Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

The Effectiveness of Implementing Problem-Based Learning Models in Improving Biology Literacy and Scientific Attitudes

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Received: August 22, 2025. Accepted: September 15, 2025. Published: October 1, 2025

Abstract: Biological literacy and scientific attitudes are important aspects that need to be developed in students because they are related to the ability to understand biological concepts contextually and foster scientific thinking. This study aims to analyze the effect of the Problem-Based Learning (PBL) model on students' biological literacy and scientific attitudes. The type of research used is a quasi-experiment with a pretest-posttest control group design. The sample consisted of 58 eleventh-grade students at MAN Lombok Barat, selected using purposive sampling, with the experimental class receiving PBL instruction and the control class receiving conventional instruction. Data were collected through validated biology literacy tests and scientific attitude questionnaires. Data analysis techniques included mean value comparisons and ANCOVA tests using SPSS version 26. The results showed that the average biology literacy score in the experimental class increased from 53.8 to 72.5, while the control class increased from 53.5 to 76.6. In terms of scientific attitude, the experimental class improved from 32 to 36.9, while the control class increased from 36 to 37.2. The results of the ANCOVA test revealed a significant difference between the experimental and control classes in biological literacy, with a p-value of 0.004 ($p < 0.05$). Similarly, in the scientific attitude, a significant difference was observed with a p-value of 0.000 ($p < 0.05$). Based on these findings, it can be concluded that the application of PBL has a significant effect on improving students' scientific attitudes; however, its effect on biology literacy is less optimal than that of conventional learning. This is thought to be influenced by time constraints and other external factors that cannot be fully controlled during the research.

Keywords: Biological Literacy; Problem-Based Learning; Scientific Attitude.

Introduction

Education is one of the main pillars of national development, because quality education produces human resources capable of competing in the global arena. One of the primary objectives of education is to develop students' skills and knowledge, enabling them to adapt and contribute to a rapidly evolving society. In the era of globalization, the need for individuals with scientific literacy, particularly in the field of biology, has increased significantly. Scientific literacy involves not only understanding scientific concepts but also the ability to apply that knowledge in daily life and make decisions based on evidence. These competencies provide a crucial foundation for developing critical and analytical thinking skills, which are essential for addressing complex issues in the modern world. Therefore, strengthening students' scientific literacy through innovative and meaningful learning approaches is a strategic step toward preparing a generation that is adaptive, competitive, and responsive to future challenges.

The Programme for International Student Assessment (PISA) defines scientific literacy as the ability to apply scientific knowledge to identify questions and draw conclusions based on evidence, thereby understanding and making informed decisions about the natural world and changes caused by human activities [1]. Scientific literacy can also be understood as the ability to utilize scientific knowledge and process skills to make appropriate decisions about environmental issues [2]. These skills are crucial for comprehending environmental phenomena and addressing the issues confronting modern societies, which are shaped by advancements in science and technology, as well as social challenges [3]. Thus, scientific literacy is not only related to mastery of concepts but also to how those concepts are applied in everyday life to critically and responsibly address real-world issues.

In Indonesia, students' science literacy, particularly in biology, and their scientific attitudes remain relatively low. The 2022 PISA results show that Indonesia's average science literacy score is 383, which is below the OECD average of 485 [4]. Although Indonesia's ranking has improved by six places compared to PISA 2018, the score remains low, indicating the need for further improvement. Low science literacy skills cause students to be slow in responding to problems, have difficulty connecting theoretical concepts to real-life contexts, and struggle with problem-solving and decision-making processes [5–6]. This situation underscores the importance of implementing innovative learning models that foster critical thinking, cultivate scientific attitudes, and enhance students' ability to apply biological concepts in their daily lives.

