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# ENHANCING CRITICAL THINKING THROUGH PROBLEM-BASED LEARNING: EVIDENCE FROM FOURTH-GRADE AT SDN MANGARAN 3 JEMBER

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**Abstrak**
Pengembangan keterampilan berpikir kritis merupakan tujuan penting pembelajaran IPA di sekolah dasar, tetapi pendekatan konvensional sering membatasi kesempatan siswa menganalisis masalah dan mengevaluasi bukti. Penelitian ini bertujuan menguji efektivitas model *Problem-Based Learning* (PBL) dalam meningkatkan keterampilan berpikir kritis siswa kelas IV SDN Mangaran 3 Jember. Penelitian menggunakan desain kuasi-eksperimen dengan 61 siswa, meliputi 30 siswa kelompok eksperimen dan 31 siswa kelompok kontrol. Kelompok eksperimen mengikuti pembelajaran PBL melalui lima tahap, sedangkan kelompok kontrol menjalani pembelajaran konvensional. Data dikumpulkan menggunakan tes esai berisi 10 soal berdasarkan lima indikator berpikir kritis Ennis. Analisis mencakup statistik deskriptif, uji-t sampel independen, N-gain, dan ukuran efek Cohen's d. Hasil menunjukkan rata-rata *posttest* kelompok eksperimen (M = 84,63) lebih tinggi daripada kelompok kontrol (M = 71,48), dengan perbedaan signifikan (t(59) = 7,66; p < 0,001). Peningkatan kemampuan kelompok eksperimen juga lebih besar, ditunjukkan oleh N-gain 0,64 dibandingkan 0,35 pada kelompok kontrol. Ukuran efek tergolong besar (Cohen's d = 1,96). Temuan ini mengindikasikan bahwa PBL berpotensi memperkuat keterampilan berpikir kritis melalui identifikasi masalah, penyelidikan, penalaran berbasis bukti, dan evaluasi. Pembelajaran ini juga mendorong partisipasi aktif siswa dalam diskusi kelompok dan penyusunan solusi secara sistematis. Generalisasi hasil perlu mempertimbangkan keterbatasan desain kuasi-eksperimen serta cakupan sampel dari satu sekolah.
**Kata Kunci: Problem-Based Learning, Keterampilan Berpikir Kritis, Pembelajaran IPA, Sekolah Dasar, Kuasi-Eksperimen**

***Abstract***
*Developing critical thinking skills is essential in elementary science education; however, conventional teaching approaches often limit students' opportunities to analyze problems and evaluate evidence. This study examines the effectiveness of Problem-Based Learning (PBL) in enhancing fourth-grade students' critical thinking skills at SDN Mangaran 3 Jember. A quasi-experimental design involved 61 students, comprising 30 in the experimental group and 31 in the control group. The experimental group received PBL instruction through five stages, while the control group experienced conventional*

*instruction. Data were collected using a 10-item essay test assessing five critical thinking indicators based on Ennis's framework. Data analysis employed descriptive statistics, an independent-samples t-test, normalized gain (N-gain), and Cohen's d. Results revealed significantly higher posttest scores in the experimental group (M = 84.63) than in the control group (M = 71.48), t(59) = 7.66, p < .001. The experimental group also achieved a higher N-gain (0.64) than the control group (0.35), with a large effect size (Cohen's d = 1.96). These findings suggest that PBL can enhance critical thinking through problem identification, inquiry, evidence-based reasoning, and evaluation. Nevertheless, the quasi-experimental design and single-school sample limit the generalizability of the findings.*

***Keywords: Problem-Based Learning, Critical Thinking Skills, Science Education, Elementary School, Quasi-Experimental Research***

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## INTRODUCTION

Developing higher-order thinking skills (HOTS) has become an important objective of twenty-first-century education. Advances in science and technology require students not only to acquire conceptual knowledge but also to analyze information, evaluate evidence, solve problems, and make reasoned decisions. Consequently, critical thinking has become an essential competency in contemporary education, particularly in enabling learners to interpret information, analyze relationships, evaluate arguments, and draw logical conclusions based on relevant evidence (Facione, 1990; OECD, 2023; *International Commission on the Futures of Education*, 2021). Developing these abilities from elementary education is particularly important because early learning experiences contribute to the development of reasoning skills and independent thinking. Abrami et al. (2015) demonstrated through a meta-analysis that critical thinking can be enhanced through instructional interventions involving authentic problems, classroom dialogue, and teacher guidance.

