Integrated Science Education Journal
Vol. 7, No. 1, January 2026, pp. 10~17
ISSN: 2716-3725, DOI: 10.37251/isej.v7i1.2454

Research Article

The Effect of Experimental-Based Problem-Based Learning on Undergraduate Students' Scientific Writing and Presentation Skills in a Basic Physics Course

Lutfiana Ditta Sari[1,*], Sudarti[1], Bea Hana Siswati[1]
[1] Master Program of Science Education, Universitas Jember, Jawa Timur, Indonesia

Article Info

Article history:

Received Sep 14, 2025
Revised Nov 06, 2025
Accepted Dec 09, 2025
OnlineFirst Dec 20, 2025

Keywords:

Experimental-Based Learning
Problem-Based Learning
Presentation Skills
Scientific Writing Skills

ABSTRACT

Purpose of the study: This study aims to examine the effect of experimental-based Problem-Based Learning (PBL) on students' scientific writing and presentation skills in a Basic Physics course.

Methodology: The study employed a quasi-experimental posttest-only control group design involving 73 undergraduate students from the Biology Education program. Participants were divided into an experimental group receiving experimental-based PBL instruction and a control group receiving conventional learning. Data were collected using validated rubrics for scientific writing and scientific presentation skills. Data analysis was conducted using descriptive statistics, independent samples *t*-tests, One-Way ANOVA, and the Mann–Whitney U test.

Main Findings: The results show that students in the experimental group achieved significantly higher scientific writing scores (M = 562.97) than those in the control group (M = 518.19), with significant differences across most writing components ($p < 0.05$). One-Way ANOVA results indicate a very large effect size (Partial Eta Squared = 0.970). In addition, scientific presentation skills were significantly higher in the experimental group across all assessed indicators, including contribution, collaboration, confidence, content mastery, and communication ($p = 0.000$).

Novelty/Originality of this study: This study provides empirical evidence that experimental-based PBL effectively enhances both scientific writing and presentation skills in an interdisciplinary Basic Physics learning context. The findings highlight the role of inquiry-oriented and experimental learning in strengthening scientific communication skills and offer practical implications for improving scientific literacy in higher education.

Corresponding Author:
Lutfiana Ditta Sari,
Master Program of Science Education, Universitas Jember,
Kalimantan Road, No.37, Jember, Jawa Timur, 68121, Indonesia
Email: fianaluf01@gmail.com

1. INTRODUCTION

Scientific writing is a fundamental component of academic literacy in higher education, particularly in science and education disciplines [1], [2]. Scientific writing serves as the primary medium for communicating research findings and academic contributions; therefore, the quality of writing strongly influences the acceptance and dissemination of scientific knowledge [3], [4]. However, numerous studies indicate that undergraduate students still experience difficulties in scientific writing, including problems in organizing text structure, using appropriate academic language, and mastering relevant scientific content [5]-[7]. These difficulties suggest that students' scientific communication skills remain insufficiently developed.

For Biology Education students, scientific writing and presentation skills are particularly essential because they are required to communicate interdisciplinary scientific knowledge through structured and methodologically sound academic texts [8], [9]. In this context, Basic Physics is a crucial foundational course, as it provides conceptual understanding of physical principles that support biological phenomena, such as energy transfer, waves, electricity, and thermodynamics [10], [11]. Nevertheless, the abstract nature of physics concepts often poses challenges for Biology Education students, especially when instruction relies on teacher-centered approaches that limit opportunities for active learning and contextual application [12]-[14].

Problem-Based Learning (PBL) has been widely recognized as an instructional model that promotes active learning, critical thinking, collaboration, and problem-solving skills [15]-[17]. Previous studies report that PBL enables students to integrate conceptual understanding with real-world problems, which aligns closely with the cognitive demands of scientific writing and scientific presentation [18], [19]. Through problem formulation, inquiry, and collaborative discussion, PBL encourages students to engage in scientific reasoning processes that are essential for developing academic communication skills [20]-[22].

The effectiveness of PBL can be further enhanced when combined with experimental methods. Experimental-based learning engages students directly in authentic scientific practices, such as designing experiments, controlling variables, collecting empirical data, and interpreting results [23]. Through experimental activities, students are trained to write scientific reports in a structured manner, formulate evidence-based arguments, and present findings clearly and confidently [24]. Experimental-based PBL has also been shown to improve students' critical thinking, collaboration, and scientific confidence, which are important components of scientific communication skills [25], [26].