One approach that has proven effective in enhancing science literacy and fostering positive attitudes toward science is Problem-Based Learning (PBL). PBL is a student-centered learning model in which students learn through the process of solving real and relevant problems

How to Cite:
T. Astuti, A. W. Jufri, and K. Kusmiyati, "The Effectiveness of Implementing Problem-Based Learning Models in Improving Biology Literacy and Scientific Attitudes", *J. Pijar.MIPA*, vol. 20, no. 6, pp. 1080–1086, Oct. 2025. https://doi.org/10.29303/jpm.v20i6.10042

[7]. In this model, students are presented with complex and open-ended problems that require collaboration, investigation, and critical thinking to solve. This process not only enhances students' conceptual understanding of biology but also strengthens their scientific attitudes, such as curiosity, critical thinking, and problem-solving skills [8]. Previous research has demonstrated that PBL can enhance student engagement and foster deep and meaningful learning experiences [9]. Therefore, the application of PBL in biology education is expected to not only strengthen students' conceptual mastery but also prepare them to face real-world challenges with scientific reasoning and responsible decision-making.

Initial observations at MAN Lombok Barat revealed that students' biological literacy and scientific attitudes remained low, as evidenced by limited conceptual understanding, weak analytical skills, and difficulty in connecting learning materials to phenomena around them. The dominance of lecture-based teaching and heavy reliance on textbooks has caused students to focus more on memorization than on deep understanding. Furthermore, scientific attitudes—such as curiosity, critical thinking, and problem-solving—have not developed optimally, as evidenced by low participation in discussions, experiments, and other scientific activities. The lack of diverse learning methods and limited learning resources are also contributing factors. Therefore, the implementation of PBL is expected to function as an interactive and exploratory learning strategy to effectively improve students' biology literacy and scientific attitudes.

Research Methods

This study is classified as a quasi-experimental study, which was chosen because the researcher could not control all external variables, but still provided specific treatment to the subject group [10]. The research design used was a pretest-posttest control group design. In this design, there are two groups involved, namely the experimental group, which receives treatment in the form of learning using the Problem-Based Learning (PBL) model, and the control group, which receives conventional learning. Both groups are given a pretest before the treatment and a posttest after the treatment.

This study was conducted at MAN Lombok Barat in the odd semester of the 2024/2025 academic year. The study population consisted of all 233 11th-grade students from seven classes. The sample was selected using purposive sampling, taking into account the input of biology teachers. The selected samples consisted of class XI Health 1 as the experimental group and class XI Health 2 as the control group, each comprising 29 students. The independent variable in this study was the problem-based learning (PBL) model, while the dependent variables were students' biology literacy and scientific attitudes.

The research stages consisted of three parts: preparation, implementation, and conclusion. The preparation stage involved the development of instruments, including a biology literacy test, a scientific attitude questionnaire, and an observation sheet, which were subsequently validated by experts and biology teachers. Additionally, PBL-based learning tools were developed for the experimental class, while conventional learning tools were used for the control class. During the implementation stage, students were given a pretest, followed by instruction according to the specified model, then a post-test and completion of the scientific attitude questionnaire. The final stage of the research involved analysing the data and drawing conclusions.

The research instruments used consisted of two types. First, a biology literacy test based on the PISA 2025 assessment framework, which encompasses context, competence, and knowledge, is administered in the form of multiple-choice and essay questions [4]. Second, a scientific attitude questionnaire with a four-point Likert scale, which includes indicators of curiosity, openness to evidence, objectivity, and perseverance [11]. Thus, this instrument allows researchers to obtain comprehensive data on students' biological literacy and scientific attitudes.

Before being used in research, the instrument was first tested to ensure its validity and consistency. Validity testing was conducted using the Product-Moment correlation technique to examine the relationship between individual items and the total score. Instruments meeting validity criteria were then tested for reliability using Cronbach's Alpha coefficient. An instrument is considered reliable if its reliability value exceeds 0.70 [12]. The results of the instrument testing showed that the items in the biology literacy test and scientific attitude questionnaire were suitable for use in the study.

Data collection was conducted by administering a pretest and a posttest to students to measure their biology literacy, as well as distributing questionnaires to assess their scientific attitudes. The data obtained were then analyzed using IBM SPSS Statistics 26 software. The analysis included a normality test using the Shapiro-Wilk test, a homogeneity test using Levene's test, and a hypothesis test using ANCOVA to determine the differences between the experimental and control groups.

