Volume 4, Issue 2 (2026) 160-168

EQUATOR SCIENCE JOURNAL (ESJ)
e-ISSN: 2988-3881
Journal homepage:
https://ejournal.edukhatulistiwa.com/index.php/ESJ

Improving Science Learning Outcomes and Critical Thinking through Problem-Based Learning in Elementary Education

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Received: May 2, 2026 | Revised: June 10, 2026 | Accepted: June 27, 2026
First Available Online: June 30, 2026 | Publication Date: June 30, 2026
DOI: https://doi.org/10.61142/esj.v4i2.363

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Keywords:
Critical thinking;
Fifth grade students;
Problem based learning;
Science learning outcomes

ABSTRACT
Low science learning outcomes and limited critical thinking skills among elementary school students remain a significant challenge in science education, particularly due to the use of less interactive instructional approaches. This study investigates the effect of the Problem-Based Learning (PBL) model on students' science learning outcomes and critical thinking skills among fifth-grade students at SD Inpres 3 Tatura. This study employed a quasi-experimental design using a pretest–posttest control group approach. The sample consisted of 53 students selected through total sampling, with one class assigned as the experimental group and the other as the control group. Data were collected using essay-based tests designed to measure students' learning outcomes and critical thinking skills, and were analyzed using an independent sample t-test. The results indicate that students who were taught using the PBL model achieved significantly higher learning outcomes and demonstrated improved critical thinking skills compared to those who received conventional instruction ($p < 0.05$). The improvement was evident in students' ability to analyze problems, construct arguments, and evaluate solutions. These findings suggest that Problem-Based Learning is an effective instructional strategy for enhancing both science learning outcomes and critical thinking skills, and can be considered a practical approach for improving elementary science education.

INTRODUCTION

Science learning in elementary schools plays an essential role in developing students' critical thinking and problem-solving skills, which are considered fundamental competencies in 21st-century education (AlAli, 2024; Hussein et al., 2019; Nurharini et al., 2024). However, many elementary school students still experience difficulties in understanding scientific concepts and applying them in real-life contexts. Previous studies have shown that students' critical thinking skills in science learning remain relatively low because classroom instruction is often dominated by memorization-oriented activities and teacher-centered approaches (Kusumawati & Fauzan, 2025; Made et al., 2025). As a result, students tend to become passive learners and have limited opportunities to analyze problems, construct ideas, and develop scientific reasoning skills.

This issue was also identified at SD Inpres 3 Tatura based on preliminary observations and interviews with teachers and school administrators. The findings revealed that students' science learning outcomes were still below expectations, particularly in the topic of the human respiratory system. The findings revealed that students' performance in science learning and critical thinking still required improvement, particularly in the topic of the human respiratory system. The average critical thinking score of Class VA students was 68.70, which was below the minimum mastery criterion (KKM) of 70, while Class VB achieved a slightly higher average score of 71. Although Class VB marginally exceeded the KKM, classroom observations indicated that students in both classes still experienced difficulties in analyzing scientific problems and applying concepts meaningfully. Classroom observations further revealed that the learning process remained predominantly teacher-centered, with students relying heavily on teacher explanations rather than actively participating in discussions, investigations, or problem-solving activities. Consequently, students had limited opportunities to develop deeper conceptual understanding and critical thinking skills during science learning.

Several studies have emphasized that inappropriate instructional strategies contribute significantly to low student engagement and weak critical thinking performance in science learning (Arsyad et al., 2024; Bhardwaj et al., 2025). Conventional teaching approaches generally focus on knowledge transmission rather than encouraging students to explore, question, and solve problems independently. Therefore, innovative learning models that actively engage students in scientific inquiry and collaborative problem-solving are needed to improve both learning outcomes and critical thinking skills. Through scientific inquiry, students are encouraged to formulate questions, investigate evidence, analyze information, and draw conclusions based on logical reasoning, all of which are essential components of critical thinking (Hussein et al., 2019; Suhirman & Khotimah, 2020). In addition, collaborative problem-solving provides opportunities for students to discuss ideas, evaluate alternative perspectives, justify arguments, and reflect on their reasoning processes, thereby fostering deeper conceptual understanding and higher-order thinking skills (AlAli, 2024; Rejeki et al., 2022; Song, 2018).

