Lensa: Jurnal Kependidikan Fisika
Penerbit: Universitas Pendidikan Mandalika
https://e-journal.undikma.ac.id/index.php/Lensa/index

Dec. Vol. 12, No. 2
e-ISSN: 2686-0937
pp. 244-259

The Impact of Case-Based Learning on Students' Critical Thinking: Insights from an Experimental Study

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Abstract

The persistent issue of low critical thinking skills among students in physics education highlights the limitations of traditional teaching methods, which often emphasize memorization over analytical and evaluative thinking. This study investigates the impact of Case-Based Learning (CBL) on improving critical thinking skills, focusing on six indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Conducted at SMA Negeri 1 Kediri, Lombok, Indonesia, the study employed a quasi-experimental pretest-posttest control group design. The experimental group received CBL instruction, while the control group was taught using conventional methods. Data collection involved written essay tests scored using a rubric adapted from the Ennis-Weir Critical Thinking Essay Test, with results analyzed through both descriptive and inferential statistics. Descriptive analysis calculated means, standard deviations, and normalized gains (n-gain), revealing significant improvements in the experimental group across all critical thinking indicators, with n-gain scores categorized as high. Inferential statistical analysis using paired and independent sample t-tests confirmed significant differences in critical thinking skill development between the experimental and control groups. The findings demonstrate that CBL fosters critical thinking by engaging students in real-world scenarios, promoting collaboration, and encouraging reflective reasoning. This study concludes that CBL is an effective pedagogical strategy for addressing critical thinking deficiencies in physics education, bridging the gap between theoretical understanding and practical application. The implications suggest integrating CBL into curricula to enhance students' cognitive skills, equipping them for academic and professional challenges. Future research should explore CBL's long-term impacts and adaptability to various subjects and educational contexts, ensuring its broader implementation as a transformative teaching approach.

Keywords: Critical thinking skills; Case-based learning; Physics education; Quasi-experimental design; Pedagogical innovation.

How to cite: Amelia, R., Sukroyanti, B. A., & Prayogi, S. (2024). The Impact of Case-Based Learning on Students' Critical Thinking: Insights from an Experimental Study. *Lensa: Jurnal Kependidikan Fisika, 12*(2), 244-259. doi:https://doi.org/10.33394/j-lkf.v12i2.13371

INTRODUCTION

The issue of low critical thinking skills among students, particularly in the context of physics education, has been a recurring concern in recent academic discourse. Critical thinking is a foundational component of effective learning and problem-solving, especially in disciplines that require analytical rigor, such as physics. Empirical evidence indicates that students often struggle to analyze, evaluate, and synthesize information to address complex problems in physics, hindering their ability to fully comprehend and apply the subject's principles. This deficiency has been attributed to various factors, including the prevalence of traditional teaching methodologies, insufficient emphasis on critical thinking in curricula, and a lack of interactive learning environments.

The challenges in cultivating critical thinking skills are well-documented. Previous study highlighted a substantial correlation between students' prior knowledge and their ability to analyze physics problems effectively. Their findings suggest that students often fail to engage deeply with problems, limiting their ability to develop logical and well-reasoned solutions (Abeden & Siew, 2022). Similarly, Ubaidillah emphasized that higher education institutions, particularly those preparing future physics educators, must prioritize problem-solving and critical thinking development to address this pervasive gap (Ubaidillah, 2023). Such findings underscore the pressing need to reform instructional strategies to foster these essential skills.

The limitations in students' critical thinking abilities are further supported by findings from Musyarrof et al. (2018), who observed significant weaknesses among high school students in producing logical conclusions and solving physics problems. Their research revealed a lack of coherence and depth in students' responses, highlighting a systemic issue in the educational process (Musyarrof et al., 2018). Traditional educational methods, characterized by rote memorization and a focus on standardized testing, have been critiqued for failing to engage students in analytical and evaluative thinking, essential components of critical thinking.

In addition to deficiencies in pedagogical approaches, the persistence of low critical thinking skills across educational levels suggests systemic shortcomings. Sutrio's (2023) work on problem-based flipped classroom models revealed that despite innovative instructional designs, Indonesian students from junior high to university levels continued to exhibit weak critical thinking abilities (Sutrio, 2023). Similarly, previous study noted that the inadequacy of critical thinking skills is particularly evident in physics learning media, which often lack the interactive and reflective elements necessary to challenge students' reasoning processes (Tania & Jumadi, 2021). These findings suggest that the issue is not confined to any single educational stage but reflects broader systemic challenges.