Despite the growing emphasis on critical thinking, developing this skill remains a significant challenge in elementary science education. Science learning requires students not only to acquire scientific knowledge but also to engage in observation, investigation, evidence interpretation, and logical reasoning to construct explanations. However, instructional practices that predominantly emphasize factual knowledge, memorization, and routine exercises may limit students' opportunities to engage in these higher-order cognitive processes. This concern is consistent with the systematic review by Jegstad et al. (2025), which highlights the importance of stronger theoretical foundations and meaningful instructional activities to foster critical thinking in primary education. In the context of the present study, this issue provides a rationale for examining science instruction at SDN

Mangaran 3 Jember, particularly regarding the extent to which classroom activities facilitate students' engagement in identifying problems, interpreting evidence, drawing conclusions, and proposing solutions. These considerations underscore the need for instructional approaches that systematically engage students in problem-solving and evidence-based reasoning, thereby providing meaningful opportunities to develop critical thinking skills during elementary science learning.

One instructional approach that may address these challenges is Problem-Based Learning (PBL). Grounded in constructivist learning theory, PBL positions students as active participants in constructing knowledge through engagement with authentic and meaningful problems. Students are encouraged to identify problems, formulate questions, conduct investigations, collaborate with peers, and evaluate possible solutions using relevant evidence. Hmelo-Silver (2004) emphasized that PBL facilitates flexible knowledge development, problem-solving abilities, self-directed learning, and collaborative learning through guided inquiry. These characteristics are particularly relevant to elementary science education because students can investigate observable phenomena and connect scientific concepts with their everyday experiences.

The potential contribution of PBL to critical thinking can be further explained through the five indicators of critical thinking proposed by Ennis (1985), namely elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. These indicators provide a more specific framework for examining how PBL activities facilitate students' critical-thinking processes. During problem orientation, students practice elementary clarification by identifying scientific problems, focusing on relevant questions, and analyzing information. Through collaborative planning and investigation, they develop strategies and tactics by determining appropriate actions and organizing investigative activities. During experiments and observations, students exercise basic support by assessing the credibility of information and evaluating observational evidence. When developing and presenting solutions, students practice inference by formulating and evaluating conclusions based on investigation findings. Finally, during the evaluation of the problem-solving process, students develop advanced clarification by examining assumptions, clarifying concepts, and evaluating the reasoning underlying their conclusions. Thus, PBL provides opportunities to integrate the five critical-thinking indicators into meaningful science learning activities.

Previous empirical studies have provided evidence supporting the potential of PBL in developing students' critical thinking skills. Anindyta and Suwarjo (2014) found that fifth-grade students participating in PBL demonstrated better critical-thinking performance than students receiving expository instruction. Similarly, Darmawati and Mustadi (2023) reported significant differences in critical-thinking performance between elementary students taught through PBL and those receiving expository instruction. Ejin (2016) also demonstrated that PBL implementation in fourth-grade science learning supported conceptual understanding and critical-thinking development through problem-solving activities related to environmental issues. Furthermore, Anggraeni et al. (2023), through a systematic review, identified the contribution of PBL to critical-thinking development across different educational contexts. Liu and Pásztor (2022) reported a positive overall effect of PBL on critical thinking based on a meta-analysis of higher education studies, while Sa'diyah et al. (2024) identified a substantial positive association between PBL implementation and critical-thinking skills in Indonesian elementary education. Yu and Zin (2023)

further emphasized that incorporating explicit critical-thinking activities into PBL can strengthen students' reasoning and evaluation abilities. Nevertheless, the effectiveness of PBL depends on the selection of appropriate problems, instructional scaffolding, and the integration of activities that explicitly encourage critical thinking (Hmelo-Silver, 2004; Qothrunnada et al., 2025).

Nevertheless, the effectiveness of PBL depends on how instructional activities are organized, facilitated, and adapted to students' developmental characteristics. Qothrunnada et al. (2025) emphasized that the effectiveness of problem-based science learning in elementary education depends on authentic problem selection, structured scaffolding, and instructional support appropriate to students' learning needs. Elementary students may encounter difficulties in identifying relevant information, formulating explanations, evaluating evidence, and communicating logical arguments without appropriate instructional guidance. Hmelo-Silver (2004) highlighted the importance of facilitation and scaffolding in supporting students throughout the problem-solving process. Similarly, Yu and Zin (2023) emphasized that explicitly incorporating critical-thinking activities into PBL can strengthen its effectiveness. Therefore, implementing PBL in elementary science education requires carefully structured learning experiences that provide opportunities for investigation, collaboration, reasoning, and evaluation while maintaining appropriate teacher guidance.

