BIO-INOVED
Jurnal Biologi-Inovasi Pendidikan
Volume 8, Issue 2, June 2026 page. 252-260

P-ISSN : 2684-9062 | E-ISSN : 2714-9803
https://ppjp.ulm.ac.id/journal/index.php/bino
DOI: 10.20527/bino.v8i2.26176

Effects of problem-based learning model on high school students' problem-solving skills, critical thinking skills, and learning outcomes

Diffia Ilham *, Firdaus Daud, Alimuddin Ali, Mushawwir Taiyeb, Ismail

Department of Biology Education, Faculty of Teacher Training and Education, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia

** Corresponding Author Email: difiailham2021@gmail.com*

Article Information

Keyword:
Problem based learning; Critical thinking skills; Problem solving skills; Learning outcomes; Biology learning

Kata Kunci:
Pembelajaran berbasis masalah; Kemampuan berpikir kritis; Kemampuan pemecahan masalah; Hasil belajar; Pembelajaran biologi

History:
Received : 10/05/2026
Revised : 10/06/2026
Accepted : 18/06/2026
Published : 25/06/2026

Abstract

The low levels of students' critical thinking skills, problem-solving skills, and learning outcomes remain a challenge in Biology learning because the learning process tends to be teacher-centered. This study aimed to examine the effect of the Problem Based Learning (PBL) model on students' problem-solving skills, critical thinking skills, and learning outcomes on environmental change material at MAN 1 Luwu Timur. The study employed a quasi-experimental design with a nonequivalent control group design involving an experimental class taught using PBL and a control class taught using direct instruction. Data were collected through pretest and posttest instruments and analyzed using descriptive statistics and ANCOVA. The results showed that the experimental class experienced greater improvement compared to the control class. Learning outcomes increased from 41.00 to 77.32, critical thinking skills improved from low to critical categories, and problem-solving skills improved from low to good categories. Inferential analysis indicated that PBL had a significant effect on problem-solving skills, critical thinking skills, and student learning outcomes ($p < 0.05$). These findings indicate that PBL is effective in creating active and student-centered learning to support 21st-century skills. The findings of this study contribute to the advancement of biology education research by providing empirical evidence of the effectiveness of PBL in improving multiple learning outcomes.

Abstrak. *Rendahnya kemampuan berpikir kritis, kemampuan pemecahan masalah, dan hasil belajar siswa masih menjadi permasalahan dalam pembelajaran Biologi karena pembelajaran cenderung berpusat pada guru. Penelitian ini bertujuan mengkaji pengaruh model Problem Based Learning (PBL) terhadap kemampuan pemecahan masalah, kemampuan berpikir kritis, dan hasil belajar siswa pada materi perubahan lingkungan di MAN 1 Luwu Timur. Penelitian menggunakan desain kuasi eksperimen dengan nonequivalent control group design yang melibatkan kelas eksperimen menggunakan PBL dan kelas kontrol menggunakan pembelajaran langsung. Data diperoleh melalui pretest dan posttest, kemudian dianalisis menggunakan statistik deskriptif dan ANCOVA. Hasil penelitian menunjukkan bahwa kelas eksperimen mengalami peningkatan lebih tinggi dibandingkan kelas kontrol. Hasil belajar meningkat dari 41,00 menjadi 77,32, kemampuan berpikir kritis meningkat dari kategori rendah menjadi kritis, dan kemampuan pemecahan masalah meningkat dari kategori rendah menjadi baik. Analisis inferensial menunjukkan bahwa PBL berpengaruh signifikan terhadap kemampuan pemecahan masalah, kemampuan berpikir kritis, dan hasil belajar siswa ($p < 0,05$). Temuan ini menunjukkan bahwa PBL efektif menciptakan pembelajaran aktif dan berpusat pada siswa untuk mendukung keterampilan abad ke-21. Hasil penelitian ini berkontribusi pada penguatan kajian pendidikan biologi dengan menyediakan bukti empiris mengenai efektivitas PBL dalam mengembangkan berbagai capaian belajar.*

A. Introduction

Education has a strategic role in improving the quality of human resources and shaping individuals who are capable of facing the global challenges of the 21st century. The development of science, technology, and globalization demands that students not only master knowledge but also possess higher-order thinking skills such as critical thinking, creativity, communication, and collaboration (Gurnatha et al., 2024). These skills serve as an important foundation for dealing with various complex problems in real life. Therefore, the learning process in schools needs to be designed innovatively in order to develop these competencies optimally (Azizah et al., 2024).

