STEM). This study aims to examine the effect of the PBL-STEM model on students' critical thinking skills. The research employed a nonequivalent control group design, involving two groups of students: an experimental group taught using the PBL-STEM model and a control group taught using the conventional PBL model. The subjects were Grade 10 science students (X MIPA) at a senior high school. Data were collected through a critical thinking skills test consisting of 10 validated essay questions, with a reliability coefficient of 0.649. The results indicate that the application of the PBL-STEM model effectively enhances students' critical thinking skills, with an N-Gain score of 72%, categorized as high. The most significant improvement was observed in the indicators of elementary clarification (the ability to understand and clarify basic concepts) and inference (the ability to draw logical conclusions). A significance test revealed a statistically significant difference between the experimental and control groups, confirming that the PBL-STEM model has a substantial impact on developing students' critical thinking skills. These findings suggest that the PBL-STEM model not only strengthens students' analytical and logical reasoning but also provides a learning experience that is relevant to real-world contexts. The study recommends the implementation of the PBL-STEM model as an innovative teaching method to foster critical thinking skills, particularly within science and technology-based learning environments.*

Keywords: *PBL-STEM; critical thinking skills; Work and Energy.*

INTRODUCTION

The low level of students' critical thinking skills has become an increasingly prominent issue in the field of education, considering the importance of this competence in preparing students to face the growing complexity of global challenges. In the 21st century, students are expected not only to master academic knowledge but also to develop critical thinking, creativity, collaboration, and communication skills collectively known as the 4Cs. According to the Partnership for 21st Century Skills (P21), critical thinking is one of the core competencies individuals must possess in order to make sound decisions, analyze information objectively, and solve problems effectively and creatively. Without this skill, students are likely to struggle with problems that require deep and structured thinking, both in academic settings and in everyday life.

Physics education, as a discipline grounded in scientific concepts and experimentation, holds great potential to cultivate critical thinking skills. However, physics learning is often dominated by conventional methods that emphasize theoretical understanding and rote memorization, which do little to enhance students' critical thinking skills (Trianggono, 2017). Therefore, an innovative instructional approach is needed to address this issue, one such approach is the Problem-Based Learning (PBL) model integrated with the STEM (Science, Technology, Engineering, and Mathematics) framework. The PBL-STEM model emphasizes learning through real-world problems, in which students are presented with situations that require collaborative and creative problem-solving, as well as interdisciplinary application of knowledge from various fields (Wardani et al., 2018).

In the PBL-STEM model, students are not only engaged in understanding physics concepts but are also encouraged to think critically while solving problems, identifying key issues, gathering relevant information, and drawing evidence-based conclusions (Diani, R., & Syarlisjiswan, 2018; Wardani et al., (2017)). This approach enables students to work collaboratively in groups, communicate effectively, and explore innovative, technology-driven solutions. As such, it provides a more meaningful learning experience in which students are not merely passive recipients of information but actively develop essential critical thinking skills that are crucial in the 21st century. Furthermore, the PBL-STEM model equips students with better readiness to face real-life challenges and the demands of the modern workforce, which often involve complex problem-solving and critical reasoning (Yuliati, 2013).

Critical thinking is an intellectual potential that can be nurtured and developed through the learning process Ennis, 2011). It involves the ability to think broadly, inquire, and analyze in order to find relevant information. Cahyono (2017) states that students’ critical thinking skills vary and must be cultivated from an early age, especially during primary education. In physics learning, critical thinking is essential for every individual to solve real-world problems, both in educational contexts and in society. Through critical thinking, students are driven to inquire, analyze information, investigate new knowledge, think broadly, and skillfully construct arguments supported by evidence in order to make informed decisions and draw conclusions about ongoing natural phenomena.

The problem identified by the researcher is the low level of students' critical thinking skills, which is influenced by the lack of engaging learning models. This is evident from students’ lack of enthusiasm during lessons, their tendency to passively wait for teacher explanations, and their reluctance to ask questions or express opinions. As a result, students’ critical thinking skills remain low. Based on the results of a critical thinking test administered by the researcher, students performed poorly across all indicators, with an average score of 46.13, falling into the low category.

