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The Effectiveness of Problem-Based Learning in Enhancing Eleventh-Grade Students' Critical Thinking Skills

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Abstract: This study investigated the effectiveness of Problem-Based Learning (PBL) in enhancing the critical thinking skills of eleventh-grade students at SMAN 1 Kediri. A quantitative approach using a quasi-experimental pretest-posttest control group design was employed. The participants consisted of 19 students in class XI MS1 as the experimental group and 23 students in class XI MS2 as the control group, selected through purposive sampling. Data were collected using six essay questions designed to assess students' critical thinking skills. The validity of the teaching module, student worksheet (LKPD), and test instruments was evaluated by three experts using Aiken's V analysis. The results showed that the mean critical-thinking score of the experimental group increased from 26 in the pretest to 75 in the posttest, while the control group increased from 24 to 57. The independent-samples t-test revealed a significant difference between the two groups ($p < 0.001$), indicating that students who experienced PBL demonstrated higher critical-thinking skills than those receiving conventional instruction. These findings suggest that PBL provides meaningful learning experiences that support students' abilities to analyze problems, evaluate information, and formulate evidence-based solutions. Therefore, PBL can be considered an alternative instructional approach for promoting critical-thinking skills in biology learning.

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INTRODUCTION

Critical thinking is one of the essential skills for twenty-first-century learning because it enables students to examine information, evaluate reasoning, and make rational decisions. This skill is increasingly important as students encounter complex and diverse information in both academic and everyday contexts. A meta-analysis by Abrami et al. (2015) showed that critical thinking can be developed through explicitly designed instructional interventions, particularly when students are given opportunities to engage in dialogue, confront authentic problems, and receive guidance that supports reasoning. Accordingly, instruction should be designed not merely to transmit knowledge but also to provide opportunities for students to scrutinize information and construct evidence-based arguments.

Conceptually, critical thinking involves the ability to interpret information, analyze relationships, evaluate evidence or arguments, and draw logical inferences (Facione, 2020). These abilities are necessary so that students do not simply accept information but can assess its quality and use it to solve problems. The relevance of these skills extends beyond academic settings; the World Economic Forum (2020) identifies critical thinking and analysis

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as a group of skills of growing importance in the workplace. Therefore, strengthening critical thinking at the secondary-school level is an important part of preparing students to address academic and real-life problems that require responsible decision-making.

Individual cognitive characteristics may also influence critical-thinking performance. Wicaksono et al. (2024) reported that students with an impulsive cognitive style experienced difficulties in interpretation, analysis, evaluation, and inference. Based on this framework, the present study defines critical-thinking skills as students' ability to understand problems, analyze information, evaluate reasons or evidence, and draw logical conclusions. Six essay questions were used to assess this construct in accordance with the instrument blueprint, thereby focusing the assessment on students' reasoning processes rather than solely on recall.

One approach that is relevant to facilitating these processes is Problem-Based Learning (PBL). PBL uses complex problems as the starting point for learning and encourages students to work collaboratively to identify what they need to learn, seek information, test ideas, and formulate defensible solutions (Hmelo-Silver, 2004; Savery, 2006). These characteristics position students as active participants in the learning process, while the teacher acts as a facilitator who guides inquiry and reflection. In the context of twenty-first-century learning, PBL is also considered relevant because it connects concepts with contextual problems and provides opportunities to develop problem-solving and communication skills (Hosnan, 2014).

Empirical support for PBL has been reported in various research syntheses. A meta-analysis by Dochy et al. (2003) found that PBL had a strong positive effect on knowledge application skills, although outcomes related to factual knowledge acquisition could vary. A meta-synthesis by Strobel and van Barneveld (2009) showed that PBL tended to be superior in long-term retention, skill development, and learner satisfaction, while Walker and Leary (2009) found that the effectiveness of PBL was influenced by problem type, implementation format, discipline, and assessment level. Yew and Goh (2016) further emphasized that the PBL process can support long-term knowledge retention and the ability to apply knowledge through group discussion, self-directed learning, and the integration of information during problem solving.