Learning conditions in the field indicate that the learning process still tends to be teacher-centered, so students are given limited opportunities to actively construct their own knowledge (Hidayat et al., 2020). Learning activities dominated by lectures cause students to focus more on memorization rather than developing a deep understanding of concepts (Wirabumi, 2020). The impact of this condition can be seen in students' low critical thinking and problem-solving skills, as well as learning outcomes that have not yet reached an optimal level.

Critical thinking skills are one of the essential competencies in modern learning because they enable students to analyze information, evaluate arguments, and make decisions logically and systematically. Problem-solving ability is also an important skill that is directly related to students' ability to face real-life situations (Aryani et al., 2025). These two abilities are interconnected and contribute to the improvement of students' learning outcomes. According to Putri (2021), critical thinking involves the abilities of interpretation, analysis, evaluation, and drawing conclusions that are used in rational decision-making. In addition, research conducted by Jannah et al. (2024) showed that students with strong problem-solving and critical thinking skills tend to achieve higher learning outcomes compared to students with lower-order thinking abilities.

The PBL model is one of the approaches that can be used to address these problems. This model places problems as the starting point of learning and encourages students to actively seek solutions through processes of investigation, discussion, and reflection (Darwati & Purana, 2021). PBL provides opportunities for students to learn independently as well as collaboratively in groups, thereby increasing student engagement in learning and enabling higher-order thinking skills to develop optimally (Adeliana et al., 2021; Handayani et al., 2021).

Biology learning on the topic of environmental change requires an approach that is capable of training students to think critically and solve problems through contextual learning experiences. Environmental change material is closely related to real phenomena around students, therefore learning needs to be problem-based so that students can connect concepts with everyday life. According to John Dewey, learning that begins with real-world problems can help students build more meaningful understanding through investigation processes and direct experiences. Research conducted by Zakiyah et al. (2023) showed that the implementation of PBL was able to significantly improve students' critical thinking skills. In addition, research by Arni et al. (2026) found that the use of the PBL model could improve students' collaboration skills through discussion activities and group problem-solving. Another study by Nurhayati (2024) also explained that the implementation of PBL made students more active in analyzing environmental phenomena and significantly improved their scientific thinking skills.

Several recent studies have shown that the PBL model is effective in improving students' critical thinking skills, learning outcomes, and problem-solving abilities in Biology learning. Research conducted by Fazrin et al. (2025) showed that PBL was able to improve students' critical thinking skills through collaborative discussion and problem-solving activities. Another study by Hardiyanti (2022) also found that the implementation of PBL significantly improved students' learning outcomes compared to conventional learning methods. In addition, research by Putri et al. (2025) explained that PBL helps students understand Biology concepts more deeply because students are directly involved in the process of investigating contextual problems. However, most previous studies have only focused on a single variable, such as learning outcomes or critical thinking skills alone. Research examining the simultaneous effect of PBL on problem-solving skills, critical thinking skills, and students' learning outcomes on environmental change material is still limited, particularly at MAN 1 Luwu Timur. Therefore, this study offers novelty by investigating the effect of the PBL model on these three aspects simultaneously within the context of Biology learning in secondary schools.

Similar problems were identified based on the results of preliminary observations conducted at MAN 1 Luwu Timur. The observations showed that students still experience difficulties in solving questions that require analytical and reasoning skills. Students also tend to be passive during the learning process and are not accustomed to dealing with contextual problems. This condition is presumed to be caused by learning activities that are still dominated by the lecture method, resulting in low student engagement in the learning process. According to Saujani et al. (2025), learning that is overly teacher-centered can cause students' critical thinking and problem-solving skills to develop less optimally. This opinion is supported by the study conducted by Aini et al. (2022), which stated that conventional learning makes students less active in identifying and solving problems independently.

The implementation of the PBL model is expected to be a solution for improving the quality of learning. This model has the potential to increase student engagement and develop critical thinking and problem-solving skills more effectively. This study aims to determine the effect of implementing the PBL model on problem-solving skills, critical thinking skills, and learning outcomes of tenth-grade students at MAN 1 Luwu Timur. The results of this study are expected to provide both theoretical and practical contributions to the development of more innovative and student-centered learning.

B. Material and method

This study employed a quantitative approach using a quasi-experimental research design with a Nonequivalent Control Group Design. The population consisted of all tenth-grade students of MAN 1 Luwu Timur in the 2025/2026 academic year. The sample comprised 50 students selected through random sampling, consisting of one experimental class and one control class.