This issue can be addressed through a student-centered learning model such as Problem-Based Learning integrated with Science, Technology, Engineering, and Mathematics (PBL-STEM). According to Yulianti, (2018), Problem-Based Learning is characterized using real-life problems as a context in which students learn to think critically, become proficient problem-solvers, and acquire knowledge. From this definition, it can be concluded that Problem-Based Learning is a student-centered model. The integration of PBL with STEM stimulates students' critical thinking skills and enhances their understanding of the subject matter, as students are required to solve problems by connecting scientific knowledge with concepts from technology, engineering, and mathematics (Cahyaningsih & Roektiningroem, 2018). This model encourages students to solve problems using their own learning strategies, thereby promoting more active engagement in the learning process.

Given the importance of developing students’ critical thinking skills and the need for innovation in classroom learning, this study applies the PBL-STEM model to the teaching of physics, specifically in the topic of work and energy.

RESEARCH METHODS

This study employed a quasi-experimental design using a non-equivalent control group design. In this design, the experimental class received instruction using the Problem-Based Learning (PBL) model integrated with STEM to assess its effect on students' critical thinking skills in physics learning. The impact of the PBL-STEM model on students' critical thinking skills was evaluated at the end of the study, following the implementation of the treatment in the experimental class.

The data collected from the pre-test and post-test were analyzed using descriptive statistical techniques to illustrate students' critical thinking skills before and after the application of the PBL-STEM model. Descriptive analysis included the calculation of the mean, highest score, and lowest score to describe students' achievement levels. To determine whether there were statistically significant differences between the pre-test and post-test scores, a paired sample t-test was conducted. A p-value less than 0.05 was considered statistically significant, indicating a meaningful difference in students' critical thinking skills. Additionally, the Normalized Gain (N-Gain) was calculated to measure the improvement in students' critical thinking skills, where an N-Gain value greater than 0.7 was categorized as high (Arikunto, 2020).

Through this analysis, the study aimed to evaluate the effectiveness of the PBL-STEM model in enhancing students' critical thinking skills.

RESULTS AND DISCUSSION

Result

In this study, the learning activities were conducted in two classes: an experimental class and a control class. The experimental class received instruction using the Problem-Based Learning (PBL) model integrated with STEM, while the control class was taught using the direct instruction model. Based on hypothesis testing at the 95% confidence level, the results showed that the calculated t-value was greater than the critical t-value, which satisfies the condition to accept the alternative hypothesis **(H_a)** and reject the null hypothesis **(H_0)** A summary of the statistical results can be seen in **Table 1**.

Table 1. Summary of t-Test Results

Data	Group		α	t_{calc}	t_{table}
	Experiment	Control			
n	35	35	0,05	3,371	1,995
Average	32,200	27,942			
StDev	5,707	4,819			
Var	32,576	23,231			

The learning process in the experimental class, which implemented the Problem-Based Learning (PBL) model integrated with STEM, had a significant impact on students' critical thinking skills, particularly in the topic of work and energy. This finding is supported by the study conducted by Nailul Khoiriyah (2018), which stated that learning using the STEM approach is effective in enhancing students' critical thinking skills. Additionally, Parno et al. (2020) reported that the PBL-STEM model can improve Critical Thinking Skills (CTS).

The influence of the PBL-STEM model lies in how it actively involves students in solving real-world problems presented at the beginning of the learning process. This approach encourages students to become more systematic in identifying problems and drives them to engage in active learning by discovering concepts contextually and meaningfully from understanding the problem, planning strategies, executing them, and evaluating solutions while the teacher functions primarily as a facilitator. Moreover, students are encouraged to participate actively and collaboratively in discussions to solve problems, which strengthens their critical thinking skills. This is in line with the findings of Khairiyah & Faizah (2020), who emphasized that learning activities that highlight the critical thinking process enable students to solve problems not only in the classroom but also in real-life situations they face daily.

Critical thinking skills improved in both the experimental and control classes, as evidenced by post-test scores being higher than pre-test scores in both groups. However, the post-test results indicated that students in the experimental class who were taught using the PBL-STEM model achieved higher levels of critical thinking than those in the control class, which used the direct instruction model. This difference can be attributed to students' active involvement during the learning process. In the experimental class, the learning was student-centered, allowing students to play an active role throughout the lesson. Conversely, the control class was teacher-centered, with students less involved and heavily dependent on the teacher. This finding is consistent with Hunaepi et al. (2014), who stated that in direct instruction models, the teacher plays a dominant role in the learning process, resulting in one-way communication.