Results and Discussion

Biology Literacy Data

Based on biology literacy data, the average pre-test score for the control group was 53.5, increasing to 76.6 on the post-test, so that $53.5 < 76.6$ with an increase of 23.1 points. In the experiment group, the average pre-test score of 53.8 increased to 72.5 on the post-test, resulting in a difference of 18.7 points, with $53.8 < 72.5$. The increase in the control group (23.1) > the increase in the experiment group (18.7), and the final post-test score of the control group (76.6) > the post-test score of the experiment group (72.5).

Based on the average scores according to the biology literacy indicators, the Biology Comprehension indicator shows that the control class experienced an increase of 25.6 points, higher than the experimental class, which increased by 21.1 points. In the Scientific Question Identification indicator, the control class increased by 23.6 points, while the experimental class only increased by 19.2 points. The New Knowledge Acquisition indicator also showed a difference, with the control class increasing by 22.8 points and the experimental class by 18.7 points. Furthermore, the Scientific Phenomenon Explanation indicator showed a 24.2-point increase in the control group, which was higher than the 19.3-point increase in the experimental group. Finally, the Conclusion Drawing indicator increased by 22.2 points in the control group, while the experimental group only increased by 18 points. Thus, all biology literacy indicators showed an increase in both groups, but the increase in the control group was higher than that in the experimental group.

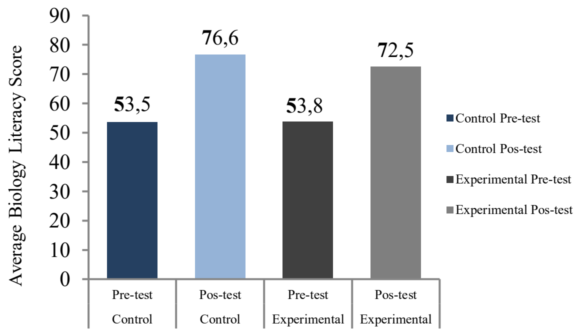

Figure 1. Average Biology Literacy Scores

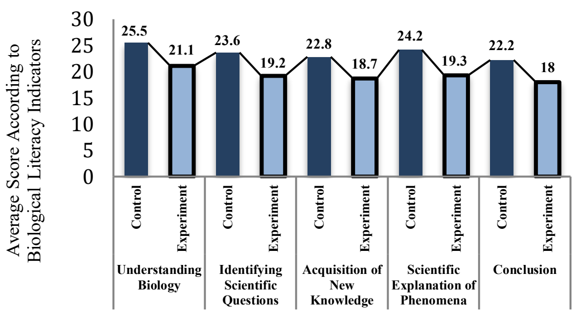

Figure 2. Average Biology Literacy Scores per Indicator

Scientific Attitude Data

Based on scientific attitude data, the average pre-test score in the control group = 36 increased to 37.2 in the post-test, so that 36 < 37.2 with an increase of 1.2 points. Meanwhile, in the PBL group, the average pre-test score of 32 increased to 36.9 in the post-test, resulting in a difference of 4.9 points, with 32 < 36.9. These results indicate that the increase in scientific attitude in the experiment group (4.9) > control (1.2), even though the initial score of the PBL group was lower than that of the control group.

