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Effectiveness of the Problem-Based Learning Model in Enhancing Biology Learning Outcomes among Senior High School Students

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ABSTRACT

This study investigated the impact of the Problem-Based Learning (PBL) model on biology learning outcomes among Grade X students. The research was motivated by the low academic performance observed in biology, largely attributed to limited student engagement under conventional teacher-centered instruction. Employing a quasi-experimental design with a Nonequivalent Control Group Design, the study involved two purposively selected classes: X MIPA 1 (experimental, PBL) with 36 students and X MIPA 2 (control, conventional) with 31 students. Data were collected through a pretest and posttest consisting of 20 multiple-choice items and analyzed using SPSS 26.0 for normality, homogeneity, and independent sample t-tests. Results revealed significantly higher posttest scores in the PBL group compared to the control group. These findings confirm that the PBL model effectively improves student learning outcomes in biology, fostering active participation, problem-solving skills, and deeper conceptual understanding.

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1. INTRODUCTION

Learning is a purposeful process that involves the interaction between teachers and students to achieve specific educational objectives (Sewagegn, 2020; Kansanen, 2003; Munna & Kalam, 2021). It not only imparts knowledge but also fosters changes in attitudes, behaviors, and skills that persist over time (Rahman, 2021; Setiawati, 2019; Braßler and Sprenger, 2021). In the context of biology education, effective learning requires strategies that engage students actively, stimulate curiosity, and enhance understanding of complex concepts. However, in many classrooms, particularly those using conventional lecture-based instruction, students often remain passive, leading to reduced interest and suboptimal academic performance (Yohana & Lufri, 2022; Maryanti & Kurniawan, 2019; Kay *et al*., 2019; Osijirin *et al*., 2025).

One promising alternative is the Problem-Based Learning (PBL) model, which emphasizes student-centered learning through the exploration of authentic, real-world problems (Chen, 2024; Peranginangin, 2025; Andayani & Gunawan, 2025; Alam, 2023). PBL encourages active inquiry, critical thinking, collaboration, and self-directed learning, allowing students to construct their understanding while developing problem-solving skills (Marwah *et al*., 2021; Djonomiarjo, 2021; Al-Najar *et al*., 2019; Manuaba *et al*., 2022). Prior studies have shown that PBL not only improves academic performance but also strengthens motivation and engagement by making learning more meaningful and relevant to students' lives (Yasa & Bhoke, 2021; Gunawan *et al*., 2021; Wijnia *et al*., 2024). Given these advantages, this study seeks to investigate the effect of the PBL model on the biology learning outcomes of Grade X students. The novelty of this research lies in its application of PBL within a rural Indonesian high school setting, providing empirical evidence of its effectiveness in enhancing learning outcomes and offering pedagogical insights for biology education in similar contexts.

2. METHODS

This research was conducted at SMAN 06 Bengkulu Selatan, Indonesia, in February-March of the 2025/2026 academic year. This research is included in the quasi-experiment by taking two classes that have relatively the same academic abilities (equivalent). Furthermore, to determine the experimental class and the control class, purposive sampling was used. This study was used to determine the effect of interest and learning outcomes between the experimental class and the control class. The design of this study was a Nonequivalent Control Group Design (see **Tables 1 and 2**).

Table 1. Research design.

Class	Pretest	Treatment	Posttest
A (Experiment)	Y1	X	Y2
B (Control)	Y1	O	Y2

Information: A is the Experimental class; B is the Control class; Y1 is the Pretest; Y2 is the Posttest; X is the Treatment using PBL; O is the Conventional treatment.

The data collection technique used in this study was a multiple-choice test of 20 questions. The data processing process used the SPSS computer program (26.0). The tests used were the normality test, the homogeneity test, and the hypothesis test (t-test). Both research classes, both the experimental class and the control class, were given a pretest before the learning was carried out, which aimed to determine the initial abilities of students, then the delivery of material where in the delivery of material the experimental

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class used the PBL model, while the control class used a conventional learning model. Furthermore, at the end of the learning, both classes were given a posttest to measure learning outcomes, and a questionnaire was given to measure learning interest.