In this context, the five instructional stages of PBL provide a systematic framework for facilitating critical thinking development. These stages include problem orientation, organizing students for learning, guiding individual and group investigations, developing and presenting solutions, and analyzing and evaluating the problem-solving process. Each stage offers opportunities for students to develop specific critical-thinking processes. Problem orientation encourages students to recognize and analyze scientific problems, while collaborative investigation enables them to collect and interpret relevant evidence. Developing and presenting solutions supports logical argumentation and the communication of scientific explanations, whereas evaluating the problem-solving process encourages students to reconsider conclusions and assess the validity of their reasoning. Through these interconnected activities, PBL provides a structured learning environment that supports the development of critical thinking in elementary science education.

Although previous studies have established the potential of PBL in developing critical thinking, several aspects require further empirical investigation. First, findings from different educational levels and learning contexts cannot automatically be generalized to fourth-grade elementary students because of differences in cognitive development, learning independence, and instructional support requirements. Second, although previous studies have examined PBL in elementary science education, further investigation is needed to evaluate its implementation through the five established instructional stages in relation to the five specific critical-thinking indicators proposed by Ennis (1985). Third, context-specific empirical evidence remains necessary to determine whether PBL produces measurable improvements in fourth-grade students' critical-thinking performance compared with conventional instruction. Existing reviews have also identified variations in instructional implementation, research designs, and critical-thinking assessment approaches (Anggraeni et al., 2023; Jegstad et al., 2025). Therefore, the present study addresses these aspects by examining the effectiveness of PBL in fourth-grade science learning at SDN

Mangaran 3 Jember using a quasi-experimental approach and an assessment framework based on Ennis's critical-thinking indicators.

Unlike studies focusing on the development of new instructional models, this research evaluates the effectiveness of the established PBL model through its five instructional stages: problem orientation, organizing students for learning, guiding individual and group investigations, developing and presenting solutions, and analyzing and evaluating the problem-solving process. A quasi-experimental pretest–posttest control group design is employed to compare the critical-thinking performance of students receiving PBL instruction with that of students receiving conventional instruction. Students' critical-thinking skills are assessed using an instrument based on the five indicators proposed by Ennis (1985), namely elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. The analysis focuses on students' pretest and posttest performance, normalized learning gains, differences between instructional groups, and effect size to provide evidence of the improvement and magnitude of the PBL intervention.

Accordingly, this study aims to: (1) examine the improvement in fourth-grade students' critical-thinking skills following the implementation of the Problem-Based Learning model in science learning, as measured through the five critical-thinking indicators proposed by Ennis (1985); (2) determine whether there is a significant difference in critical-thinking performance between students receiving PBL instruction and those receiving conventional instruction; and (3) determine the magnitude of the effect of PBL implementation on students' critical-thinking skills based on normalized gain and effect-size analysis. The study addresses the following research questions:

RQ1. To what extent do fourth-grade students' critical-thinking skills improve following the implementation of the Problem-Based Learning model in science learning?

RQ2. Is there a significant difference in critical-thinking performance between fourth-grade students taught using the Problem-Based Learning model and those receiving conventional instruction?

RQ3. What is the magnitude of the effect of the Problem-Based Learning model on fourth-grade students' critical-thinking skills, as indicated by normalized gain and effect size?

The findings are expected to provide empirical evidence regarding the effectiveness of PBL in elementary science education, particularly in supporting the development of critical-thinking skills among fourth-grade students. Furthermore, this study may offer practical insights for elementary school teachers in designing science learning activities that integrate authentic problem-solving, collaborative investigation, evidence evaluation, and reasoned decision-making.

**Theoretical Foundation of the Problem-Based Learning (PBL) Model**

Problem-Based Learning (PBL) is grounded in constructivist learning theory, which emphasizes that knowledge is actively constructed through experience, inquiry, and social interaction. PBL encourages students to investigate authentic problems, collaborate with peers, and develop evidence-based solutions. Hmelo-Silver (2004) described PBL as a student-centered approach that promotes conceptual understanding, independent inquiry, and problem-solving skills through guided learning experiences. Hmelo-Silver and Barrows (2006) emphasized that effective PBL facilitation involves guiding students to construct explanations, develop reasoning strategies, and participate actively in collaborative problem-solving without reducing their responsibility for learning.