Despite these potential advantages, empirical studies that specifically examine the impact of experimental-based Problem-Based Learning on students' scientific writing and presentation skills remain limited, particularly in interdisciplinary learning contexts such as Basic Physics for Biology Education students. Most previous research focuses on conceptual understanding and learning outcomes, while academic literacy aspects especially scientific writing and presentation receive comparatively less attention. Based on this gap, the present study focuses on examining the effect of experimental-based Problem-Based Learning on students' scientific writing skills, identifying the scientific writing components most influenced by this instructional approach, and analyzing its effect on students' scientific presentation skills in Basic Physics learning. In this study, scientific writing and scientific presentation skills are conceptualized as complementary dimensions of students' scientific communication competence developed through experimental-based Problem-Based Learning. The findings of this study are expected to contribute empirical evidence for improving instructional strategies aimed at strengthening scientific literacy and interdisciplinary learning in higher education.

2. RESEARCH METHOD

This study employed a quasi-experimental posttest-only control group design to examine the effect of experimental-based Problem-Based Learning (PBL) on students' scientific writing and presentation skills. The participants were 73 undergraduate Biology Education students enrolled in a Basic Physics course at a public university. Cluster random sampling was applied to four intact classes after homogeneity testing to ensure comparable academic characteristics. One class was randomly assigned as the experimental group (n = 37), while another class served as the control group (n = 36).

The experimental group was taught using Problem-Based Learning integrated with experimental activities. The instructional process followed standard PBL phases, including problem orientation, problem analysis, inquiry planning, investigation, data analysis, and reporting. Students collaboratively solved contextual physics problems, designed and conducted experiments, analyzed empirical data, and communicated their findings through scientific writing and oral presentations. The instructor acted as a facilitator, guiding students' inquiry and reflection. In contrast, the control group received conventional lecture-based instruction emphasizing content delivery, guided discussion, and limited practicum activities without structured inquiry or systematic experimental integration.

Scientific writing skills were assessed using an analytic rubric adapted from the *Program Kreativitas Mahasiswa* Scientific Article Guidelines and Hartfield's ESL academic writing criteria. The rubric consisted of seven indicators: title relevance, abstract completeness, introduction coherence, methodological rigor, clarity of results and discussion, conclusion accuracy, and reference quality. Content validity was established through expert judgment involving two physics education experts and one educational evaluation expert. Reliability testing yielded a Cronbach's Alpha coefficient of $\alpha = 0.87$, indicating high internal consistency.

Scientific presentation skills were measured using a rubric adapted from previous studies on scientific communication, covering five indicators: contribution, collaboration, confidence, content mastery, and communication. The instrument demonstrated satisfactory reliability with a Cronbach's Alpha coefficient of α = 0.85. Data were analyzed using descriptive and inferential statistics. Independent samples t-tests were employed to compare overall scientific writing scores between groups, while One-Way ANOVA was used to examine differences across writing components. Because presentation skill data did not meet the normality assumption, the Mann–Whitney U test was applied. All statistical analyses were conducted at a significance level of 0.05

3. RESULTS AND DISCUSSION

3.1 Effect of Experimental-Based PBL on Scientific Writing Skills

Scientific writing data were collected after the completion of the instructional intervention in the Basic Physics course. The experimental group was taught using experimental-based Problem-Based Learning (PBL), while the control group received conventional lecture-based instruction. Descriptive statistics of students' scientific writing performance are presented in Table 1.

Table 1. Descriptive Statistics of Students' Scientific Writing Skills

	Group	N	Mean	Std. Deviation	Std. Error Mean
Scientific Writing	Control	36	518.19	55.769	9.295
Skills	Experimental	37	562.97	25.859	4.251

As shown in Table 1, students in the experimental group achieved a higher mean score ($M = 562.97$, $SD = 25.86$) than those in the control group ($M = 518.19$, $SD = 55.77$). An independent samples t-test indicated a statistically significant difference in scientific writing scores between the two groups ($p < 0.05$), demonstrating that experimental-based PBL had a significant effect on students' scientific writing performance. The results of this study indicate that experimental-based Problem-Based Learning (PBL) has a positive effect on students' scientific writing skills in the Basic Physics course. Students who learned through experimental-based PBL achieved higher scientific writing scores than those who received conventional instruction. This finding suggests that learning activities which combine problem-solving with experimental inquiry support the development of students' academic writing abilities.

From a learning perspective, PBL emphasizes student-centered activities through problem identification, investigation, and collaborative learning. These learning processes are closely related to the requirements of scientific writing, which include logical organization, use of evidence, and clear argumentation. The integration of experimental activities further strengthens these skills by involving students directly in scientific processes such as data collection, observation, and analysis [27]-[29]. This result is consistent with previous studies showing that PBL can improve students' academic and scientific writing performance [30], [31]. Through experimental-based PBL, students are encouraged to write based on empirical findings rather than descriptive explanations, resulting in more structured and systematic scientific texts. In this context, the present study provides empirical evidence that experimental-based PBL is effective in supporting scientific writing development in interdisciplinary Basic Physics learning for Biology Education students.