More specifically, several studies have demonstrated an association between PBL and the development of critical thinking. Tiwari et al. (2006) reported that students who learned through PBL showed greater development in critical-thinking dispositions than those taught through conventional lectures, while Gholami et al. (2016) found greater improvement in critical-thinking skills following PBL than after the lecture method. A systematic review by Anggraeni et al. (2023) also showed that PBL has been consistently used to foster critical-thinking skills across diverse learning contexts, including science education and studies conducted in Asian countries. These findings are consistent with studies in Indonesia reporting the contribution of PBL to critical-thinking skills across educational levels and subjects (Herzon et al., 2018; Sarwastuti & Purnomo, 2023; Fa'uni et al., 2024). Nevertheless, the effectiveness of PBL still needs to be examined within specific school contexts, student characteristics, and subject areas.

In the context of SMAN 1 Kediri, Apriana et al. (2025) reported that the use of PBL in Grade X biology learning affected students' motivation and learning outcomes compared with conventional instruction. These findings indicate that PBL already has an empirical basis for implementation at the same school; however, that study did not specifically measure critical-thinking skills. Empirical evidence comparing changes in critical-thinking skills using a pretest-posttest design with a control group among Grade XI students also remains limited. Therefore, this study aimed to investigate the effectiveness of Problem-Based Learning (PBL) in enhancing the critical-thinking skills of Grade XI students at SMAN 1 Kediri and to

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compare the changes in critical-thinking scores between students who received PBL-based instruction and those who experienced conventional learning.

RESEARCH METHOD

This study employed a quantitative approach using a quasi-experimental pretest-posttest control group design. The design was selected because the study involved intact classes without individual random assignment. The experimental group received Problem-Based Learning (PBL), whereas the control group received conventional instruction. Both groups completed pretest and posttest assessments to examine changes in students' critical-thinking skills after the instructional intervention.The research design is presented in Table 1.

Table 1. Pretest-posttest control group design

Group	Pretest	Treatment	Posttest
Experimental	O1	X (treatment administered)	O2
Control	O1	– (no PBL)	O2

Class XI MS1 was assigned as the experimental group with 19 students, while class XI MS2 was assigned as the control group with 23 students through purposive sampling. The two classes were selected from the intact classes available in the Grade XI population at SMA Negeri 1 Kediri. Baseline ability was examined descriptively using pretest scores, with a mean of 26 in the experimental group and 24 in the control group. The primary instrument consisted of six essay questions assessing critical-thinking skills. The learning materials included a teaching module and a student worksheet (LKPD). The content validity of the teaching module, LKPD, and test items was evaluated by three validators using Aiken's V.

Aiken's V was calculated based on ratings from three validators (n = 3), five score categories (c = 5), and a lowest possible score of 1. The coefficient was calculated using the formula $V = \Sigma s/[n(c - 1)]$, where $s = r - l_0$, r is the score assigned by a validator, and l_0 is the lowest score on the rating scale (Aiken, 1985). Aiken's V values were used to describe the content validity of the teaching module, LKPD, and test items.

Data analysis included descriptive statistics, the Shapiro-Wilk normality test, Levene's test for homogeneity of variance, and an independent-samples t-test using SPSS version 25. Descriptive statistics were used to compare the mean pretest and posttest scores. The Shapiro-Wilk test was used to evaluate the assumption of normality (Shapiro & Wilk, 1965), while Levene's test was used to assess homogeneity of variance. The independent-samples t-test was used to test between-group differences. The significance level was set at $\alpha = 0.05$.

RESULT AND DISCUSSION

The study was conducted in two Grade XI classes at SMA Negeri 1 Kediri: class XI MS1 as the experimental group and class XI MS2 as the control group. The findings are presented in terms of the validity of the learning materials and instrument, descriptive statistics of critical-thinking skills, assumption tests, and between-group difference testing.

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Results

The reported content-validity analysis covered the teaching module, student worksheet (LKPD), and critical-thinking test items.