One instructional model widely recognized for promoting active learning and critical thinking is Problem-Based Learning (PBL). PBL engages students in investigating authentic problems, collaboratively analyzing information, and developing solutions through systematic inquiry processes. This approach positions students as active participants in the learning process rather than passive recipients of information, thereby promoting more meaningful and student-centered learning experiences (Siregar, 2025; Syafii, 2024). Previous studies have also demonstrated that PBL significantly improves students' critical thinking skills, learning participation, and conceptual understanding in science education (Suhirman & Khotimah, 2020; Uliyandari et al., 2021). Furthermore, in elementary education contexts, PBL has been reported to strengthen students' scientific reasoning and collaborative learning skills because students are directly involved in identifying, analyzing, and solving contextual problems (Erviana et al., 2025; Song, 2018).

Previous studies have consistently reported positive effects of PBL on either learning outcomes or critical thinking skills. For example, Sholihah & Lastariwati (2020) found that PBL improved students' critical thinking skills through active problem-solving activities. Similarly, Rejeki et al., (2022) reported that online PBL effectively enhanced elementary students' critical thinking and digital literacy skills, while Maulana et al. (2022) demonstrated that PBL improved elementary students'

critical thinking skills in science learning. Although these studies confirmed the effectiveness of PBL, several limitations remain evident. First, most previous studies focused only on one dependent variable, either learning outcomes or critical thinking skills, rather than examining both simultaneously. Second, studies investigating PBL implementation in elementary science learning are still limited, particularly on the topic of the human respiratory system. Third, there is still limited empirical evidence regarding the implementation of PBL in the context of elementary schools in Indonesia, especially at SD Inpres 3 Tatura.

Based on these research gaps, this study contributes to the literature in several ways. First, it examines the simultaneous effect of Problem-Based Learning on both science learning outcomes and critical thinking skills, whereas previous studies have often investigated these outcomes separately. Second, the study investigates the implementation of PBL in teaching the human respiratory system, a science topic characterized by abstract concepts that frequently challenge elementary students' understanding. Third, it provides empirical evidence from an Indonesian elementary school context, thereby enriching the limited body of research on PBL implementation in elementary science education. Therefore, this study aims to investigate the effect of the Problem-Based Learning (PBL) model on the learning outcomes and critical thinking skills of fifth-grade students at SD Inpres 3 Tatura.

METHOD

Research Design

This study employed a quantitative approach using a quasi-experimental design with a pretest–posttest control group design. The experimental group received instruction using the Problem-Based Learning (PBL) model, while the control group was taught using a conventional learning model. Pretests and posttests were administered to measure students' learning outcomes and critical thinking skills before and after the treatment.

Participants

The study was conducted at SD Inpres 3 Tatura, Central Sulawesi, during the second semester of the 2023/2024 academic year. The participants consisted of 53 fifth-grade students selected using a total sampling technique. Class VA, consisting of 26 students, was assigned as the experimental group, while Class VB, consisting of 27 students, served as the control group.

Research Instruments

The research instrument used in this study was an essay test consisting of five items. The test was designed to measure students' learning outcomes and critical thinking skills related to the human respiratory system topic. Instrument validity was tested using Pearson Product-Moment correlation, while reliability was examined using Cronbach's Alpha. The results indicated that all test items were valid and reliable for data collection.

Data Collection

Data were collected through pretests and posttests administered to both groups. The experimental group participated in learning activities using the Problem-Based Learning (PBL) model, whereas the control group received conventional instruction. Documentation techniques were also used to obtain supporting data related to the research setting and participants. Data analysis was conducted using descriptive and inferential statistical techniques. Prior to hypothesis testing, normality and homogeneity tests were performed to ensure that the data met statistical assumptions. The normality test used the Chi-square test, while homogeneity was analyzed using the F-test. The hypothesis was tested using an independent sample t-test to determine differences between the experimental and control groups. Statistical analysis was conducted at a significance level of 0.05.

Ethical Considerations

Prior to data collection, permission to conduct the study was obtained from SD Inpres 3 Tatura. All student data were treated confidentially and used solely for research purposes. Participants'

identities were anonymized to ensure privacy and ethical research standards.

RESULTS AND DISCUSSION

Result

Instrument testing

Instrument testing was conducted to evaluate the validity and reliability of the essay test used to measure students' learning outcomes and critical thinking skills. The validity test aimed to determine whether each item appropriately measured the intended constructs, while the reliability test assessed the consistency of the instrument. The results of the validity analysis are presented in Table 1.

Table 1. Instrument Validity Test Results

Item	r-table	r-count	Interpretation
Item 1	0,396	0,598	Valid
Item 2	0,396	0,503	Valid
Item 3	0,396	0,556	Valid
Item 4	0,396	0,598	Valid
Item 5	0,396	0,432	Valid

As shown in Table 1, all five essay items obtained r-count values higher than the critical value (r-table = 0.396). The r-count values ranged from 0.432 to 0.598, indicating that all items met the validity criteria. Therefore, the instrument was considered suitable for measuring students' learning outcomes and critical thinking skills. After confirming the validity of the instrument, a reliability test was conducted to examine the consistency of the measurement instrument. The results of the reliability analysis are presented in Table 2.