The research procedure was conducted in three stages: preparation, implementation, and evaluation. During the preparation stage, the researcher developed learning materials, research instruments, and conducted instrument validation. The implementation stage began with the administration of a pretest to both the experimental and control classes to determine students' initial abilities. Subsequently, the experimental class received instruction using the PBL model, while the control class was taught using the direct instruction model. After the treatment was completed, both classes were given a posttest to measure students' problem-solving skills, critical thinking skills, and learning outcomes.

Data were collected through observation, interviews, tests, and documentation. The test instruments were administered in the form of pretests and posttests to assess students' problem-solving skills, critical thinking skills, and learning outcomes. The collected data were analyzed using descriptive and inferential statistics. Inferential analysis was conducted using Analysis of Covariance (ANCOVA) at a significance level of 0.05 after the prerequisite tests, including normality and homogeneity tests, had been satisfied. Figure 1 presents the research procedure.

In the descriptive analysis, students' scores were first converted into percentage scores using the formula: (obtained score/maximum score) × 100. The percentage scores were then classified into achievement categories to facilitate data interpretation. Learning outcomes were categorized as very low (0–54), low (55–64), moderate (65–79), high (80–89), and very high (90–100) (Riduwan, 2010). Critical thinking skills were categorized as not critical (0–54), less critical (55–64), moderately critical (65–79), critical (80–89), and very critical (90–100) (Sugiyono, 2013). Likewise, problem-solving skills were categorized as very poor (0–54), poor (55–64), fair (65–79), good (80–89), and very good (90–100) (Nurkancana, 2009). These categories were established based on the score interpretation criteria adopted from the Indonesian Ministry of Education and Culture (Kemendikbud, 2017) and were used to describe students' levels of achievement for each research variable.

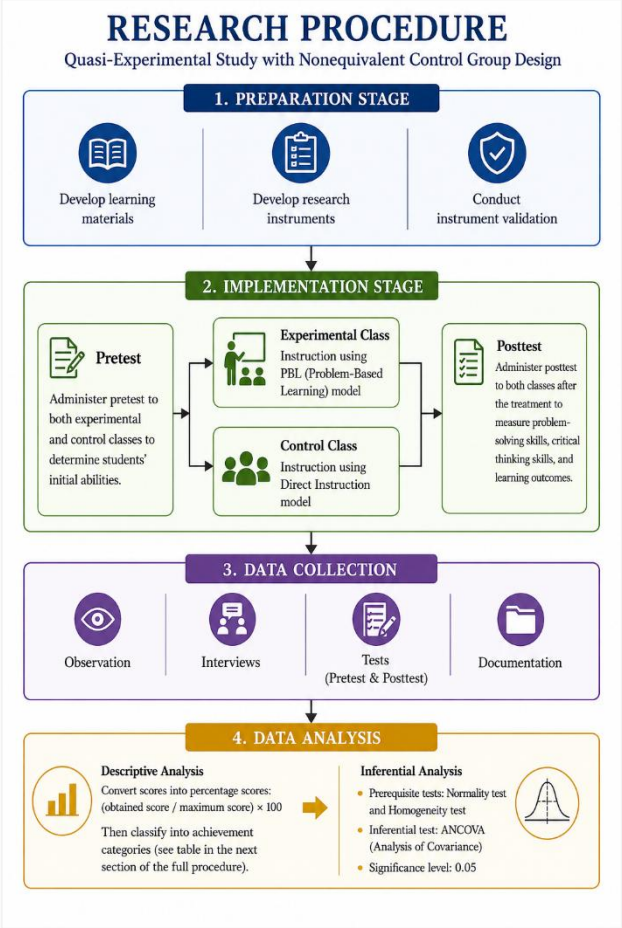

Figure 1 The research procedure

C. Results and discussion

Based on the results of the descriptive statistical analysis of problem-solving skills, critical thinking skills, and learning outcomes among tenth-grade students at MAN 1 Luwu Timur, an improvement in students' abilities was observed after the learning process. The learning outcomes of students in the experimental class taught using the PBL model showed a greater improvement than those of students in the control class taught using the direct instruction model. This finding indicates that the implementation of PBL provides more meaningful learning experiences and encourages students' active engagement in the learning process.