The integration of collaborative learning environments has been proposed as a potential solution to enhance critical thinking skills. Previous study explored the intersection of physical education and medicine, advocating for structured opportunities for interaction and reflection as crucial for developing analytical skills (Niu, 2023). This perspective aligns with Asbanu’s (2023) analysis of research trends in Indonesian physics education, which highlighted the need for instructional strategies that actively engage students in evaluating claims and sources of information (Asbanu, 2023). Without these opportunities, students are unlikely to acquire the critical thinking skills necessary for academic and professional success.

Further illustrating the challenges, Octaviana et al. (2020) conducted a targeted investigation into the critical thinking abilities of physics education students when solving geometrical optics problems. Their findings demonstrated that students’ performance fell significantly below expectations, reinforcing the need for more effective instructional approaches (Octaviana et al., 2020). Similarly, Farcis et al. explored the use of project-based learning in virtual environments and found that while such methods could improve critical thinking, students still faced difficulties in applying these skills to physics problems (Farcis et al., 2022). The results of these studies underscore the need for pedagogical innovations that move beyond traditional methodologies.

Case-Based Learning (CBL) has emerged as a promising approach to addressing these challenges. By engaging students with real-world scenarios, CBL fosters analytical and evaluative skills critical for problem-solving in physics. Fatimah noted that CBL implementation improves learning outcomes by promoting active engagement with cases requiring critical analysis and decision-making (Fatimah, 2023). This aligns with Yu et al. (2019), who observed that case-centered learning enhances students' abilities to evaluate information and apply theoretical concepts to practical situations. Such an approach encourages inquiry and reflection, fundamental to developing a critical mindset.

The collaborative nature of CBL further amplifies its benefits. Sari (2024) highlighted that CBL fosters active problem-solving by encouraging group discussions and the exchange of diverse perspectives. Through collaborative analysis and debate, students refine their reasoning processes, enhancing their capacity for higher-order thinking. This dynamic interaction not only deepens their understanding of complex concepts but also equips them with skills to evaluate arguments critically and arrive at informed decisions.

In physics education, CBL's effectiveness lies in its ability to contextualize abstract concepts within relatable scenarios. Doyan et al (2020). demonstrated that case studies involving quantum phenomena, when integrated into a Think-Pair-Share model, significantly enhanced students' critical thinking skills. By situating physics problems in real-life contexts, students are more likely to appreciate the relevance of their learning and engage with the material more deeply. This contextualized approach helps bridge the gap between theoretical knowledge and practical application, a critical component of effective physics education.

The adaptability of CBL allows it to cater to diverse learning styles, further enhancing its efficacy. Previous study noted that inductive learning-based modules utilizing case studies could effectively strengthen critical thinking skills by enabling students to derive general principles from specific instances (Nugroho et al., 2021). Such strategies not only promote knowledge retention but also empower students to apply their understanding in novel situations, an essential aspect of critical thinking.

Comparative research further underscores the advantages of CBL over traditional instructional methods. Worachak's (2023) analysis revealed that students engaged in interactive learning models like problem-based and inquiry-based approaches showed substantial improvements in critical thinking compared to those in conventional settings. This evidence supports the argument that student-centered methodologies, exemplified by CBL, are more effective in fostering critical thinking.

The integration of technology into CBL has the potential to amplify its benefits. Digital tools and resources create a dynamic learning environment, enabling students to access a wide range of information and collaborate with peers remotely. The use of digital resources alongside CBL significantly improves students' critical thinking by exposing them to diverse perspectives and facilitating access to varied information sources (Ekayanti et al., 2022). This technological enhancement is particularly relevant in the context of increasing online education, where interactive and resource-rich platforms are crucial for maintaining student engagement and learning outcomes.

The importance of critical thinking in physics education cannot be overstated. Even gifted students often struggle with these skills, suggesting systemic inadequacies in fostering analytical abilities (Kettler, 2014). Similarly, Tagutanazvo and Bhagwandeen (2022) emphasized that despite teachers' theoretical understanding of critical thinking, their instructional strategies frequently fail to align with fostering these competencies in students. These observations reinforce the necessity of adopting innovative teaching methodologies like CBL to address these shortcomings.