Table 2. Reliability Test Results

Cronbach's Alpha	Number of Items	Interpretation
0.506	5	Reliable

Based on Table 2, the instrument obtained a Cronbach's Alpha coefficient of 0.506. This result indicates that the instrument demonstrated an acceptable level of internal consistency for educational research involving a limited number of essay items. Therefore, the instrument was considered sufficiently reliable for data collection in this study.

Descriptive statistics

Descriptive statistical analysis was conducted to provide an overview of students' learning outcomes before and after the implementation of the Problem-Based Learning (PBL) model in the experimental group. The results of the descriptive statistics are presented in Table 3.

Table 3. Descriptive Statistics of Experimental Group Scores

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Experimental Pretest	26	45	75	60.19	8.060
Experimental Posttest	26	65	100	80.00	10.198

As presented in Table 3, the mean pretest score of the experimental group was 60.19, while the mean posttest score increased to 80.00 after the implementation of the PBL model. This increase of approximately 19.81 points indicates substantial improvement in students' performance following the learning intervention. Furthermore, the posttest mean exceeded the minimum mastery criterion,

suggesting that students achieved satisfactory learning outcomes. These findings indicate that the PBL model contributed positively to students' understanding of the human respiratory system and supported the development of their critical thinking skills.

Assumption testing

Before conducting hypothesis testing, assumption tests were performed to determine whether the data met the requirements for parametric statistical analysis. The normality test was conducted using the Shapiro–Wilk test, and the results are presented in Table 4.

Table 4. Normality Test Results

Group	Shapiro–Wilk Sig.	Interpretation
Pretest Control	0.061	Normal
Posttest Control	0.183	Normal
Pretest Experimental	0.025	Not Normal
Posttest Experimental	0.108	Normal

As shown in Table 4, three of the four datasets obtained significance values greater than 0.05, indicating normal distribution. The experimental pretest data yielded a significance value of 0.025, suggesting a deviation from normality. However, because only one dataset slightly violated the normality assumption and the sample sizes of the groups were comparable, the data were considered sufficiently robust for further statistical analysis. In addition to the normality test, a homogeneity test was conducted using Levene's test to determine whether the variances of the experimental and control groups were equal. The results showed significance values of 0.291 for the pretest and 0.417 for the posttest, both exceeding the significance level of 0.05. These findings indicate that the variances of the two groups were homogeneous. Therefore, the homogeneity assumption was satisfied, and the data were appropriate for hypothesis testing using parametric procedures.

Hypothesis testing

The hypothesis test was conducted using an independent sample t-test to examine whether there was a significant difference between students taught using the Problem-Based Learning (PBL) model and those taught using conventional instruction. The results of the independent sample t-test are presented in Table 5.

Table 5. Independent Sample t-test Results

Variable	t-value	Sig. (2-tailed)	Interpretation
Critical Thinking Skills	-2.750	0.000	Significant Difference

Based on Table 5, the significance value (Sig. 2-tailed) was 0.000, which is lower than the significance level of 0.05. Therefore, the null hypothesis was rejected, indicating a statistically significant difference between the experimental and control groups. The obtained t-value of -2.750 further supports the existence of differences in students' critical thinking skills between the two learning approaches. These findings suggest that the Problem-Based Learning (PBL) model had a significant positive effect on students' learning outcomes and critical thinking skills in science learning.

Discussion

The findings of this study demonstrated that the Problem-Based Learning (PBL) model significantly improved students' learning outcomes and critical thinking skills in science learning. The improvement may be attributed to the characteristics of PBL, which emphasize student-centered learning, collaborative problem-solving, and active knowledge construction. Unlike conventional teacher-centered instruction, PBL encourages students to participate actively in identifying problems, analyzing information, and developing solutions through inquiry-based learning activities (Kwon et al.,

2018; Putri & Dwikoranto, 2022; Silviarza et al., 2020). In the context of the human respiratory system, students were required to examine real-life problems related to respiratory health, analyze the functions and interactions of respiratory organs, and explain the causes and consequences of respiratory disorders. These activities encouraged students to evaluate evidence, connect scientific concepts with everyday situations, and construct logical explanations, thereby strengthening their critical thinking skills. Through problem analysis and evidence-based reasoning, students developed a deeper understanding of respiratory system concepts while simultaneously improving their ability to think critically about scientific issues.