The average learning outcome score in the experimental class increased from 41.00 in the pretest to 77.32 in the posttest, while the control class

improved from 38.08 to 71.52 (see Table 1). This improvement suggests that students who learned through the PBL model achieved a better understanding of concepts than those who learned through direct instruction. Theoretically, learning outcomes are influenced not only by the ability to recall information but also by students' active involvement in constructing knowledge through meaningful learning experiences. In PBL, students are encouraged to identify problems, seek information, analyze alternative solutions, and communicate their findings. These activities enable students to develop a deeper conceptual understanding, which ultimately contributes to improved learning outcomes.

Table 1 Descriptive statistics of learning outcomes in the experimental and control classes

Statistic	Control class		Experiment class	
	Statistical values		Statistical values	
	Pretest	Posttest	Pretest	Posttest
Sample size	25	25	25	25
Maximum score	60.00	93.00	67.00	93.00
Minimum score	20.00	53.00	20.00	53.00
Mean score	38.08	71.52	41.00	77.32
Variance	5.50	3.75	7.61	3.98
Score range	40.00	40.00	47.00	40.00

Table 2 Frequency distribution of students' learning outcomes in biology for before and after the implementation of the PBL model

Statistic	Category	Pretest		Posttest	
		Frequency	Percentage (%)	Frequency	Percentage (%)
0-54	Very low	23	92.0	1	4.0
55-64	Low	2	8.0	11	44.0
65-79	Moderate	0	0	0	0
80-89	High	0	0	10	40.0
90-100	Very high	0	0	3	12.0
	Total	**25**	**100**	**25**	**100**

Table 3 Frequency distribution of students' learning outcomes in biology before and after the implementation of the direct instruction model

Statistic	Category	Pretest		Posttest	
		Frequency	Percentage (%)	Frequency	Percentage (%)
0-54	Very low	24	96.0	2	8.0
55-64	Low	1	4.0	2	8.0
65-79	Moderate	0	0	13	52.0
80-89	High	0	0	7	28.0
90-100	Very high	0	0	1	4.0
	Total	**25**	**100**	**35**	**100**

Table 4 Descriptive statistics of students' critical thinking skills before and after the implementation of the PbL model

Statistic	Control class		Experimental class	
	Statistical values		Statistical values	
	Pretest	Posttest	Pretest	Posttest
Sample size	25	25	25	25
Maximum score	53.00	83.00	60.00	93.00
Minimum score	20.00	30.00	20.00	60.00
Mean score	39.00	59.48	40.56	78.00
Variance	104.667	168.593	139.423	67.667
Score range	33.00	53.00	40.00	33.00

Table 5 Frequency distribution of students' critical thinking skills in biology before and after the implementation of the PBL model

Statistic	Category	Pretest		Posttest	
		Frequency	Percentage (%)	Frequency	Percentage (%)
0-54	Not critical	13	52.0	0	0
55-64	Less critical	9	36.0	0	0
65-79	Moderately critical	3	12.0	1	4.0
80-89	Critical	0	0	17	68.0
90-100	Very critical	0	0	7	28.0
	Total	**25**	**100**	**25**	**100**

Table 6 Frequency distribution of students' critical thinking skills in biology before and after the implementation of the direct instruction model

Statistic	Category	Pretest		Posttest	
		Frequency	Percentage (%)	Frequency	Percentage (%)
0-54	Not critical	15	60.0	3	12.0
55-64	Less critical	10	40.0	4	16.0
65-79	Moderately critical	0	0	9	36.0
80-89	Critical	0	0	8	32.0
90-100	Very critical	0	0	1	4.0
	Total	**25**	**100**	**25**	**100**

Table 7 Descriptive statistics of students' problem-solving skills before and after the implementation of the PBL model

Statistic	Control class		Experimental class	
	Statistical values		Statistical values	
	Pretest	Posttest	Pretest	Posttest
Sample size	25	25	25	25
Maximum score	57.00	77.00	57.00	90.00
Minimum score	20.00	33.00	20.00	47.00
Mean score	37.08	56.20	37.44	72.88
Variance	132.577	176.750	128.423	123.443
Score range	37.00	44.00	37.00	43.00

Table 8 Frequency distribution of students' problem-solving skills in biology before and after the implementation of the PBL model

Statistic	Category	Pretest		Posttest	
		Frequency	Percentage (%)	Frequency	Percentage (%)
0-54	Very poor	4	16.0	0	0
55-64	Poor	11	44.0	0	8.0
65-79	Fair	10	40.0	4	52.0
80-89	Good	0	0	15	40.0
90-100	Very good	0	0	6	0
	Total	**25**	**100**	**25**	**100**

Table 9 Frequency distribution of students' problem-solving skills before and after the implementation of the direct instruction model