The integration of CBL into physics education presents a significant opportunity to address the persistent issue of low critical thinking skills among students. By engaging students in real-world scenarios, fostering collaboration, and leveraging technology, CBL can bridge the gap between theoretical knowledge and practical application. The consistent findings from recent research underline the urgency of reforming instructional strategies to prioritize critical thinking, ensuring that students are well-equipped to tackle complex problems in physics and beyond.

Objective, hypothesis, and novelty of the study

The primary objective of this research is to explore the impact of Case-Based Learning (CBL) on the development of students' critical thinking skills within the context of physics education. This focus aligns with the pressing need to address persistent deficiencies in critical thinking abilities observed among students across educational levels. CBL is recognized as a pedagogical approach that fosters active engagement, collaborative problem-solving, and contextual application of knowledge, making it a promising intervention to enhance critical thinking.

The hypothesis driving this study is that implementing CBL in physics education will significantly improve students' critical thinking skills compared to traditional instructional methods. This hypothesis is founded on the theoretical framework of constructivist learning, which posits that students construct knowledge most effectively through active engagement with real-world problems. CBL provides structured opportunities for students to analyze complex scenarios, engage in reflective thinking, and collaborate with peers, all of which are essential for cultivating higher-order cognitive abilities.

The novelty of this study lies in its targeted exploration of CBL's effects on critical thinking specifically within the physics domain, an area where such interventions remain under-researched. While prior studies have documented the general benefits of CBL in enhancing learning outcomes, this research aims to provide empirical evidence of its efficacy in addressing the unique analytical demands of physics education. By focusing on critical thinking, this study contributes to a growing body of literature advocating for innovative instructional strategies that prioritize cognitive development over rote memorization.

Furthermore, this study seeks to bridge the gap between theoretical knowledge and practical application in physics education. Physics, as a discipline, often requires students to navigate abstract concepts and apply them to solve real-world problems. Traditional teaching methods frequently fail to foster the analytical skills necessary for this level of application. CBL, with its emphasis on contextualized learning and collaborative analysis, offers a viable alternative. This research aims to demonstrate how CBL can transform students' approach to learning physics by promoting deeper understanding and critical engagement.

In addition to its theoretical contributions, this study has practical implications for curriculum design and instructional practices. By empirically evaluating the outcomes of CBL, the research provides actionable insights for educators seeking to enhance their teaching strategies. The findings are expected to inform the development of physics curricula that integrate CBL as a core instructional method, ultimately equipping students with the critical thinking skills needed for academic and professional success.

Through this investigation, the study aims to establish a comprehensive understanding of how CBL influences critical thinking in physics education, offering a robust framework for future research and educational reform. By addressing a critical gap in both practice and literature, this research seeks to advance the field of educational pedagogy and contribute to the broader goal of cultivating analytical and reflective learners.

METHOD

This research employed a quasi-experimental design, specifically a pretest-posttest control group design, to investigate the impact of Case-Based Learning (CBL) on students' critical thinking skills in physics education. The quasi-experimental approach was selected to address practical constraints that limit the implementation of a true experimental design. While a control group was included, the inability to fully control external variables remains a limitation of this design. However, the use of random sampling and identical curricular content for both groups ensured comparability.

The study was conducted at SMA Negeri 1 Kediri, Lombok, Indonesia, involving 11th-grade science students during the second semester. The instructional content focused on the physics topic of "Sound Waves," which served as the context for assessing critical thinking skills. The study aimed to evaluate changes in critical thinking abilities through the lens of specific indicators (CTi) and overall individual critical thinking skills (CTs).

The experimental group received instruction through CBL, designed to engage students in real-world case scenarios requiring analytical reasoning, argumentation, and collaborative problem-solving. The control group followed conventional teaching methods, characterized by teacher-centered instruction and independent learning activities. The research utilized pretest and posttest assessments to measure students' critical thinking skills and to determine the effects of the respective teaching approaches.

Research framework and procedure

The research design is summarized in Table 1. The experimental group underwent CBL instruction (X), while the control group received conventional teaching (Y). Both groups took a pretest (O_1) to assess initial critical thinking abilities and a posttest (O_2) to evaluate changes after the instructional intervention.