Critical thinking is a fundamental cognitive outcome of PBL. According to Facione (1990), critical thinking involves interpretation, analysis, evaluation, inference, explanation, and self-regulation. Through problem-solving activities, students learn to evaluate information, examine alternative explanations, and formulate logical conclusions. Previous studies have demonstrated that PBL positively influences critical thinking development by encouraging active investigation, collaborative reasoning, and evidence-based decision-making (Anggraeni et al., 2023; Liu & Pásztor, 2022).

**Table 1 - Stages of Problem-Based Learning (PBL) and Critical Thinking Indicators Based on Ennis (1985)**

| No. | PBL Stages | Learning Activities | Critical Thinking Indicators (Ennis, 1985) |
|---|---|---|---|
| 1 | Problem Orientation | Students identify authentic scientific problems, formulate questions, and analyze relevant information. | Elementary Clarification: Focusing on questions, analyzing arguments, and asking clarification questions. |
| 2 | Organizing Students for Learning | Students collaborate in groups, identify learning objectives, discuss possible approaches, and plan investigations. | Strategies and Tactics: Determining appropriate actions and interacting with others. |
| 3 | Guiding Individual and Group Investigations | Students conduct observations, experiments, and investigations to collect and evaluate scientific evidence. | Basic Support: Evaluating source credibility and observing and judging observation reports. |
| 4 | Developing and Presenting Solutions | Students analyze findings, formulate evidence-based conclusions, and present alternative solutions. | Inference: Making and evaluating deductions, inductions, and value judgments. |
| 5 | Analyzing and Evaluating the Problem-Solving Process | Students evaluate solutions, identify assumptions, reconsider evidence, and assess the reasoning behind their conclusions. | Advanced Clarification: Defining terms, evaluating definitions, and identifying assumptions. |

These five stages systematically facilitate critical thinking by integrating problem identification, collaborative inquiry, evidence evaluation, logical argumentation, and reflective judgment. In elementary science education, PBL provides meaningful opportunities for students to connect scientific concepts with real-world experiences. Therefore, this study employs PBL as an instructional framework to examine its effectiveness in enhancing fourth-grade students' critical thinking skills at SDN Mangaran 3 Jember. Walker and Leary (2009) demonstrated that PBL outcomes vary across problem types, implementation approaches, disciplines, and assessment

levels, indicating the importance of designing problem-solving activities that align with specific learning objectives.

## METHOD

### Research Design and Participants

This study employed a quantitative approach using a quasi-experimental method with a nonequivalent control group design. The participants consisted of 61 fourth-grade students at SDN Mangaran 3 Jember, Indonesia. The students were divided into two groups: an experimental group consisting of 30 students who received Problem-Based Learning (PBL) instruction and a control group consisting of 31 students who received conventional instruction.

The groups were selected using a nonrandomized sampling procedure based on the existing classroom organization and school arrangements. Because individual students were not randomly assigned to the experimental and control groups, the study employed a nonequivalent control group design. Before the intervention, both groups completed an initial assessment (pretest) to determine their existing critical thinking skills. The pretest results were examined to describe the initial characteristics of both groups and assess their baseline comparability before the instructional intervention.

### Research Instrument

Students' critical thinking skills were measured using a 10-item essay test developed based on five critical thinking indicators proposed by Ennis (1985): elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. The instrument was designed to assess students' abilities to identify and clarify problems, evaluate the credibility of information, formulate logical conclusions, examine assumptions, and determine appropriate solutions.

The test consisted of 10 essay items designed to assess five critical thinking indicators. Each indicator was measured by two items, resulting in an equal distribution of test items across the five indicators. The instrument blueprint was developed by aligning each indicator with the expected cognitive performance and the science learning content addressed in the study. Each essay item was assessed using an analytical scoring rubric that considered the accuracy, completeness, relevance, and logical justification of students' responses. Each essay item was scored on a scale of 0–10 points, based on the accuracy, relevance, and completeness of students' responses. With 10 test items, the total possible score ranged from 0 to 100 points. The scores were used to assess students' critical thinking skills across the five indicators. The students' scores were subsequently converted into a standardized scale of 0–100 for analysis.

This study employed a quantitative, quasi-experimental approach with a nonequivalent control group design involving 61 fourth-grade students at SDN Mangaran 3 Jember. The experimental group comprised 30 students receiving Problem-Based Learning (PBL), while the control group comprised 31 students receiving conventional instruction.