Table 2. Research population.

No	Class	Total Population
1	X MIPA I	36
2	X MIPA II	31
3	X MIPA III	33
4	X MIPA IV	35
	Amount	135 people

A sample is a portion of the number and characteristics possessed by the population. (Amin *et al.*, 2023). The sample in this study was taken from two classes taken by purposive sampling as many as two classes, namely the control class (conventional) X MIPA 2 and the experimental class (PBL) X MIPA 1.

3. RESULTS AND DISCUSSION

At SMAN 06 Bengkulu Selatan, classroom observations and interviews with teachers revealed that biology lessons predominantly follow a teacher-centered approach, where students primarily listen and take notes. This mode of instruction has resulted in decreased engagement, with students appearing bored or distracted during lessons. Semester 1 examination results for Grade X in the 2025/2026 academic year further highlight this issue, with average biology scores of 71 and 73, below the school's Minimum Completion Criteria (KKM). Such outcomes indicate that the current learning process is less effective and requires pedagogical innovation to enhance student participation and achievement.

Initial ability data were obtained from the test scores of the control class and experimental class before being given treatment (pretest). Student learning outcome data used 20 multiple-choice questions (see **Table 3**). The average initial ability of students in the control class using the conventional learning model is 44.83, with the highest score of 65 and the lowest score of 25, while for the experimental class using the PBL model, the average value is 51.45, with the highest score of 75 and the lowest score of 30. To find out whether the data is normal or not, a normality test is carried out using the Kolmogorov-Smirnov test on SPSS 26.0.

Table 3. Calculation of student learning outcome scores based on the initial test (pretest).

	Pretest	
Calculation	**Control**	**Experiment**
Total score	1390	1595
Highest score	65	75
Lowest score	25	30
Average	44,83	51,45
Number of students	31	36

Posttest data of students' learning outcomes with a sample of 67 students, consisting of 36 students in the experimental class and 31 students in the control class (**Table 4**). The results of the calculation of the two research classes between the experimental and control classes, then a posttest was given to determine the final results of student learning

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outcomes. Thus, the average value is obtained, namely, in the experimental class it is 80 while in the control class it is 68.70. Before conducting a hypothesis test using the t-test, a normality test and a variance homogeneity test must be carried out.

Table 4. Posttest calculation of student learning outcomes.

Calculation	Post-test Control	Post-test Experiment
Total score	2130	2480
Highest score	90	100
Lowest score	50	55
Average	68.70	80
Number of students	31	36

The results of the data analysis are presented in **Tables 5, 6, and 7**. The experimental class (X MIPA 1) achieved an average posttest score of 80.00, compared to 51.45 on the pretest, while the control class (X MIPA 2) recorded an average posttest score of 68.70 and a pretest score of 44.83. These results indicate that the experimental class outperformed the control class in biology learning outcomes. The normality test showed that the posttest data were normally distributed ($p = 0.182 > 0.05$), and the homogeneity test confirmed that the data were homogeneous ($p = 0.427 > 0.05$). Furthermore, the independent samples t-test revealed significant differences between the two classes in both the pretest ($p = 0.021 < 0.05$) and posttest ($p = 0.000 < 0.05$) scores. These findings indicate that the PBL learning model had a significant positive effect on the biology learning outcomes of Grade X students, leading to the rejection of Ho and acceptance of H1.

Table 5. Results of pretest and posttest normality tests.

Normality Test	One-Sample Kolmogorov-Smirnov Test Asymp. Sig. (2-tailed)
Pretest	0.058
Posttest	0.182

Table 6. Results of Pretest and Posttest Homogeneity Test

Test of Homogeneity of Variances				
	Levene Statistic	df1	df2	Sig.
Pretest	1.877	1	65	0.175
Posttest	0.640	1	65	0.427

Table 7. Results of hypothesis testing or t-test: pretest and posttest.

t-test	Independent Samples Test Sig. (2-tailed)
Pretest	0.021
Posttest	0.000

The findings of this study demonstrate that the PBL model significantly improves biology learning outcomes among Grade X students. The experimental class, which received PBL instruction, achieved a higher posttest mean score (80.00) compared to the control class taught using conventional methods (68.70), with the difference being statistically significant ($p < 0.05$). This improvement suggests that the PBL approach provides a more effective learning environment for fostering conceptual understanding and academic achievement in biology.