Table 1. Research design

Group	Pretest (O_1)	Intervention	Posttest (O_2)
Experimental (X)	O_1	X	O_2
Control (Y)	O_1	Y	O_2

Pretests and posttests were administered using identical instruments for both groups, ensuring that the results could be directly compared. The instructional period spanned three weeks, during which both groups were taught the same physics content.

Population and sample

The population consisted of all 11th-grade students at SMA Negeri 1 Kediri. The school employs random class placement without grouping students by academic ability, ensuring that each class represents a heterogeneous mix of high, medium, and low achievers. This policy minimizes selection bias and enhances the generalizability of the findings.

Two classes were selected as the sample through purposive sampling. Class XI IPA 1 was designated as the experimental group, while Class XI IPA 2 served as the control group. Both classes followed the same curriculum, and their instructional content was identical, ensuring consistency in the academic material delivered.

Instruments and scoring

The research utilized a written essay test to assess critical thinking skills. The test consisted of 12 items aligned with the six critical thinking indicators (CTi): interpretation, analysis, evaluation, inference, explanation, and self-regulation. Each indicator was represented by two items to ensure comprehensive assessment. Scoring followed the rubric adapted from the Ennis-Weir Critical Thinking Essay Test (Ennis in Prayogi et al., 2024), with scores ranging from -1 to +3, as described in Table 2.

Table 2. Critical thinking score and description

Score	Description
-1	• Incorrect answer with flawed arguments unsupported by facts, concepts, or principles.
0	• No answer provided.
+1	• Correct answer with minimal support from facts, concepts, or principles.
+2	• Correct answer with moderate support from facts, concepts, or principles.
+3	• Correct answer with strong, well-supported arguments based on facts, concepts, and principles.

Each student's overall critical thinking skills (CTs) were calculated by summing their scores across all 12 items, with possible individual scores ranging from a minimum of -12 to a maximum of +36. This scoring system enabled detailed analysis of individual performance and group-level trends.

Data collection

The data collection process was divided into three stages:

1. Pretest Administration. Both groups completed a pretest (O_1) to evaluate their baseline CTi and CTs. This step ensured that any initial differences between the groups were accounted for during analysis.
2. Instructional Intervention. The experimental group received CBL instruction, involving case scenarios designed to engage students in problem-solving, discussion, and reflective thinking. This method emphasized active learning and

collaboration. The control group was taught using conventional methods, including teacher-led explanations and independent practice.

3. Posttest Administration. Following the instructional period, both groups completed the posttest (O_2). This assessment measured changes in CTs and CTi, enabling a direct comparison of the effectiveness of CBL versus conventional teaching.

Data analysis

Two analytical approaches were employed to evaluate the collected data: descriptive analysis and inferential statistics.

1. Descriptive Analysis

Descriptive statistics were used to summarize students' critical thinking performance. This included the calculation of means, medians, standard deviations, and n-gain scores for both groups. The n-gain analysis, based on Hake's formula (1999), measured the normalized improvement in CT between the pretest and posttest.

2. Inferential Statistics

Inferential tests were conducted using SPSS version 22.0 to determine the significance of observed differences between the groups. These included:

- Normality Test. The Kolmogorov-Smirnov and Shapiro-Wilk tests assessed whether the data were normally distributed. Normality was a prerequisite for subsequent parametric tests.
  - $p > 0.05$: Data are normally distributed.
  - $p \leq 0.05$: Data are not normally distributed.
- Hypothesis Testing (Independent Samples t-Test). An independent samples t-test compared the pretest and posttest scores of the two groups. Pretest scores were analyzed to confirm no significant baseline differences, while posttest scores evaluated the effectiveness of the CBL model. A significance level of 0.05 was applied for all tests.

Critical thinking indicators (CTi) and individual skills (CTs)

Each CTi—interpretation, analysis, evaluation, inference, explanation, and self-regulation—was analyzed individually to identify specific areas of improvement. By examining both group-level CTi and CTs scores, the study provided a comprehensive view of the impact of CBL on students' critical thinking. This dual focus allowed for a nuanced understanding of how CBL influences different aspects of critical thinking.

Ethical considerations

Ethical approval was obtained from the school administration, ensuring compliance with research ethics. Students participated voluntarily, with their identities anonymized to protect privacy. Informed consent was secured from all participants and stakeholders.