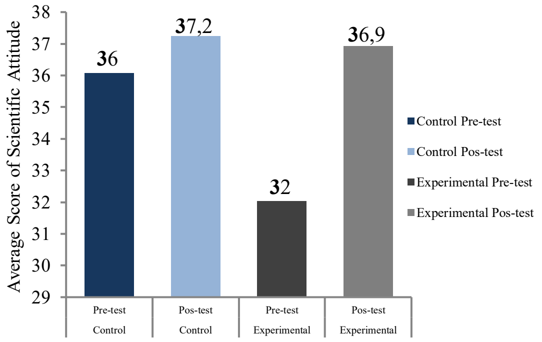

Figure 3. Average Scientific Attitude Scores

Based on the average scores according to the scientific attitude indicators, it can be seen that all aspects improved in both the control and experimental classes, although the increase was higher in the experimental class. In terms of curiosity, the control class increased by 1.2 points, while the experimental class increased by 4.9 points. Scepticism increased by 0.9 points in the control class and 3.6 points in the experimental class. In terms of positive attitude toward failure, the control class increased by 0.7 points, while the experimental class increased by 3.9 points. The indicator of prioritizing evidence increased by 0.9 points in the control class and 4.1 points in the experimental class. Meanwhile, the ability to work together increased by 1.0 points in the control class and 4.2 points in the experimental class. Finally, the indicator of valuing others' opinions also showed an increase of 0.8 points in the control class and 4.0 points in the experimental class. Overall, the data indicate that the implementation of problem-based learning is more effective in enhancing students' scientific attitudes compared to conventional learning.

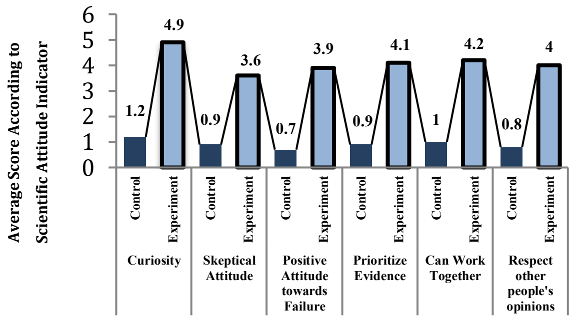

Figure 4. Average Scientific Attitude Scores per Indicator

Normality Test

A normality test was conducted on each experimental class and control class for both the scientific attitude test and the biology literacy test. The normality test in this study was conducted using the Shapiro-Wilk statistical test with the assistance of SPSS version 26. The results of the normality test are shown in the following table.

Table 1. Results of the Normality Test for Biology Literacy

Class	Statistic	df	Sig.
Pretest A (control)	0.971	29	0.577
Posttest A (control)	0.955	29	0.244
Pretest B (Experiment)	0.976	29	0.739
Posttest B (Experiment)	0.957	29	0.280

Table 1 shows that the significance value for the biology literacy test of the control class pre-test is 0.577 > 0.05 and for the control class post-test is 0.244 > 0.05. The significance value for the pre-test of the experimental class is 0.739 > 0.05, and for the post-test of the experimental class is 0.280 > 0.05. Therefore, it can be concluded that the data from both classes are normally distributed in the biology literacy test.

Table 2 shows that the significance value for the scientific attitude test of the control class pre-test is 0.813 > 0.05 and for the control class post-test is 0.242 > 0.05. The significance value for the pre-test of the experimental class is 0.209 > 0.05, and for the post-test of the experimental class is 0.206 > 0.05. Therefore, it can be concluded that the data from both classes are normally distributed in the scientific attitude test.

Table 2. Results of Scientific Attitude Normality Test

Class	Statistic	df	Sig.
Pretest A (control)	0.979	29	0.813
Posttest A (control)	0.955	29	0.242
Pretest B (Experiment)	0.952	29	0.209
Posttest B (Experiment)	0.952	29	0.206

Homogeneity Test

The homogeneity test in this study was conducted using the Levene Statistic test with the assistance of SPSS version 26. The results of the homogeneity test are shown in the following table.

Table 3. Results of the Homogeneity Test for Biology Literacy & Scientific Attitude

Test of Homogeneity of Variance (Levene Statistic)				
		df1	df2	Sig.
Biology Literacy	0.359	1	56	0.551
Scientific Attitude	0.110	1	56	0.741

Table 3 presents the results of the biology literacy test homogeneity test, showing that the significance value of the biology literacy score is 0.551, which is greater than 0.05. Therefore, it can be concluded that the data are homogeneous. In terms of scientific attitude, it is known that the significance value of the scientific attitude score is 0.741 > 0.05, so it can be said that the value is also homogeneous.

Hypothesis Testing

Before conducting hypothesis testing using analysis of covariance (ANCOVA), prerequisite tests were performed to ensure that the data used met the basic assumptions of parametric analysis, specifically normality and homogeneity of variance tests. The normality test aims to determine whether the data is normally distributed, while the homogeneity test is used to ensure that the variance between data groups is homogeneous. Once the data meet both assumptions, hypothesis testing is continued using Ancova, which is processed using SPSS software version 26.