Statistic	Category	Pretest		Posttest	
		Frequency	Percentage (%)	Frequency	Percentage (%)
0-54	Very poor	4	16.0	0	0
55-64	Poor	12	48.0	2	8.0
65-79	Fair	9	36.0	13	52.0
80-89	Good	0	0	10	40.0
90-100	Very good	0	0	0	0
	Total	**25**	**100**	**25**	**100**

Based on Table 2, the frequency distribution of learning outcomes in the experimental class also confirms this improvement. Before the implementation of the PBL model, most students (92.0%) were classified in the very low category. After the learning process, no students remained in the very low category, whereas 40.0% reached the high category and 12.0% achieved the very high category. This shift indicates that the implementation of PBL successfully moved students toward higher achievement categories.

Based on Table 3, students in the control class also showed an increase in learning outcomes after learning through the direct instruction model. Initially, 96.0% of students were categorized as very low. Following instruction, most students (52.0%) reached the moderate category, while only 28.0% and 4.0% achieved the high and very high categories, respectively. Although improvement occurred, the distribution of scores remained lower than that of the experimental class, indicating that PBL produced a greater improvement in students' Biology learning outcomes.

Students' problem-solving skills also improved following the implementation of the PBL model. This improvement occurred because PBL places problems at the center of the learning process, allowing students to practice understanding problems, formulating solution strategies, implementing plans, and evaluating outcomes in accordance with Polya's problem-solving stages. Through this process, students not only acquire knowledge but also develop systematic thinking skills in addressing various issues related to the learning material. The enhancement of problem-solving skills indicates that students became increasingly capable of connecting learned concepts with real-life situations they encounter.

Based on Table 8, the improvement in problem-solving skills is reflected in the shift of students' achievement categories. Before the implementation of PBL, most students were classified in the poor (44.0%) and fair (40.0%) categories. After the learning process, 52.0% of students were classified as fair, 40.0% reached the good category, and several students attained the very good category. These findings demonstrate that PBL effectively trained students to solve contextual problems through systematic investigation and collaborative learning activities.

Based on Table 9, students in the control class also experienced improvements in problem-solving skills after learning through the direct instruction model. Most students shifted from the poor category (48.0%) to the fair category (52.0%), while 40.0% reached the good category. However, no students achieved the very good category. Compared with the experimental class, this result indicates that the improvement obtained through direct instruction was relatively lower than that achieved through PBL.

Furthermore, students' critical thinking skills showed greater development in the class that implemented PBL. Problem-based instruction provides opportunities for students to analyze information, evaluate arguments, identify relevant evidence, and draw logical conclusions. These activities are consistent with the indicators of critical thinking, which emphasize analysis, evaluation, and reasoning. Through group discussions and investigations of the problems presented, students became more active in expressing their opinions and defending their arguments based on available evidence. As a result, critical thinking skills developed more effectively than in teacher-centered learning environments.

Based on Table 5, the distribution of students' critical thinking skills in the experimental class changed substantially after the implementation of PBL. Before treatment, most students were classified as not critical (52.0%) and less critical (36.0%). After the learning process, 68.0% of students reached the critical category, while 28.0% achieved the very critical category. This finding indicates that the PBL model successfully facilitated students in developing higher-order thinking skills through collaborative discussion, investigation, and evidence-based reasoning.

Based on Table 6, students in the control class also demonstrated improvement in critical thinking skills after learning through direct instruction. Initially, students were dominated by the not critical (60.0%) and less critical (40.0%) categories. Following instruction, most students reached the moderately critical (36.0%) and critical (32.0%) categories, while only 4.0% attained the very critical category. These findings suggest that although direct instruction contributed to improving critical thinking skills, the improvement was still lower than that achieved through the implementation of PBL**.**

The findings of this study support constructivist theory, which asserts that knowledge is actively constructed by learners through interaction with their environment and learning experiences. The PBL model provides opportunities for students to construct knowledge through investigation and problem-solving activities, making the learning process more meaningful. When students are actively involved in finding solutions to problems, they not only gain a deeper understanding of the subject matter but also develop higher-order thinking skills that are essential for 21st-century learning. The results of this study are also consistent with previous research demonstrating that PBL has a positive effect on students' problem-solving skills, critical thinking skills, and learning outcomes. This model creates a learning environment that promotes collaboration, communication, and inquiry, enabling students to take a more active role in constructing their own knowledge. Therefore, the implementation of PBL can be considered an effective alternative instructional model for improving

students' problem-solving skills, critical thinking skills, and biology learning outcomes in schools.