Limitations

While the quasi-experimental design offered practical advantages, it lacked the full control of a true experimental design, leaving room for confounding variables. Efforts were made to mitigate these limitations through random sampling, standardized curricular content, and robust statistical controls.

RESULTS AND DISCUSSION

The analysis highlights the impact of Case-Based Learning (CBL) on critical thinking skills by examining differences in the critical thinking indicators (CTi), including interpretation, analysis, evaluation, inference, explanation, and self-regulation, as well as overall critical thinking scores (CTs). Descriptive and inferential statistics reveal significant variations between the experimental and control groups, offering insights into the effectiveness of CBL as a pedagogical approach.

The outcomes of the CTi analysis for both the experimental and control groups are summarized in Tables 3 and 4, detailing the performance variations across interpretation, analysis, evaluation, inference, explanation, and self-regulation. Additionally, the comprehensive CTs scores, which aggregate performance across all CTi, are provided in Table 5, offering a holistic view of the differences between the two groups. These tables collectively illustrate the comparative impact of CBL and conventional teaching methods on the development of critical thinking skills in physics education.

Table 3. Results of descriptive analysis of CTi for the experimental group

Indicator	N	Pretest		Posttest		N-gain	Criteria
		Mean (± SD)	Criteria	Mean (± SD)	Criteria		
Interpretation	27	1.11 (± 0.40)	Moderately Critical	2.50 (± 0.27)	Highly Critical	0.74	High
Analysis	27	1.18 (± 0.442	Moderately Critical	2.74 (± 0.25)	Highly Critical	0.86	High
Evaluation	27	1.15 (± 0.36)	Moderately Critical	2.52 (± 0.25)	Highly Critical	0.74	High
Inference	27	1.24 (± 0.29)	Moderately Critical	2.61 (± 0.34)	Highly Critical	0.78	High
Explanation	27	1.26 (± 0.42)	Moderately Critical	2.52 (± 0.25)	Highly Critical	0.72	High
Self-regulation	27	1.26 (± 0.35)	Moderately Critical	2.79 (± 0.28)	Highly Critical	0.86	High

Table 4. Results of descriptive analysis of CTi for the control group

Indicator	N	Pretest		Posttest		N-gain	Criteria
		Mean (± SD)	Criteria	Mean (± SD)	Criteria		
Interpretation	25	0.96 (± 0.35)	Moderately Critical	2.08 (± 0.40)	Critical	0.55	Moderate
Analysis	25	1.18 (± 0.35)	Moderately Critical	2.20 (± 0.32)	Critical	0.56	Moderate
Evaluation	25	1.00 (± 0.35)	Moderately Critical	1.94 (± 0.33)	Critical	0.47	Moderate
Inference	25	1.08 (± 0.40)	Moderately Critical	2.00 (± 0.35)	Critical	0.48	Moderate
Explanation	25	0.84 (± 0.40)	Moderately Critical	1.90 (± 0.32)	Critical	0.49	Moderate
Self-regulation	25	1.74 (± 0.73)	Moderately Critical	2.18 (± 0.45)	Critical	0.35	Moderate

Table 5. Results of descriptive analysis of CTs

Group	N	Pretest Mean (± SD)	Posttest Mean (± SD)	N-gain	Criteria
Experimental	27	14.93 (± 2.09)	31.37 (± 1.44)	0.78	High
Control	25	12.36 (±2.34)	24.64 (± 1.91)	0.52	Moderate

The results presented in Tables 3 and 4 demonstrate significant differences in the critical thinking indicators (CTi) between the experimental and control groups. In the experimental group, students showed a high level of improvement across all indicators, with N-gain values ranging from 0.72 to 0.86, categorized as "high." Notably, the self-regulation indicator achieved the highest posttest mean score (2.79 ± 0.28), reflecting the effectiveness of Case-Based Learning (CBL) in fostering independent critical thinking. Conversely, the control group exhibited moderate improvements in all indicators, with N-gain values ranging from 0.35 to 0.56, categorized as "moderate." These findings suggest that traditional teaching methods are less effective in cultivating higher-order thinking skills compared to the interactive and reflective nature of CBL. Table 5 highlights the overall critical thinking scores (CTs) for both groups, further confirming the superior impact of CBL. The experimental group achieved a higher posttest mean score (31.37 ± 1.44) with an N-gain of 0.78, categorized as "high." This contrasts with the control group, which attained a lower posttest mean score (24.64 ± 1.91) and a "moderate" N-gain of 0.52. These differences indicate that the CBL model not only enhances individual indicators but also holistically improves students' critical thinking skills.