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A key factor underlying this improvement is PBL's emphasis on active student engagement in solving authentic problems. In contrast to traditional lecture-based instruction, where students often play a passive role, PBL positions students as active constructors of knowledge. This aligns with the constructivist learning paradigm, where learning is seen as an active process of meaning-making through interaction with peers, teachers, and learning materials (Marwah *et al*., 2021; Djonomiarjo, 2021). The collaborative nature of PBL also enables students to develop communication skills, share diverse perspectives, and build collective understanding skills that are less prominent in conventional instruction.

The results are consistent with previous studies that have reported positive effects of PBL on learning outcomes in science subjects. PBL enhanced mathematics achievement by encouraging critical thinking and problem-solving (Yasa & Bhoke, 2021), while some researchers noted similar benefits in science learning through increased student motivation and participation (Gunawan *et al*., 2021). The present study extends these findings to biology education in an Indonesian senior high school context, reinforcing the applicability of PBL beyond higher education or urban settings.

Another notable implication is the role of PBL in sustaining student interest and motivation. Observations during the intervention indicated that students in the experimental class were more engaged, asked more questions, and actively participated in group discussions. This aligns with previous studies (Astutik, 2022; Ulhaq, 2024), which emphasized that PBL fosters autonomy and responsibility for learning, leading to deeper and more lasting knowledge retention. By working on relevant and challenging problems, students are more likely to perceive the learning process as meaningful, which in turn enhances their intrinsic motivation.

Furthermore, the improvement in learning outcomes observed in this study may be linked to PBL's ability to address different cognitive styles among students. In the control group, where instruction was uniform and teacher-led, slower learners had limited opportunities for exploration, while in the PBL group, tasks could be approached collaboratively, allowing for peer support and differentiated learning paths. This flexibility can be particularly beneficial in heterogeneous classrooms, as it accommodates varying levels of prior knowledge and learning pace.

The findings have practical implications for biology teachers seeking to improve student performance. Implementing PBL requires careful planning, including selecting problems that are both challenging and relevant to students' experiences, as well as facilitating rather than directing the learning process. While this approach may initially demand more time and resources, the long-term benefits in terms of improved learning outcomes and skill development justify its adoption.

In the context of educational policy, the results support initiatives that encourage active, student-centered pedagogies as part of curriculum reform. The alignment of PBL with Sustainable Development Goal (SDG) 4: Quality Education is particularly noteworthy, as it promotes equitable and inclusive learning by engaging all students in meaningful learning experiences. However, the study is not without limitations. The sample was limited to two classes in one school, which may affect the generalizability of the results. Additionally, the duration of the intervention was relatively short, and further research could examine the long-term effects of PBL on knowledge retention, as well as its integration with digital learning tools.

Overall, the present study confirms that the PBL model is an effective pedagogical strategy for enhancing biology learning outcomes in senior high school students. By

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fostering active engagement, collaboration, and problem-solving skills, PBL not only improves academic achievement but also prepares students with competencies relevant to lifelong learning and the demands of the 21st century.

4. CONCLUSION

This study provides empirical evidence that the PBL model significantly enhances biology learning outcomes among senior high school students. The experimental group taught with PBL achieved higher posttest scores compared to the control group taught with conventional methods, indicating that PBL fosters deeper understanding, active engagement, and improved problem-solving skills. The student-centered, collaborative nature of PBL not only supports conceptual mastery but also stimulates motivation and participation in the learning process. These findings suggest that integrating PBL into biology instruction can be an effective strategy for addressing low student achievement and engagement. Future research should explore the long-term effects of PBL, its application across different subject areas, and its integration with technology to further enrich the learning experience.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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