Inferential analysis

Inferential analysis was conducted to determine the effect of the implementation of the PBL model on students' learning outcomes, critical thinking skills, and problem-solving abilities in Biology. Prior to hypothesis testing, assumption tests were carried out, including tests of normality, homogeneity, and homogeneity of regression. The results of the assumption tests showed that all data were normally distributed and homogeneous, thus meeting the requirements for analysis using ANCOVA.

Based on the results of the ANCOVA analysis in Table 10, a significance value of 0.000 < 0.05 was obtained. This indicates that the implementation of the PBL model has a positive and significant effect on students' learning outcomes, critical thinking skills, and problem-solving abilities in Biology learning at MAN 1 Luwu Timur. These findings show that students taught using the PBL model achieved better results compared to those taught using direct instruction.

Thus, learning activities centered on contextual problem-solving have been proven to be more effective in improving students' conceptual understanding and higher-order thinking skills. The inferential analysis results also show that the experimental class achieved higher average posttest scores across all variables compared to the control class. For the learning outcomes variable, the experimental class obtained an average score of 77.32, while the control class scored 71.52 (see Table 1). In terms of critical thinking skills, the experimental class reached an average of 78.00, whereas the control class only achieved 59.48 (see Table 4). Similarly, for problem-solving skills, the experimental class obtained an average of 72.88, while the control class scored 56.20 (see Table 7). These differences indicate that the PBL model contributes more significantly to the development of students' cognitive and analytical abilities compared to conventional learning approaches.

The significant improvement in the experimental class can be explained by the characteristics of the PBL model, which encourages students to actively identify problems, discuss possible solutions, conduct investigations, and collaboratively evaluate outcomes. These learning activities train students to think critically and systematically in solving contextual Biology problems. Through active engagement in the learning process, students become more capable of connecting concepts with real-life situations, thereby improving conceptual understanding and long-term retention.

This study's findings are consistent with previous research showing that PBL is effective in improving students' learning outcomes and higher-order thinking skills. A study conducted by Puji and Ahmad (2024) found that students taught using PBL had higher critical thinking skills compared to those taught through conventional instruction. Research by Istikomah et al. (2025) also reported that PBL has a positive effect on Biology learning outcomes because students are actively involved in collaborative problem-solving processes. In addition, Lestari (2025) demonstrated that PBL significantly improves students' problem-solving abilities through investigative and discussion-based activities. Compared to previous studies, this research provides a more comprehensive analysis by simultaneously examining the effect of PBL on learning outcomes, critical thinking skills, and problem-solving abilities in Biology learning.

From a theoretical perspective, the findings of this study support constructivist theory, which emphasizes that students actively construct knowledge through interaction with problems and their learning environment (Matriano, 2020; Zajda, 2021; Machmud et al., 2023). The PBL facilitates meaningful learning experiences because students are directly involved in constructing concepts, evaluating information, and developing solutions independently as well as collaboratively (Hung, 2019; Ghani et al., 2021). This learning process not only enhances cognitive achievement but also develops analytical and reflective thinking skills required for 21st-century learning.

Overall, the results of this study indicate that the implementation of PBL successfully addresses the problems identified in the introduction, namely the low levels of students' learning outcomes, critical thinking skills, and problem-solving abilities caused by teacher-centered instruction. Therefore, PBL can be considered an effective and innovative alternative learning model to improve the quality of Biology instruction, particularly in developing students' higher-order thinking skills.

D. Conclusion

Based on the results of the study, it can be concluded that the implementation of the PBL model has a positive effect on students' problem-solving abilities, critical thinking skills, and learning outcomes in Grade X Biology at MAN 1 Luwu Timur. This is indicated by the higher increase in posttest mean scores in the experimental class compared to the control class, which used direct instruction. The implementation of PBL also enhances students' engagement in the learning process through active problem-solving activities, group discussions, and investigations of contextual problems. Therefore, the PBL model can be considered an effective alternative learning model for improving the quality of Biology instruction, particularly in developing students' higher-order thinking skills.

E. Acknowledgement

The author would like to express sincere gratitude to the administration of MAN 1 Luwu Timur for granting permission and providing support during the implementation of this research. Appreciation is also extended to the supervising lecturers for their guidance, feedback, and assistance throughout the preparation of this study, as well as to all Grade
X students of MAN 1 Luwu Timur who participated in the research process. It is hoped that this study will contribute to the development of Biology learning in schools. feedback, and assistance throughout the preparation of this study, as well as to all Grade
X students of MAN 1 Luwu Timur who participated in the research process. It is hoped that this study will contribute to the development of Biology learning in schools.