Table 5. Ancova Test Results for Biology Literacy and Scientific Attitude

Tests of Between-Subjects Effects					
Dependent Variable: postest					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Biology Literacy	224.179	1	224.179	8.962	0.004
Scientific Attitude	40.709	1	40.709	18.363	0.000

Table 5, the results of the Ancova test for Biology Literacy and Scientific Attitude with 29 students in the experimental class and 29 students in the control class show that for the biology literacy variable, a significance value of 0.004 < 0.05 was obtained, which means that there is a significant difference in the posttest results for biology literacy between the two classes after controlling for the pretest scores. For the scientific attitude variable, a significance value of 0.000 < 0.05 was obtained, indicating a significant difference in posttest scientific attitude scores. These results confirm that the implementation of problem-based learning effectively enhances biology literacy and scientific attitude among 11th-grade students at MAN Lombok Barat. Thus, the alternative hypothesis (Ha) is accepted, and the null hypothesis (H0) is rejected. The results of the ANCOVA test in this study are presented in the following table.

The study's results indicate an increase in students' biology literacy and scientific attitudes following the implementation of the problem-based learning (PBL) model. The average biology literacy score of the experimental class increased from 53.8 on the pre-test to 72.5 on the post-test, while the control class only increased from 53.5 to 76.6. In terms of scientific attitudes, the experimental class's score increased from 32 on the pre-test to 36.9 on the post-test, while the control class only increased from 36 to 37.2. This suggests that the implementation of PBL is effective in enhancing students' biological literacy and scientific attitudes, as it encourages them to think more critically and reflectively, and connect biological concepts with everyday phenomena. These findings align with the view that implementing PBL can enhance students' critical thinking skills, thereby significantly improving their scientific literacy. Additionally, the explanation that scientific attitudes can develop optimally when students are actively involved in finding solutions to a problem [13] and [14] is supported.

In addition to the average increase, the number of students in the experimental class who achieved the minimum passing grade also increased significantly more than those in the control class, and in terms of scientific attitude, the number of students in the experimental class who achieved a high score was also higher than those in the control class. This shows that PBL helps students understand biology material more deeply by relating it to everyday life while training them to think reflectively, ask questions, and work collaboratively. This finding is supported by the statement that PBL can improve science literacy because students are encouraged to explore real phenomena relevant to their lives. Additionally, problem-based learning is effective in building scientific attitudes, as it requires active involvement in critical thinking and real problem-solving [15-16].

Hypothesis testing reinforces these results, as the significance value (p-value) of 0.004 (<0.05) for the biology literacy variable and 0.000 (<0.05) for the scientific attitude variable indicates a significant difference between the experimental and control classes. This difference is due to PBL emphasizing collaborative activities, discussions, and real-world problem-solving, which stimulate higher-order thinking skills while fostering scientific attitudes. The problem-based approach provides opportunities for students to be more active in analyzing and evaluating biological concepts, thereby directly impacting their literacy improvement. The PBL strategy encourages students to develop scientific attitudes through learning experiences that emphasize the inquiry process [17] and [18]. Similar support is also provided by the finding that students' scientific attitudes developed more when learning was centered on independent investigation and collaboration [19].

When viewed through the lens of biology literacy indicators, the ability to explain scientific phenomena showed the greatest improvement in the experimental class. Students were better able to explain the relationship between biological concepts and real phenomena, such as the relationship between human activities and ecosystem changes. This finding aligns with the observation that problem-based learning can enhance students' ability to connect theory with real-life contexts encountered in everyday life [20]. Meanwhile, in terms of scientific attitude indicators, curiosity and open-mindedness showed the greatest improvement in the experimental class. Students were more willing to ask questions, express opinions, and accept criticism in group discussions. This also aligns with the statement that PBL-based differentiated learning can foster students' collaboration skills and open-mindedness [21].