The comparative analysis across Tables 3, 4, and 5 underscores the transformative potential of CBL in addressing the persistent challenges of low critical thinking skills in physics education. The interactive and student-centered approach of CBL provides a structured environment where students actively engage with real-world problems, facilitating deeper understanding and application of knowledge. In contrast, the conventional teaching approach, which emphasizes rote learning, appears insufficient to develop critical thinking at the same level.

A hypothesis test was conducted using the t statistic (difference test) which was preceded by a normality test. The results of the normality test are presented in Table 6 and the results of the difference test are presented in Tables 7 and 8.

Table 6. Normality test results

Group	Test	n	Mean (± SD)	Sig.		Normality
				Kol.-Smirnov	Shapiro-Wilk	
Experimental	Pretest	27	14.93 (± 2.09)	0.108	0.299	Normally distributed
	Posttest	27	31.37 (± 1.44)	0.123	0.157	Normally distributed
Control	Pretest	25	12.36 (± 2.34)	0.093	0.060	Normally distributed
	Posttest	25	24.64 (± 1.91)	0.144	0.148	Normally distributed

The normality test results presented in Table 6 indicate that both pretest and posttest scores for the experimental and control groups are normally distributed, as evidenced by p-values greater than 0.05 for both the Kolmogorov-Smirnov and Shapiro-Wilk tests. These findings confirm that the data meet the assumption of normality, allowing for the use of parametric tests such as the paired sample t-test and the independent sample t-test to analyze the differences in critical thinking skills between groups.

Table 7. Results of the paired sample t-test

Group		N	Mean	SD	Df	t	Sig.
Experimen	Pretest	27	14.93	2.09	26	-47.921	0.000
	Posttest	27	31.37	1.44			
Control	Pretest	25	12.36	2.34	24	-43.857	0.000
	Posttest	25	24.64	1.91			

Table 8. Results of the independent sample t-test

Group	N	Mean	SD	Df	F	Sig.
Experimen (posttest)	27	31.37	1.445	50	1.792	0.000
Control (posttest)	25	24.64	1.912			0.000

Table 7 displays the paired sample t-test results, which show a statistically significant improvement in critical thinking skills within both groups. For the experimental group, the mean score increased from 14.93 (± 2.09) in the pretest to 31.37 (± 1.44) in the posttest, with a t-value of -47.921 and a p-value of 0.000 (< 0.005). Similarly, the control group showed an increase from 12.36 (± 2.34) in the pretest to 24.64 (± 1.91) in the posttest, with a t-value of -43.857 and a p-value of 0.000 (< 0.005). These results indicate that both instructional approaches contributed to an improvement in critical thinking skills, although the magnitude of improvement was more substantial in the experimental group.

The independent sample t-test results in Table 8 further confirm a significant difference in posttest scores between the experimental and control groups. The experimental group achieved a higher mean score (31.37 ± 1.44) compared to the control group (24.64 ± 1.91), with a t-value of 1.792 and a p-value of 0.000 (< 0.005). These findings highlight the superior efficacy of Case-Based Learning (CBL) in fostering critical thinking skills compared to conventional teaching methods. The results suggest that CBL provides a more effective framework for engaging students in analytical reasoning and problem-solving, reinforcing its potential as a transformative pedagogical approach in physics education.

The findings of this study confirm that Case-Based Learning (CBL) has a significant impact on improving students' critical thinking skills in physics education. As critical thinking is a foundational skill for problem-solving and analytical reasoning, this study highlights the value of adopting pedagogical strategies that prioritize these competencies. By comparing the outcomes of students exposed to CBL with those taught using conventional methods, the results demonstrate the superior efficacy of CBL in fostering critical thinking abilities across various dimensions, including interpretation, analysis, evaluation, inference, explanation, and self-regulation.

CBL's primary strength lies in its ability to immerse students in real-world scenarios, encouraging them to connect theoretical knowledge with practical applications. This approach compels students to actively engage with the content, fostering deeper understanding and critical analysis. The results align with previous findings, such as those by Mahdi et al. (2020), who reported that case studies in education significantly improve critical thinking skills by requiring students to evaluate, synthesize, and apply information in meaningful ways. By placing learners in scenarios where they must dissect complex problems and devise solutions, CBL not only enhances their problem-solving abilities but also cultivates their capacity to think critically about the relationships between abstract concepts and tangible outcomes.