F. References

Adeliana, F., Sintawati, M., & Anggara, R. (2021). Problem-based learning: Alternative learning model to improve students' critical thinking ability. *Al-Adzka: Jurnal Ilmiah Pendidikan Guru Madrasah Ibtidaiyah, 11*(2), 93–102. DOI: https://doi.org/10.18952/aladzkapgmi.v11i2.5012

Aini, N., Molle, J. S., & Palinussa, A. L. (2022). Perbandingan hasil belajar peserta didik yang menggunakan model pembelajaran reciprocal teaching dan konvensional pada materi barisan dan deret. *Jurnal Pendidikan Matematika Unpatti, 3*(3), 71–79. DOI: https://doi.org/10.30598/jpmunpatti.v3.i3.p71-79

Aryani, I., & Hadi, M. S. (2025). Implementasi gerakan literasi di sekolah dasar: Implikasinya pada kemampuan berpikir kritis siswa sekolah dasar. *Jurnal Ilmiah Pendidikan Citra Bakti, 12*(2), 329–338. DOI: https://doi.org/10.38048/jipcb.v12i2.5116

Azizah, N. N., & Hidayat, R. (2024). Pengembangan asesmen digital berbasis game edukatif Quizizz pada mata pelajaran marketing. *Journal of Innovation and Teacher Professionalism, 2*(2), 195–209. DOI: https://doi.org/10.17977/um084v2i2 2024p195-209

Darwati, I. M., & Purana, I. M. (2021). Problem based learning (PBL): Suatu model pembelajaran untuk mengembangkan cara berpikir kritis peserta didik. *WIDYA ACCARYA: Jurnal Kajian Pendidikan FKIP Universitas Dwijendra, 12*(1), 61–69. DOI: https://doi.org/10.46650/wa.12.1.1056.61-69

Fazrin, I. S., Azizah, A. R., Aliyyah, J., Aini, I. N., & Suherman, U. (2025). Problem-based learning sebagai strategi penguatan berpikir kritis dalam pembelajaran pendidikan agama Islam. *Tsaqafatuna: Jurnal Ilmu Pendidikan Islam, 7*(1), 77-89. DOI: https://doi.org/10.54213/tsaqafatuna.v7i1.604

Ghani, A. S. A., Rahim, A. F. A., Yusoff, M. S. B., & Hadie, S. N. H. (2021). Effective learning behavior in problem-based learning: a scoping review. *Medical science educator*, *31*(3), 1199-1211. DOI: https://doi.org/10.1007/s40670-021-01292-0

Gurnatha, I. W., Widiasri, D. A., & Ekasriadi, I. A. A. (2024). Asesmen dan pembelajaran bahasa Indonesia berbasis HOTS: Upaya peningkatan kemampuan berpikir kritis siswa di era digital abad ke-21. *Prosiding Sandibasa Seminar Nasional Pendidikan Bahasa dan Sastra Indonesia, 2*(1), 109–125. Retrieved from https://ojs.mahadewa.ac.id/index.php/sandibasa/article/view/3711

Handayani, M., Puryatmi, H., & Hanafi, H. (2021). Peningkatan keterampilan berpikir kritis melalui model problem-based learning dalam pembelajaran IPA di sekolah dasar. *Edukatif: Jurnal Ilmu Pendidikan, 4*(1), 548–555. DOI: https://doi.org/10.31004/edukatif.v4i1.1829

Hardiyanti, D. (2022). Penerapan model pembelajaran problem-based learning (PBL) untuk meningkatkan pemahaman konsep dan hasil belajar siswa sekolah dasar pada pembelajaran IPA. *Jurnal Pendidikan dan Konseling, 4*(4), 3135–3143. DOI: https://doi.org/10.31004/jpdk.v4i4.5998

Hidayat, A., Maemunah, S., & Lisnawati, S. (2020). Metode pembelajaran aktif dan kreatif pada Madrasah Diniyah Takmiliyah di Kota Bogor. *Edukasi Islami: Jurnal Pendidikan Islam, 9*(1), 71–86. DOI: https://doi.org/10.30868/ei.v9i01.639

Hung, W. (2019). Problem design in PBL. *The Wiley Handbook of problem-based learning*, 249-272. DOI: https://doi.org/10.1002/9781119173243.ch11