Critical thinking skills were measured using a 10-item essay test based on five indicators proposed by Ennis (1985): elementary clarification, basic support, inference, advanced clarification, and strategies and tactics.

### Instrument Validity and Reliability

Content validity was evaluated by three experts in elementary and science education through expert judgment. Instrument reliability was assessed using Cronbach's alpha, with coefficients above 0.70 considered acceptable (Hair et al., 2022).

**Research Procedure**

The research involved four phases: pretesting, instructional intervention, posttesting, and data analysis. The experimental group followed five PBL stages proposed by Arends (2012): problem orientation, organizing students for learning, guiding individual and group investigations, developing and presenting solutions, and evaluating the problem-solving process. Meanwhile, the control group received conventional instruction.

The research was conducted through four main phases: pretesting, instructional intervention, posttesting, and data analysis. First, both the experimental and control groups completed a pretest to measure their initial critical thinking skills. Second, the instructional intervention was implemented over 1 meetings/weeks, with each meeting lasting six. Both groups studied the same science topics, learning objectives, and instructional content to ensure comparability. The experimental group received instruction using the Problem-Based Learning (PBL) model based on the five stages proposed by Arends (2012): orienting students to the problem, organizing students for learning, guiding individual and group investigations, developing and presenting solutions, and analyzing and evaluating the problem-solving process. Learning activities included identifying scientific problems, conducting investigations, discussing findings, developing evidence-based explanations, and evaluating proposed solutions. Meanwhile, the control group received conventional instruction based on the teaching practices commonly implemented at the school. Both groups were provided with equivalent science content, learning objectives, and instructional time, ensuring that differences in learning outcomes could be examined in relation to the instructional approaches. Third, after the intervention, both groups completed a posttest using the same critical thinking assessment instrument as the pretest. Finally, the pretest and posttest results were compiled and analyzed to examine students' learning improvement, differences in critical thinking performance between groups, and the magnitude of the instructional effect.

**Data Analysis**

The collected data were analyzed using IBM SPSS Statistics version 27. Descriptive statistics, including the mean and standard deviation, were calculated to summarize students' critical thinking performance in the experimental and control groups before and after the intervention. Before conducting inferential statistical analyses, the data were examined for normality and homogeneity. The Shapiro–Wilk test was used to assess the normality of the data distribution, while Levene's test was employed to examine the homogeneity of variances. The data were considered normally distributed when the Shapiro–Wilk significance value was greater than 0.05 and homogeneous when the Levene's test significance value exceeded 0.05.

An independent-samples t-test was used to examine differences in critical thinking performance between the experimental and control groups. Statistical significance was determined at the 0.05 level. A p-value below 0.05 indicated a statistically significant difference between the groups, whereas a p-value greater than or equal to 0.05 indicated that the difference was not statistically significant.

## RESULTS AND DISCUSSION

### Results

### Descriptive Statistics

Descriptive statistics were conducted to examine students' critical thinking skills before and after the learning intervention. Table 2 presents the pretest and posttest scores of the experimental and control groups.

**Table 2 - Descriptive Statistics of Students' Critical Thinking Scores**

| Group | Pretest (Mean ± SD) | Posttest (Mean ± SD) |
|---|---|---|
| Experimental (n=30) | 56.83 ± 8.74 | 84.63 ± 6.21 |
| Control (n=31) | 55.97 ± 8.16 | 71.48 ± 7.15 |

As shown in Table 2, the experimental and control groups demonstrated improvements in their critical thinking scores following the instructional intervention. The experimental group's mean score increased from 56.83 (SD = 8.74) in the pretest to 84.63 (SD = 6.21) in the posttest, representing an improvement of 27.80 points. Similarly, the control group's mean score increased from 55.97 (SD = 8.16) to 71.48 (SD = 7.15), representing an improvement of 15.51 points. The experimental group demonstrated a greater mean improvement than the control group, with a difference of 12.29 points in the observed score increases. These descriptive findings suggest that students receiving PBL instruction achieved greater improvements in critical thinking performance than those receiving conventional instruction. However, the statistical significance of the difference requires further examination through inferential analysis.

### Assumption Testing

Before conducting hypothesis testing, statistical assumptions were examined to determine whether the critical thinking scores met the requirements for parametric analysis. The Shapiro–Wilk test was used to assess the normality of students' critical thinking scores in the experimental and control groups, while Levene's test was used to examine the homogeneity of variances.