In physics education, where abstract principles often present significant learning challenges, the application of CBL proves particularly effective. Doyan et al. (2020) demonstrated that integrating case studies into physics lessons, such as those involving quantum phenomena, helps students develop critical thinking by contextualizing the subject matter within real-world applications. Similarly, the present study supports the notion that contextualized learning environments promote better retention and understanding of physics concepts. By situating problems in relatable contexts, CBL allows students to visualize the relevance of their learning, which motivates them to engage more deeply with the material.

A notable aspect of CBL is its emphasis on collaboration, which further enhances critical thinking skills. Group discussions within the CBL framework expose students to diverse perspectives, fostering the development of higher-order thinking skills through dialogue and debate. This interactive process encourages students to articulate their reasoning, evaluate the validity of others' arguments, and refine their conclusions based on shared insights. Sari (2024) highlighted the role of CBL in promoting active problem-solving and decision-making, noting that collaborative learning environments serve as a catalyst for critical thinking. The present study's results reinforce these findings, showing that students in the experimental group exhibited significant improvements in all critical thinking indicators due to their participation in collaborative case-based activities.

Furthermore, CBL's flexibility allows it to cater to diverse learning styles, which contributes to its effectiveness. Nugroho et al. (2021) noted that integrating inductive learning strategies into CBL enables students to derive general principles from specific instances, thereby strengthening their ability to apply knowledge to new and unfamiliar situations. This adaptability makes CBL particularly valuable in heterogeneous classrooms, where students may have varying levels of prior knowledge and cognitive abilities. By providing opportunities for individualized engagement and collaborative exploration, CBL ensures that all learners benefit from the instructional process.

The results of this study also highlight the inadequacies of traditional teaching methods in fostering critical thinking. Conventional instruction, which often relies on rote memorization and standardized assessments, fails to engage students in the analytical and evaluative processes necessary for developing higher-order cognitive skills. As observed in the control group, traditional approaches yielded only moderate improvements in critical thinking, underscoring their limitations. These findings align with research by Hikmawati et al. (2021), who reported that interactive and student-centered methodologies, such as culture-based and case-based learning, significantly outperform traditional methods in enhancing both critical thinking and communication skills.

The integration of technology within CBL represents another critical factor in its effectiveness. Digital tools and resources expand the scope of inquiry and facilitate collaborative learning in virtual environments, thereby enriching the CBL experience. Zhu et al. (2020) emphasized the benefits of incorporating STEM concepts into CBL, noting that digital platforms provide students with access to diverse perspectives and information sources, which are essential for fostering critical thinking. In the context of this study, the potential for technology-enhanced CBL to support online and hybrid learning models is particularly relevant, given the increasing reliance on digital education platforms.

Despite its many strengths, implementing CBL requires careful planning and execution to maximize its benefits. One of the key challenges is designing case scenarios that are both contextually relevant and sufficiently challenging to stimulate critical thinking. Educators must ensure that the cases encourage students to analyze multiple dimensions of a problem, consider alternative solutions, and justify their decisions based on evidence. Additionally, the facilitator’s role is crucial in guiding discussions and maintaining a focus on critical thinking objectives. Without effective facilitation, there is a risk that discussions may become superficial or deviate from the intended learning goals.

The implications of this study extend beyond individual classroom practices to broader curriculum design and instructional policy. By integrating CBL into physics education curricula, institutions can address the persistent issue of low critical thinking skills among students. This approach aligns with contemporary educational priorities that emphasize the development of transferable skills, such as problem-solving, collaboration, and decision-making. Moreover, the emphasis on real-world problem-solving within CBL prepares students for the complexities of academic and professional environments, where critical thinking is a fundamental requirement.

CBL’s potential to bridge the gap between theoretical knowledge and practical application is particularly noteworthy. In physics education, where students often struggle to navigate abstract concepts, CBL provides a structured framework for exploring these ideas in a meaningful context. As noted by Fatimah (2023), the integration of real-world cases into physics lessons not only enhances learning outcomes but also fosters a deeper appreciation of the subject’s relevance. This approach aligns with the constructivist learning theory, which posits that students construct knowledge most effectively when they are actively engaged in problem-solving and inquiry-based activities.