Istikomah, Alibasyah, L. M. P., Buntu, A., Agni, R., Rauf, A., & Jamhari, M. (2025). Penerapan model pembelajaran problem-based learning (PBL) dalam meningkatkan hasil belajar siswa pada mata pelajaran biologi kelas X di SMK Manbaul Hikmah. *Bioscientist: Jurnal Ilmiah Biologi, 13*(4), 2868–2876. DOI: https://doi.org/10.33394/bioscientist.v13i4.18916

Jannah, R., Soraya, R. A., Suriansyah, A., & Cinantya, C. (2024). Kemampuan berpikir kritis dalam pembelajaran matematika terhadap hasil belajar di sekolah dasar. *MARAS: Jurnal Penelitian Multidisiplin, 2*(4), 1991–1998. DOI: https://doi.org/10.60126/maras.v2i4.550

Lestari, M. (2025). *Perbedaan kemampuan pemecahan masalah fisika antara model problem-based learning dan inkuiri* (Skripsi, Universitas Lampung).

Machmud, M. T., Wattanachai, S., & Samat, C. (2023). Constructivist gamification environment model designing framework to improve ill-structured problem solving in learning sciences. *Educational technology research and development*, *71*(6), 2413-2429. DOI: https://doi.org/10.1007/s11423-023-10279-0

Matriano, E. A. (2020). Ensuring Student-Centered, Constructivist and Project-Based Experiential

Learning Applying the Exploration, Research, Interaction and Creation (ERIC) Learning Model. *International Online Journal of Education and Teaching*, *7*(1), 214-227. Retrieved from https://iojet.org/index.php/IOJET/article/view/727

Nurhayati, N. (2024). *Pengaruh model pembelajaran contextual teaching and learning (CTL) terhadap kemampuan pemahaman konsep matematis siswa ditinjau dari disposisi matematis siswa SMP* (Skripsi, Universitas Islam Negeri Sultan Syarif Kasim Riau).

Nurkancana. (2009). *Evaluasi hasil belajar.* Surabaya: Usaha Nasional.

Puji, C. V., & Ahmad, F. (2024). Efektivitas problem-based learning terhadap keterampilan berpikir kritis, hasil belajar, dan motivasi siswa. *Venn: Journal of Sustainable Innovation on Education, Mathematics and Natural Sciences, 3*(2), 76–82. DOI: https://doi.org/10.53696/venn.v3i2.155

Putri, A., Ayu, D. P., & Palennari, M. (2025). Konseptualisasi pengembangan model pembelajaran Deep-PBL untuk meningkatkan pengetahuan dan sikap peduli lingkungan peserta didik pada pembelajaran biologi. *Pendas: Jurnal Ilmiah Pendidikan Dasar, 10*(4), 248–260. DOI: https://doi.org/10.23969/jp.v10i04.37159

Putri, L. N., Ragil, I., Atmojo, W., Ardiansyah, R., & Saputri, I. (2021). Analisis instrumen asesmen IPA berdasarkan teori berpikir kritis Facione. *Jurnal Pendidikan Dasar, 9*(2), 44–49. DOI: https://doi.org/10.20961/jpd.v9i2.59886

Riduwan. (2010). *Dasar-dasar statistika.* Bandung: Alfabeta.

Saujani, M. A. N., Salsabila, D. A., Violita, D. N., Ramadhan, B., & Nurdin. (2025). Pengaruh model pembelajaran berbasis masalah pada keterampilan berpikir kritis. *Morfologi: Jurnal Ilmu Pendidikan, Bahasa, Sastra dan Budaya, 3*(1), 183–189. DOI: https://doi.org/10.61132/morfologi.v3i1.1343

Sugiyono. (2013). *Metode penelitian kuantitatif, kualitatif dan R&D.* Bandung: Alfabeta.

Wirabumi, R. (2020). Metode pembelajaran ceramah. *Annual Conference on Islamic Education and Thought (ACIET), 1*(1), 105–113. Retrieved from https://pkm.uika-bogor.ac.id/index.php/aciet/article/view/660

Zajda, J. (2021). Constructivist learning theory and creating effective learning environments. In *Globalisation and education reforms: Creating effective learning environments* (pp. 35-50). Cham: Springer International Publishing. DOI: https://doi.org/10.1007/978-3-030-71575-5_3

Zakiyah, R. E., Suryana, D., & Zulkarnaen, R. H. (2023). Meningkatkan keterampilan berpikir kritis siswa menggunakan model pembelajaran problem-based learning (PBL). *Jurnal Basicedu, 7*(3), 1852–1861. DOI:https://doi.org/10.31004/basicedu.v7i3.5693