Table 2. Content validity results for the teaching module

Item	Validator			S1	S2	S3	$\sum s$	n(c-1)	V	Interpretation
	I	II	III							
1-28	111	113	118	83	85	90	258	336	0.76	High validity

Validation of the teaching module yielded an Aiken's V coefficient of 0.76, categorized as high validity. This value indicates a high level of agreement among the validators regarding the content suitability of the teaching module for supporting instruction.

Table 3. Content validity results for the student worksheet

Item	Validator			S1	S2	S3	$\sum s$	n(c-1)	V	Interpretation
	I	II	III							
1-13	55	51	56	42	38	43	123	156	0.78	High validity

Validation of the LKPD yielded an Aiken's V coefficient of 0.78, categorized as high validity. This result indicates that the LKPD was judged to be aligned with the learning activities and the critical-thinking indicators used in the study.

Table 4. Content validity results for the test items

Item	Validator			S1	S2	S3	$\sum s$	n(c-1)	V	Interpretation
	I	II	III							
1-6	11	12	12	5	6	6	17	18	0.94	Very high validity

Validation of the test items yielded an Aiken's V coefficient of 0.94, categorized as very high validity. This value indicates a very high level of alignment among the test items, the targeted competencies, and the critical-thinking indicators being measured. Descriptive statistics for critical-thinking skills are presented in Table 5.

Table 5. Descriptive analysis of critical-thinking skills

Category	Pretest		Posttest	
	Experimental	Control	Experimental	Control
Number of students	19	23	19	23
Mean	26	24	75	57

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As shown in Table 5, the experimental group had a mean pretest score of 26, which increased to 75 on the posttest, while the control group increased from 24 to 57. Descriptively, the experimental group improved by 49 points, compared with 33 points in the control group. The normality-test results are presented in Table 6.

Table 6. Normality test results

Tests of Normality							
	Score group	**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Critical thinking	Experimental pretest	.212	19	.025	.912	19	.082
	Experimental posttest	.153	19	.200*	.922	19	.125
	Control pretest	.200	23	.017	.917	23	.058
	Control posttest	.153	23	.172	.926	23	.090

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Based on the Shapiro-Wilk test in Table 6, the significance values were 0.082 for the experimental pretest, 0.125 for the experimental posttest, 0.058 for the control pretest, and 0.090 for the control posttest. All values exceeded 0.05, indicating that all four score sets met the assumption of normality (Shapiro & Wilk, 1965). The homogeneity-test results are presented in Table 7.

Table 7. Homogeneity of Variance Test Results

Test of Homogeneity of Variance					
		Levene Statistic	**df1**	**df2**	**Sig.**
Critical thinking	Based on Mean	2.049	3	80	.114
	Based on Median	1.698	3	80	.174
	Based on Median and with adjusted df	1.698	3	78.662	.174
	Based on trimmed mean	1.915	3	80	.134

Table 7 presents Levene's test, with a Based on Mean value of 2.049, df1 = 3, df2 = 80, and p = 0.114. Because p > 0.05, the variances of the four score sets met the assumption of homogeneity. Table 8 subsequently presents the Levene's test associated with the independent-samples t-test; because it pertains to a different statistical comparison, its significance value may differ from that reported in Table 7.

Table 8. Independent-samples T-test results

Assumption	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% CI of Difference**
Equal variances assumed	-14.843	40	< .001	-48.947	3.298	[-55.635, -42.259]

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In Table 8, an independent-samples t-test was conducted to examine the difference in critical thinking skills between students who received Problem-Based Learning (PBL) and those who experienced conventional instruction. Levene's test indicated that the assumption of homogeneity of variance was met (F = 0.121, p = .730). The results showed a significant difference between the two groups, t(40) = -14.843, p < .001. The absolute mean difference between groups was 48.947 points (95% CI [42.259, 55.635]), suggesting that students who participated in PBL demonstrated significantly higher critical thinking skills compared with students in the conventional learning group.