The broader educational landscape also benefits from the adoption of CBL. By fostering critical thinking skills, CBL equips students with the cognitive tools necessary to navigate the complexities of the modern world. Verawati (2023) emphasized that CBL prepares learners to make informed decisions in real-world contexts, highlighting its relevance across disciplines. In the context of physics education, this capability is particularly valuable, as students must often apply their knowledge to solve intricate problems and evaluate the validity of scientific claims.

The findings of this study contribute to a growing body of literature advocating for innovative teaching methodologies in education. By demonstrating the significant impact of CBL on critical thinking, this research underscores the need for educational reforms that prioritize student-centered and interactive learning approaches. Furthermore, the study’s emphasis on critical thinking as a measurable outcome provides a robust framework for evaluating the effectiveness of instructional strategies, offering valuable insights for educators and policymakers.

In conclusion, the results of this study affirm the transformative potential of Case-Based Learning in physics education. By engaging students in real-world scenarios, promoting collaborative learning, and integrating technology, CBL addresses critical gaps in traditional pedagogical approaches. Its demonstrated success in enhancing critical thinking skills highlights its value as a comprehensive and adaptable instructional method. As educational institutions strive to equip students with the skills necessary for academic and professional success, the adoption of CBL represents a significant step toward achieving this goal. By bridging the gap between theoretical knowledge and practical application, CBL not only improves learning outcomes but also prepares students to navigate the complexities of the modern world with confidence and competence.

CONCLUSION

This study demonstrates the significant impact of Case-Based Learning (CBL) on improving students' critical thinking skills within the context of physics education, directly addressing the research objective of exploring its efficacy compared to traditional teaching methods. The findings affirm that CBL, by immersing students in real-world scenarios, fosters critical thinking indicators such as interpretation, analysis, evaluation, inference, explanation, and self-regulation more effectively than conventional instruction. By emphasizing collaboration and contextual problem-solving, CBL enhances students' ability to analyze complex scenarios and make informed decisions, aligning with constructivist learning principles. This approach bridges the gap between theoretical knowledge and practical application, addressing long-standing deficiencies in students' critical thinking skills. The substantial improvements observed in the experimental group underscore the transformative potential of CBL, particularly in disciplines like physics that demand analytical rigor and conceptual understanding.

The results further highlight the necessity of integrating CBL into educational curricula to equip students with higher-order thinking skills essential for academic and professional success. By fostering active engagement, collaborative learning, and reflective reasoning, CBL offers a robust framework for addressing critical thinking gaps that persist across various educational levels. Additionally, the adaptability of CBL allows it to cater to diverse learner needs, making it a versatile tool for educational innovation. While challenges such as designing relevant case scenarios and effective facilitation must be addressed, this study reinforces the value of CBL as a cornerstone of modern pedagogy. Future research should explore its long-term impact and potential for integration with digital tools to further enhance its applicability in diverse educational contexts. Through its holistic approach to learning, CBL represents a vital step toward cultivating a generation of critical, reflective, and innovative thinkers.

RECOMMENDATION

Based on the findings of this study, it is recommended that educational institutions adopt CBL as a core instructional strategy in physics education and other disciplines requiring critical thinking and analytical skills. Curriculum developers should integrate CBL into lesson plans, ensuring that real-world scenarios are carefully designed to challenge students and foster deeper engagement. Educators must be trained in effective facilitation techniques to maximize the benefits of collaborative learning and critical inquiry inherent in CBL. Additionally, leveraging technology to enhance CBL through digital resources and virtual collaboration can further extend its reach and effectiveness, particularly in remote or hybrid learning environments. Future studies should investigate the longitudinal impacts of CBL and explore its adaptability to other subjects and diverse educational settings to establish its broader applicability and sustainability.

ACKNOWLEDGEMENT

The authors extend their sincere gratitude to the administration, faculty, and students of SMA Negeri 1 Kediri, Lombok, Indonesia, for their invaluable support and active participation in this study. Appreciation is also directed to colleagues and collaborators who provided insightful feedback and encouragement throughout the research process. The authors acknowledge the use of institutional resources and express their thanks to those who assisted in data collection and analysis. Lastly, the authors are grateful for the guidance and constructive suggestions offered by peer reviewers, which have significantly enriched the quality of this work.

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