**Table 3 - Shapiro–Wilk Normality Test**

| Group | W | p-value | Decision |
|---|---|---|---|
| Experimental | 0.973 | .482 | Normal |
| Control | 0.968 | .391 | Normal |

As presented in Table 3, the Shapiro–Wilk test indicated that students' critical thinking scores in both groups were normally distributed. The experimental group obtained a Shapiro–Wilk statistic of W = 0.973 (p = .482), while the control group obtained W = 0.968 (p = .391). Both p-values exceeded the significance threshold of .05, indicating that the normality assumption was satisfied for both groups. Therefore, the data met the normality requirement for subsequent parametric statistical analysis.

**Table 4 - Homogeneity Test**

| Variable | Levene Statistic | p-value | Decision |
|---|---|---|---|
| Critical Thinking | 0.724 | .398 | Homogeneous |

As presented in Table 4, Levene's test produced a statistic of 0.724 with a p-value of .398. Since the p-value exceeded the significance threshold of .05, the null hypothesis of equal variances was not rejected. Therefore, the variances of critical thinking scores in the experimental and control groups were considered homogeneous. This result indicates that the homogeneity of variance assumption was satisfied, supporting the use of the equal-variances-assumed option in the subsequent independent-samples t-test.

### Effectiveness of the PBL Model

An independent-samples t-test was conducted to examine differences in students' posttest critical thinking scores between the experimental and control groups.

**Table 5 - Independent-Samples t-Test Results**

| Variable | t | df | p-value |
|---|---|---|---|
| Critical Thinking | 7.658 | 59 | < .001 |

The independent samples t-test indicated a statistically significant difference in posttest critical thinking scores between the experimental and control groups, $t(59) = 7.658$, $p < .001$. The mean difference was 13.15 points, indicating that students who received Problem-Based Learning instruction achieved higher critical thinking scores than those who received conventional instruction.

**Learning Improvement (N-Gain)**

Normalized gain (N-gain) analysis was conducted to determine the magnitude of students' learning improvement.

**Table 6 - N-Gain Analysis of Critical Thinking Skills**

| Variable | Experimental N-Gain | Category | Control N-Gain | Category |
|---|---|---|---|---|
| Critical Thinking | 0.64 | Moderate | 0.35 | Moderate |

Normalized gain (N-gain) analysis was conducted to determine the magnitude of imprvement in students' critical thinking skills following the implementation of the PBL model. The N-gain was calculated using the difference between the mean posttest and pretest scores divided by the difference between the maximum possible score (100) and the mean pretest score. The interpretation followed Hake's (1998) criteria, in which an N-gain of 0.70 or higher is classified as high, 0.30–less than 0.70 as moderate, and below 0.30 as low.

As presented in Table 6, the experimental group obtained an N-gain of 0.64, whereas the control group obtained 0.35. Both groups were classified in the moderate category. However, the experimental group's N-gain was higher than that of the control group, indicating greater improvement in critical thinking skills among students who received PBL instruction. These findings provide additional descriptive evidence of the favorable contribution of PBL to students' critical thinking development.

In addition to N-gain analysis, Cohen's d was used to examine the magnitude of the difference in posttest scores between the experimental and control groups. Based on the previously calculated value of Cohen's $d = 1.96$, the effect was classified as large according to Cohen's (1988) conventional criteria: 0.20 (small), 0.50 (medium), and 0.80 (large). This result indicates a substantial difference in critical thinking performance between the two groups, favoring the experimental group.

**Effect Size**

Cohen's d effect size was used to evaluate the practical significance of the instructional intervention.

**Table 7 - Cohen's d Effect Size**

| Variable | Cohen's d | Interpretation |
|---|---|---|
| Critical Thinking | 1.961 | Large |

The reported effect size ($d = 1.31$) indicates a large difference in critical thinking performance between the experimental and control groups. This finding suggests that the observed improvement was not only statistically significant but also educationally meaningful.

Overall, the findings indicate that the experimental group achieved higher critical thinking scores, greater learning gains, and a large reported effect size compared with the control group. These results suggest that Problem-Based Learning (PBL) can support the development of fourth-grade students' critical thinking skills through authentic problem-solving, collaborative investigation, evidence-based reasoning, and systematic evaluation.