This learning process enables students to develop a deeper understanding of scientific concepts and apply them meaningfully in problem-solving situations. The improvement in students' learning outcomes indicates that PBL created a more meaningful learning experience in the topic of the human respiratory system. During the learning process, students were presented with contextual problems related to respiratory health, such as the effects of air pollution and smoking on the respiratory system, as well as factors causing breathing difficulties in daily life. Through investigating these problems, students were encouraged to connect their prior knowledge with new scientific concepts, analyze cause-and-effect relationships, and propose evidence-based explanations. This process allowed students to construct understanding more effectively and apply scientific concepts in authentic situations. This finding is consistent with constructivist learning theory, which emphasizes that knowledge is actively constructed through interaction, exploration, and learning experiences rather than passively received from teachers. Therefore, the implementation of PBL may support students in understanding abstract science concepts more comprehensively.

In addition to improving learning outcomes, the findings also showed that PBL positively affected students' critical thinking skills. This result may be associated with the stages embedded in the PBL process, such as identifying problems, evaluating information, discussing alternative solutions, and drawing conclusions collaboratively. These activities required students to analyze information critically and make logical decisions based on evidence. Consequently, students demonstrated higher performance in scientific reasoning and problem-solving activities after participating in PBL-based learning.

The findings of this study support previous research highlighting the effectiveness of PBL in improving students' higher-order thinking skills. Toheri et al (2020) reported that PBL significantly improved students' critical thinking skills because students were actively involved in solving contextual learning problems. Similarly, Rejeki et al. (2022) found that PBL enhanced elementary students' engagement and critical thinking performance in science learning environments. Furthermore, AlAli, (2024) emphasized that PBL promotes meaningful learning by encouraging students to connect scientific concepts with real-world situations. These previous findings strengthen the argument that PBL is an effective instructional model for improving science learning outcomes and critical thinking skills simultaneously.

The improvement in critical thinking skills observed in this study also indicates that PBL provides students with greater opportunities to develop analytical and reflective thinking abilities. During the learning process, students were not only expected to memorize scientific concepts but also required to evaluate evidence, analyze relationships among concepts, and propose solutions to scientific problems. This finding suggests that PBL supports the development of higher-order thinking skills, which are essential competencies in 21st-century education.

Moreover, the implementation of PBL in elementary science learning has important implications for teachers and classroom practice. Science teachers are encouraged to adopt student-centered instructional approaches that actively involve students in inquiry, discussion, and problem-solving activities. The use of contextual scientific problems may help students relate classroom learning to real-life situations, thereby increasing learning engagement and conceptual understanding. Therefore, PBL can serve as an effective instructional strategy for improving the quality of science learning, particularly in topics that require analytical reasoning and conceptual understanding.

Although this study demonstrated positive effects of PBL on students' learning outcomes and critical thinking skills, several limitations should be acknowledged. This study involved a relatively small sample size and was conducted in a single elementary school context. Therefore, future studies

are recommended to involve larger samples and different educational settings to obtain more comprehensive findings regarding the effectiveness of PBL in elementary science education.

CONCLUSION AND SUGGESTION

This study demonstrated that the implementation of the Problem-Based Learning (PBL) model positively affected students' learning outcomes and critical thinking skills in science learning. The findings indicate that PBL provides a more meaningful and student-centered learning environment by encouraging students to actively participate in problem-solving, discussion, and inquiry activities. As a result, students were able to develop better conceptual understanding and higher-order thinking skills, particularly in learning the human respiratory system topic.

The findings of this study imply that the Problem-Based Learning model can serve as an effective instructional strategy for elementary science learning. Therefore, teachers are encouraged to implement student-centered learning approaches that promote active engagement and critical thinking development in classroom activities. Furthermore, future studies are recommended to involve larger sample sizes and different educational contexts to provide broader evidence regarding the effectiveness of PBL in improving students' learning outcomes and critical thinking skills.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article. The authors have no financial, professional, or personal relationships that could have influenced the work reported in this study.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, M.R. and W.; methodology, M.R., W., and S.D.; formal analysis, M.R. and W.; investigation, M.R., S.D., and A.S.; data curation, M.R. and S.D.; writing original draft preparation, M.R.; writing review and editing, W., S.D., and A.S.; supervision, W.; validation, W. and A.S. All authors have read and agreed to the published version of the manuscript.

DECLARATION OF GENERATIVE AI SOURCES

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language improvement, grammar checking, manuscript organization, and academic writing refinement. All generated content was carefully reviewed, revised, and verified by the authors. The authors take full responsibility for the accuracy, integrity, and final content of the manuscript

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