Discussion

The descriptive results indicate that students in the experimental group who received Problem-Based Learning (PBL) showed a greater improvement in critical thinking skills compared with those in the control group. The mean score of the experimental group increased from 26 in the pretest to 75 in the posttest, whereas the control group increased from 24 to 57. This larger improvement suggests that PBL provided a more supportive learning environment for developing students' critical-thinking abilities.

The effectiveness of PBL can be explained by its emphasis on engaging students in authentic problem-solving activities. Instead of passively receiving information, students are encouraged to identify problems, explore relevant information, discuss possible solutions, evaluate evidence, and construct reasoned conclusions. These learning processes involve several dimensions of critical thinking, including interpretation, analysis, evaluation, and inference. Therefore, the problem-solving activities embedded in PBL may facilitate students' ability to think critically when dealing with complex learning situations. This finding is consistent with previous studies by Herzon et al. (2018) and Fa'uni et al. (2024), which reported that PBL positively contributes to the development of students' critical-thinking skills.

The assumption testing results supported the appropriateness of the statistical analysis. The Shapiro–Wilk normality test showed significance values above 0.05 for all groups, indicating that the data distribution met the normality assumption. Furthermore, the homogeneity test results showed that the variance between groups was comparable (Table 7, $p = 0.114$; Table 8, Levene's test $p = 0.730$). Therefore, the independent-samples *t*-test was appropriate for examining differences in critical-thinking skills between the PBL and conventional learning groups.

The independent-samples *t*-test results demonstrated a statistically significant difference between the two groups, $t(40) = -14.843$, $p < .001$. The mean difference of 48.947 points (95% CI [42.259, 55.635]) indicates that students who participated in PBL achieved higher critical-thinking scores than those who experienced conventional instruction. This finding suggests that PBL may provide meaningful advantages in promoting students' critical-thinking development by creating opportunities for inquiry, collaboration, argumentation, and reflective evaluation.

However, several limitations should be considered when interpreting these findings. The study involved students from only two classes in a single school, with purposive sampling, which may limit the generalizability of the findings to broader educational contexts. In addition, this study focused on comparing differences between groups and did not include further analyses such as effect size estimation or ANCOVA to control for initial differences. Future research is recommended to involve larger and more diverse samples,

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incorporate effect-size analysis, and apply more comprehensive statistical approaches to further examine the effectiveness of PBL in enhancing students' critical-thinking skills.

CONCLUSION

Based on the findings, students who received Problem-Based Learning (PBL) demonstrated greater improvement in critical-thinking skills compared with those who experienced conventional instruction. The experimental group showed an increase in mean scores from 26 in the pretest to 75 in the posttest, whereas the control group increased from 24 to 57. The independent-samples *t*-test revealed a significant difference between the two groups, $t(40) = -14.843$, $p < .001$, indicating that students involved in PBL achieved higher critical-thinking scores than students in the conventional learning group.

These findings suggest that PBL can serve as an effective instructional approach for supporting the development of students' critical-thinking skills by engaging them in problem identification, information analysis, evaluation of evidence, and formulation of logical solutions. Nevertheless, the findings should be interpreted within the context of the study limitations, including the limited sample size and the involvement of students from only one school. Further studies involving larger and more diverse samples are recommended to confirm the effectiveness of PBL in different educational settings.

RECOMMENDATIONS

Based on the findings of this study, teachers are recommended to consider implementing Problem-Based Learning (PBL) as an alternative instructional approach to promote students' critical-thinking skills. The application of PBL should be supported by carefully designed problems that are relevant to students' experiences and encourage investigation, discussion, evaluation of evidence, and the development of reasoned solutions.

Future studies are recommended to involve larger samples from different schools and educational contexts to improve the generalizability of the findings. Further research may also consider examining the long-term effects of PBL implementation and incorporating additional analyses, such as effect-size measurement and control of initial differences between groups, to provide a more comprehensive understanding of the impact of PBL on students' critical-thinking development.

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