## Discussion

### The Effect of Problem-Based Learning (PBL) on Students' Critical Thinking Skills

The findings indicate that fourth-grade students who participated in Problem-Based Learning (PBL) achieved higher critical thinking performance than those who received conventional instruction. The experimental group obtained a higher posttest mean score ($M = 84.63$) than the control group ($M = 71.48$), with a statistically significant difference between the groups ($p < .001$). Furthermore, the experimental group demonstrated a higher normalized gain (N-gain = 0.64) than the control group (N-gain = 0.35). Although both groups were classified in the moderate improvement category, the greater gain in the experimental group suggests that students who experienced PBL made more substantial progress in their critical thinking performance.

These findings can be understood through constructivist learning theory, which emphasizes active knowledge construction through meaningful experiences, inquiry, and social interaction. In contrast to instruction that primarily emphasizes the delivery of information, PBL engages students in identifying problems, investigating relevant information, discussing alternative explanations, and developing evidence-based solutions. Hmelo-Silver (2004) explained that PBL supports knowledge construction and the development of thinking strategies through collaborative problem-solving and guided inquiry. In elementary science learning, these activities provide opportunities for students to connect scientific concepts with observable phenomena and to develop explanations based on evidence.

The findings are consistent with previous research reporting the potential of PBL to support critical thinking development. Anggraeni et al. (2023) and Mutiara et al. (2024), through systematic literature reviews, identified active inquiry, meaningful problem-solving, and student participation as important features of PBL that support critical thinking. Similarly, Liu and Pásztor (2022) reported an overall positive effect of PBL on critical thinking in higher education, although its effectiveness varied across instructional contexts. At the elementary level, Ardiansya et al. (2024) also reported improvements in students' critical thinking through problem-based instruction. These findings share a common emphasis on the role of problem-solving and active engagement in developing students' thinking skills. However, the present study extends this discussion by examining PBL in the specific context of fourth-grade elementary science learning.

Differences in educational levels and instructional contexts should also be considered when interpreting these studies. For example, Affandy et al. (2024) investigated the integration of creative pedagogy into PBL among eighth-grade science students and reported improvements in higher-order thinking skills, particularly in analyzing problems, evaluating alternatives, and generating solutions. Although the study involved older students and an integrated pedagogical approach, its findings support the importance of structured problem-solving activities in science education. The present study, in contrast, focused on fourth-grade students and examined critical thinking through five indicators based on Ennis (1985). Thus, its contribution lies in providing empirical evidence of the potential of PBL to support critical thinking development at an earlier stage of formal science education.

### The Contribution of PBL Stages to Critical Thinking Development

The five instructional stages of PBL proposed by Arends (2012) provide a framework for understanding how classroom activities may create opportunities for developing the five critical


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thinking indicators identified by Ennis (1985): elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. The relationship between these stages and indicators is conceptual rather than a direct measurement of the independent contribution of each stage.

The first stage, orienting students to the problem, encourages students to recognize scientific phenomena, identify relevant problems, and formulate questions. These activities are conceptually related to elementary clarification, which involves identifying problems and asking relevant questions. For fourth-grade students, presenting problems connected to familiar scientific phenomena may help make abstract concepts more meaningful and encourage them to examine situations before proposing explanations.

The second stage, organizing students for learning, provides opportunities for students to discuss the problem, share initial ideas, and plan their investigations. Through these activities, students can begin considering the information and evidence needed to address the problem. This stage may support elementary clarification and strategies and tactics because students are encouraged to determine what needs to be investigated and how the investigation should be organized.

The third stage, guiding individual and group investigations, involves collecting information, conducting observations or experiments, and examining relevant evidence. These activities are particularly related to the basic support indicator, which concerns assessing the credibility and relevance of information used to support an argument. In elementary science learning, direct observation and investigation can help students distinguish between explanations based on evidence and assumptions that have not been adequately supported.

The fourth stage, developing and presenting solutions, encourages students to formulate conclusions, explain their findings, and provide reasons for their proposed solutions. These activities are closely related to inference because students are required to draw conclusions from the information and evidence obtained during their investigations. Presenting and discussing solutions may also provide opportunities to clarify and justify their reasoning.

The fifth stage, analyzing and evaluating the problem-solving process, encourages students to reconsider their explanations, examine the strengths and limitations of proposed solutions, and reflect on the strategies used during the investigation. These activities are conceptually associated with advanced clarification and strategies and tactics. Students have opportunities to examine assumptions, refine their explanations, and consider whether their chosen solutions are appropriate for the problem.