Other indicators that also showed improvement were the ability to evaluate and design scientific investigations, as well as scientific attitude indicators such as objectivity and respect for data. Students in the experimental class were better trained in formulating research questions, identifying variables, designing simple steps to test hypotheses, and thinking critically and systematically in processing information before drawing conclusions. This is consistent with research indicating that PBL can enhance science literacy in the aspect of investigation, as students are trained to think scientifically in a systematic manner [22]. Similar support was also found in the explanation that the application of PBL can accustom students to think reflectively and analytically when facing problems, and that PBL trains students to think critically and systematically in processing information before drawing conclusions [23] and [24].

Overall, the application of PBL has proven effective in improving students' biology literacy and scientific attitudes in the experimental class. Problem-based learning enables students to build knowledge through experience, think critically, and relate concepts to everyday phenomena, while developing the skills of reflection and openness to diverse perspectives. This is supported by the statement that students' scientific literacy can be improved through problem-based learning that emphasizes active engagement, and that problem-based learning not only improves cognitive outcomes but also builds scientific attitudes because students actively participate as researchers in the learning process [25-26]. Research also confirms that PBL strategies can foster biology literacy and scientific attitudes comprehensively because students are trained to understand concepts, interpret data, and apply them in real-life contexts [27-28].

Based on the above description, the implementation of problem-based learning (PBL) has proven to be effective in improving the biological literacy and scientific attitudes of 11th-grade students at MAN Lombok Barat. PBL provides students with the opportunity to actively construct knowledge through direct experience, critical thinking, and connecting biological concepts with everyday phenomena. This approach requires active participation in observation, discussion, and problem-solving, resulting in a deeper understanding and the development of students' reflective and collaborative thinking skills. However, this study also identified several challenges in implementing PBL. The learning process requires more time, especially during stages that demand students to actively seek and develop concepts, while classroom time is often limited, making it difficult for teachers to accommodate all stages optimally. The varying levels of readiness and independence among students pose a challenge, as students with lower academic abilities or those unaccustomed to active learning tend to struggle with the process, resulting in uneven participation and engagement in the classroom.

Conclusion

Based on the results of data analysis and discussion, it can be concluded that: a. The application of problem-based learning models is effective in improving the biology literacy of grade XI students with a significance value ($p < 0.05$), so that Ha is accepted and H0 is rejected at MAN Lombok Barat in the 2024/2025 academic year. b. The implementation of the problem-based learning model is also effective in improving the scientific attitudes of 11th-grade students with a significance level ($p < 0.05$), thus accepting Ha and rejecting H0 at MAN Lombok Barat for the 2024/2025 academic year.

Author's Contribution

Tika Astuti: contributed to the conceptualization and design of the study, data collection, data analysis, and writing of the article. A. Wahab Jufri and Kusmiyati: guided the entire research process, provided theoretical insights, and reviewed the final draft. All authors have read and approved the final manuscript.

Acknowledgements

Praise and thanks be to Allah SWT for the ease and opportunity given to complete this research. Thank you to my parents and entire family for their constant support. Thank you to my supervisor for his patience in guiding me. Thank you to my extended family and all the residents of MAN Lombok Barat, as well as everyone who participated in this research.

References

[1] Y. Yuliati, "Literasi Dalam Pembelajaran IPA," *Jurnal Cakrawala Pendas*, vol. 3, no. 2, pp. 21–28, 2017, doi: 10.31949/jcp.v3i2.592.

[2] N. Wulandari and H. Sholihin, "Analisis Kemampuan Literasi Sains Pada Aspek Pengetahuan Dan Kompetensi Sains Siswa SMP Pada Materi Kalor," *Edusains*, vol. 8, no. 1, pp. 66–73, 2016, doi: 10.15408/es.v8i1.1762.

[3] I. Rosidi, "Profil Literasi Sains Aspek Kompetensi Siswa Pondok Pesantren di Masa Pandemi Dengan Menggunakan Penilaian Berbasis Digital," *Jurnal*

Natural Science Educational Research, vol. 4, no. 1, pp. 1–9, 2021, doi: 10.21107/nser.v4i1.11467.