Although both learning models were able to improve students' critical thinking skills, the PBL-STEM model proved to be more effective compared to the direct instruction model. According to Piaget's theory of constructivism, an individual's potential can develop and succeed through self-construction or self-directed learning (Saputro & Pakpahan, 2021). The average scores for each critical thinking indicator are presented in Table 2.

Table 2. Average Percentage of Critical Thinking Skill Scores

No	Indicaor of CTS	Experiment		Control	
		Percentage (%)	Category	Percentage (%)	Category
1	*elementary clarification*	82,14	Very High	69,64	Moderate
2	*basic support*	79,29	High	71,07	moderate
3	*inference*	82,14	Very High	68,93	moderate
4	*advanced clarification*	78,57	High	68,93	moderate
5	*strategy and tactics*	80,83	High	70,71	moderate

Based on Table 2, the average post-test percentage score of students' critical thinking skills in the experimental class was 80.5%, categorized as "high". Meanwhile, the control class achieved an average percentage of 69.85%, which falls into the "moderate" category. The highest improvement in the experimental class was observed in the elementary clarification and inference indicators, each reaching 82.14%, categorized as "very high". The other indicators basic support, advanced clarification, and strategy and tactics were classified as "high".

In the control class, after being taught using the direct instruction model, students' critical thinking indicators remained within the "moderate" category across all indicators. The N-Gain scores for all critical thinking skill indicators were 0.72 in the experimental class (categorized as "high") and 0.57 in the control class (categorized as "moderate").

Table 3. Summary of N Gain Test

Results	Experiment	Control
Average of *Pretest*	11,971	11,657
Average of *Posttest*	32,200	27,943
Average of $N - Gain$	0,72	0,57
Category	High	Moderate

Discussion

Based on the above discussion, it can be concluded that the use of the Problem-Based Learning (PBL) model integrated with STEM is appropriate for teaching Physics, particularly on the topic of work and energy. This conclusion is supported by the average post-test score of the experimental class, which was 32.2, compared to 27.9 in the control class. The average percentage of post-test scores per critical thinking indicator in the experimental class using the PBL-STEM model was 80.5%, categorized as high, while in the control class, which used the direct instruction model, the average percentage was 69.86%, categorized as moderate.

The N-Gain score for critical thinking skills in the experimental class was 0.72, indicating a high level of improvement, while the control class scored 0.57, classified as moderate. These findings are consistent with the research by Cahyaningsih & Roektiningroem (2018), who found that learning through the PBL-STEM model enhances students' critical thinking and understanding of the material, as students solve problems by integrating knowledge from science, technology, engineering, and mathematics. Similarly, Sudirman (2017) stated that critical thinking is a systematic process that provides students with opportunities to formulate and evaluate their beliefs and opinions. In this context, students are required to actively engage in the learning process, which in turn trains their critical thinking skills to solve encountered problems.

This active student involvement aligns with the findings of Prihatiningtyas et al. (2013), who emphasized that critical thinking skills can be developed through learning approaches that actively engage students (*student-centered learning*) and the integration of STEM (LaForce et al., 2017).

This study aimed to investigate the effect of the Problem-Based Learning model integrated with STEM (PBL-STEM) on students' critical thinking skills. The results of data collection and analysis confirmed that the PBL-STEM model had a significant impact on students' critical thinking skills in the topic of work and energy.

CONCLUSION

Based on the results of the study, data analysis, and hypothesis testing, it can be concluded that the Problem-Based Learning (PBL) model integrated with STEM has a significant effect on students' critical thinking skills in the topic of work and energy in class X-5, second semester, at SMA Negeri 4 Tasikmalaya during the 2023/2024 academic year. The results of the t-test indicated that the $t_{calculated} \geq 1.67$, which means the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted, with a $t_{calculated}$ value of 3.35. Therefore, it can be concluded that the PBL-STEM model significantly influenced students' critical thinking skills in the topic of work and energy in class X at SMA Negeri 4 Tasikmalaya for the academic year 2023/2024. The N-Gain score of students' critical thinking skills also indicated that the experimental class outperformed the control class. The experimental class, which used the PBL-STEM model, achieved an N-Gain score of 0.72, categorized as high, while the control class obtained an N-Gain score of 0.57, categorized as moderate.

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