The relationship between PBL stages and critical thinking indicators is also supported by previous research emphasizing guided reasoning and classroom interaction. Marthaliakirana et al. (2022) demonstrated that PBL supported by metacognitive prompts improved argumentation and critical thinking among secondary school students. Their findings highlight the importance of guiding students to evaluate their reasoning during problem-solving activities. Although their participants were at a different educational level, the study provides relevant support for incorporating reflection and reasoning guidance into PBL implementation. Similarly, Jegstad et al. (2025) emphasized the importance of meaningful subject content and critical dialogue in promoting critical thinking in primary education. These findings suggest that the potential of PBL depends not

only on presenting problems but also on providing appropriate teacher guidance, opportunities for discussion, and systematic evaluation throughout the learning process.

Taken together, the higher posttest performance and N-gain in the experimental group are consistent with the opportunities for critical thinking provided by the five PBL stages. Nevertheless, the present study measured students' overall critical thinking performance rather than the separate contribution of each instructional stage or each Ennis indicator. Therefore, the proposed relationship should be understood as an explanation of the learning processes that may have supported the observed improvement, rather than evidence that a particular PBL stage independently produced a specific improvement.

**Educational Implications, Limitations, and Future Research**

The findings have implications for elementary science education. PBL provides teachers with a structured instructional approach for engaging students in identifying scientific problems, investigating evidence, discussing explanations, and evaluating possible solutions. The five stages proposed by Arends (2012) can be used to organize learning activities that encourage students to participate actively in scientific inquiry and develop their reasoning skills. In particular, teachers can connect problems to phenomena in students' everyday environments, provide guidance during investigations, and encourage students to explain the evidence supporting their conclusions.

These implications are consistent with Strobel and van Barneveld (2009), who reported that PBL may offer advantages in skill development and long-term knowledge retention, although conventional approaches may sometimes perform better on assessments emphasizing short-term knowledge retention. This comparison indicates that instructional effectiveness should be considered in relation to the intended learning outcomes. In the context of the present study, the observed differences concern students' critical thinking performance rather than all dimensions of science learning.

Several limitations should be considered when interpreting the findings. First, the study involved only 61 fourth-grade students from one elementary school, which limits the generalizability of the results to other schools and educational contexts. Second, the study employed a nonequivalent control group design without random assignment. Consequently, pre-existing differences between the groups and other contextual factors may have influenced the observed outcomes. Although the experimental group achieved higher posttest scores and N-gain, the findings should not be interpreted as establishing that PBL alone caused all the observed improvements. Other factors, including students' initial abilities, classroom interactions, teacher guidance, and differences in learning experiences, may also have contributed.Third, critical thinking was assessed using an essay test based on five indicators, and no delayed posttest was administered. Therefore, the study does not establish whether the observed improvement was maintained over time. In addition, because the analysis focused on overall critical thinking performance, it cannot determine which individual indicators improved most or which PBL stages contributed most strongly to the outcomes.

Future research should involve larger samples from multiple elementary schools and, where feasible, stronger group assignment procedures to improve the basis for causal interpretation. Further studies could examine changes in each critical thinking indicator separately, investigate the relationship between specific PBL activities and students' reasoning processes, and incorporate

classroom observations or learning-process assessments. Delayed assessments would also be valuable for determining whether improvements in critical thinking are sustained over time.

Overall, the findings suggest that PBL is a promising instructional approach for supporting fourth-grade students' critical thinking development in elementary science learning. The higher posttest performance and N-gain observed in the experimental group are consistent with the opportunities for problem identification, collaborative investigation, evidence-based reasoning, and reflection provided by PBL. However, these findings should be interpreted within the limitations of the quasi-experimental design and the specific school context in which the study was conducted.

## CONCLUSION

This study aimed to examine the effect of the Problem-Based Learning (PBL) model on fourth-grade students' critical thinking skills in elementary science learning. The findings revealed a statistically significant difference in posttest performance between students who received PBL instruction and those who received conventional instruction, with the PBL group demonstrating higher critical thinking performance and greater learning improvement. These results suggest that PBL is a promising instructional approach for supporting the development of critical thinking skills through problem identification, collaborative investigation, evidence-based reasoning, and evaluation of proposed solutions.

However, because this study employed a quasi-experimental design without random assignment and involved students from only one elementary school, the findings should be interpreted within the context of the study. They do not establish that PBL alone caused the observed differences. Further research involving larger and more diverse samples, as well as different educational settings, is needed to strengthen the evidence regarding the contribution of PBL to students' critical thinking development.

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