[4] OECD, *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*. Paris: OECD Publishing, 2023, doi: 10.1787/53f23881-en.

[5] OECD, *PISA 2018 Results (Volume III): Students' Well-Being*. Paris: OECD Publishing, 2019, doi: 10.1787/acd78851-en.

[6] M. Nofiana and T. Julianto, "Upaya peningkatan literasi sains siswa melalui pembelajaran berbasis keunggulan lokal," *Biosfer: Jurnal Tadris Biologi*, vol. 9, no. 1, pp. 24–35, 2018, doi: 10.24042/biosf.v9i1.2876.

[7] F. Yusmar and R. E. Fadilah, "Analisis Rendahnya Literasi Sains Peserta Didik Indonesia: Hasil Pisa dan Faktor Penyebab," *Lensa (Lentera Sains): Jurnal Pendidikan IPA*, vol. 13, no. 1, pp. 11–19, 2023, doi: 10.24929/lensa.v13i1.283.

[8] I. G. A. S. Gayatri, D. S. D. Jekti, and A. W. Jufri, "Efektifitas Pembelajaran Berbasis Masalah (PBM) Dan Strategi Kooperatif Terhadap Kemampuan Menyelesaikan Masalah Dan Hasil Belajar Kognitif Biologi Ditinjau Dari Kemampuan Akademik Awal Siswa Kelas X SMA Negeri 3 Mataram," *Jurnal Pijar MIPA*, vol. 8, no. 2, pp. 41–46, 2013, doi: 10.29303/jpm.v8i2.77.

[9] I. B. N. Mantra, "Promoting Critical Thinking And Writing Skills Through Problem-based Learning," *JOSELT (Journal on Studies in English Language Teaching)*, vol. 5, no. 1, pp. 1–7, 2024.

[10] V. H. Kristanto, *Metode Penelitian Pedoman Penulisan Karya Tulis Ilmiah (KTI)*. Yogyakarta, Indonesia: Budi Utama, 2018.

[11] N. P. D. Yuliantari, I. W. Sadia, and A. A. I. N. Marhaeni, "Pengaruh Model Problem Based Learning terhadap Literasi Sains dan Keterampilan Berpikir Kritis Siswa," *The Science Education Journal (TSCJ)*, vol. 8, no. 1, pp. 27–34, 2024. [Online]. Available: https://ejournal.undiksha.ac.id/index.php/TSCJ/article/view/80696

[12] W. Harlen, *Principles and Big Ideas of Science Education*. ASE, 2010.

[13] R. Aradia, A. Asrial, and S. Syahrial, "The Effect of Problem Based Learning Models on High School Biology Science Literacy Ability," *Symbiotic: Journal of Biology Education and Science*, vol. 6, no. 1, pp. 21–28, 2023, doi: 10.32939/symbiotic.v4i1.83.

[14] E. Surya, "Penerapan Pembelajaran Berbasis Masalah (PBL) untuk Meningkatkan Kemampuan Sikap Ilmiah Siswa pada Konsep Sistem Pernapasan di SMA Negeri 11 Banda Aceh," *Jurnal Biology Education*, vol. 4, no. 1, 2015. [Online]. Available: https://garuda.kemdikbud.go.id/documents/detail/1119283

[15] Y. Wulandari, M. Syukri, and M. Murniati, "Enhancing Senior High School Students' Scientific Attitude Through Problem-Based Learning," in *Proc. Int. Conf. on Science, Technology, Mathematics, and Science Education (ICSTMS)*, 2020.

[16] I. Yasmin, A. W. Jufri, Kusmiyati, and I. W. Merta, "The Effect of Problem-Based Learning Model on Students' Scientific Reasoning and Scientific Attitude Abilities," *Jurnal Pijar MIPA*, vol. 20, no. 3, pp. 430–436, 2025, doi: 10.29303/jpm.v20i3.8898.

[17] I. Idris, A. Maryam, R. Rusni, R. Rakhmiyanti, and R. E. Ahmad, "Improving Scientific Literacy Skills Integrated with the Problem-Based Learning Model," *Paedagoria: Jurnal Kajian, Penelitian dan Pengembangan Kependidikan*, vol. 16, no. 2, pp. 227–231, 2025, doi: 10.31764/paedagoria.v16i2.29644.

[18] N. W. Rati, K. H. D. Utami, I. M. H. Sukmayasa, I. N. T. Esaputra, and J. Deng, "Optimizing students' scientific attitudes and collaboration skills through Problem-Based Learning based on Tri Hita Karana," *Journal of Innovation in Educational and Cultural Research*, vol. 5, no. 4, pp. 736–744, 2024, doi: 10.46843/jiecr.v5i4.662.

[19] I. Irwanto, "The impact of research-oriented collaborative inquiry learning on pre service teachers' scientific process skills and scientific attitudes," *Journal of Technology and Science Education*, vol. 12, no. 2, pp. 410–425, 2022, doi: 10.3926/jotse.1583.

[20] R. A. Pakpahan, "Meningkatkan literasi sains siswa melalui pembelajaran berbasis masalah," *Judik: Jurnal Pendidikan dan Ilmu Kependidikan*, vol. 2, no. 2, pp. 68–73, 2022, doi: 10.54076/judik.v2i02.257.

[21] Y. D. Afelia, A. P. Utomo, and H. Sulistyaningsih, "Implementasi model Problem Based Learning (PBL) berbasis pembelajaran berdiferensiasi untuk meningkatkan keterampilan kolaborasi pada mata pelajaran biologi di kelas X SMA," *Jurnal Pendidikan Sains*, vol. 11, no. 2, pp. 120–128, 2023.

[22] K. Nihlah, R. H. Ristanto, and T. H. Kurniati, "The effect of PBL integrated RMS on biological literacy and critical thinking ability of high school students," *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 10, no. 3, pp. 714–723, 2024, doi: 10.22219/jpbi.v10i3.35515.

[23] S. Ramadhanti, S. Suharsono, and E. Nuryadin, "The Effect of Problem Based Learning on Students' Science Literacy Skills on the Topic of Human Excretory System," *Bioedukasi: Jurnal Pendidikan Biologi*, vol. 16, no. 1, pp. 53–63, 2023. [Online]. Available: https://jurnal.uns.ac.id/bioedukasi/article/view/74864

[24] I. Shafira, F. F. Rahayu, F. R. Rahman, J. Mawarni, and D. Fitriani, "Penerapan model PBL berbasis pembelajaran berdiferensiasi berdasarkan gaya belajar peserta didik pada pelajaran biologi materi ekosistem kelas X SMA," *Journal on Education*, vol. 6, no. 1, pp. 48–53, 2023, doi: 10.31004/joe.v6i1.2912.

[25] L. G. N. Erayani and I. N. Jampel, "Meningkatkan kemampuan literasi sains dan kemampuan metakognitif siswa melalui model problem based learning berbantuan media interaktif," *Jurnal Penelitian dan Pengembangan Pendidikan*, vol. 6,

no. 2, pp. 248–258, 2022, doi: 10.23887/jppp.v6i2.48525.

[26] A. Dirmanto, E. Cahyono, and T. Sulistyaningsih, "The effectiveness of problem based learning on acid-base materials to improve scientific attitude and creativity of SMA N 1 Comal students," *Journal of Innovative Science Education*, vol. 10, no. 2, pp. 193–198, 2021. [Online]. Available: https://journal.unnes.ac.id/sju/jise/article/view/43051

[27] F. Auliya and Muchlis, "Scientific literacy-oriented problem based learning model on improving critical thinking skills," *Thinking Skills and Creativity Journal*, vol. 7, no. 1, pp. 10–20, 2024, doi: 10.23887/tscj.v7i1.77780.

[28] N. L. D. Restiani, I. G. Margunayasa, and M. V. Arie Paramita, "Improving scientific literacy of elementary school students through problem-based learning model with Balinese local wisdom," *Jurnal Ilmiah Sekolah Dasar*, vol. 7, no. 4, pp. 590–598, 2024, doi: 10.23887/jisd.v7i4.62080