3.2 Effects of Experimental-Based Problem-Based Learning on Scientific Writing Indicators

Further analysis was conducted to examine differences across individual scientific writing components. The results of the independent samples t-test revealed statistically significant differences between the experimental and control groups in the abstract, introduction, research method, results and discussion, and reference list components ($p < 0.05$). No statistically significant difference was found in the conclusion component ($p > 0.05$). One-Way ANOVA analysis indicated significant differences among scientific writing indicators within each group. The experimental group demonstrated a very large effect size (Partial Eta Squared = 0.970), while the control group showed a smaller effect size (Partial Eta Squared = 0.886). Figure 1 presents the percentage comparison of scientific writing performance between the experimental and control groups across all indicators.

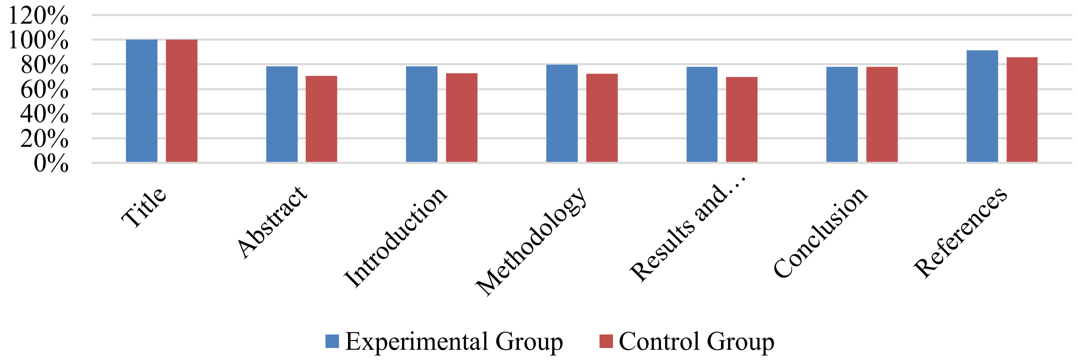

Figure 1. Comparison of Scientific Writing Skill Percentages between Experimental and Control Groups across Indicators

Figure 1 shows that the experimental group obtained higher percentage scores in almost all scientific writing indicators compared to the control group. Both groups demonstrated similar performance in the title component. The largest differences were observed in the methodology and results and discussion components, whereas the smallest difference occurred in the conclusion component. The substantial improvement in the methodology section indicates that experimental-based PBL effectively supports students' ability to describe experimental procedures, identify variables, and explain data collection processes. Through repeated engagement in hands-on experiments, students become more familiar with scientific procedures and are better able to articulate them in written form. Similarly, improvement in the results and discussion section reflects students' enhanced ability to interpret empirical data and relate findings to scientific concepts.

In contrast, the absence of significant differences in the conclusion component suggests that synthesizing research findings into concise and integrative conclusions remains a challenging skill for students in both groups. Writing conclusions requires higher-order cognitive processes, such as abstraction and synthesis, which may not be sufficiently developed through inquiry-based learning alone. This finding indicates the need for explicit instructional support and guided reflection activities to strengthen students' conclusion-writing skills within experimental-based PBL.

Further analysis of scientific writing components shows that experimental-based PBL had a stronger influence on the abstract, introduction, methodology, and results and discussion sections. Improvement in the abstract and introduction indicates that students were better able to formulate research objectives and present relevant theoretical backgrounds. This improvement may be related to the problem orientation stage of PBL, which requires students to clearly define learning problems and research purposes. The largest differences were found in the methodology and results and discussion components. Students in the experimental group showed better ability to describe experimental procedures, identify variables, and explain data analysis results. They were also more capable of interpreting findings and linking them to scientific concepts. This finding supports inquiry-based learning theory, which emphasizes learning through direct involvement in scientific investigation. However, no significant difference was found in the conclusion component. This result indicates that drawing concise and integrative conclusions remains a challenging aspect of scientific writing for students in both learning groups. Writing conclusions requires higher-order synthesis skills, which may need explicit instruction and guided practice beyond inquiry-based learning activities.

The results of this study indicate that experimental-based Problem-Based Learning (PBL) has a significant effect on most components of students' scientific writing skills, particularly in the abstract, introduction, methodology, and results and discussion sections [32], [33]. This finding is consistent with previous studies by Gillis and Winarta and Kirom , which reported that PBL effectively improves the quality of students' scientific writing through active engagement in problem solving and research processes [34]-[37]. Improvements in the abstract and introduction suggest that students became more capable of formulating research objectives and presenting relevant theoretical backgrounds. This supports the findings of Susanti [4], who emphasized the close relationship between PBL, critical thinking, and students' ability to construct scientific arguments. The largest differences were observed in the methodology and results and discussion sections, where students in the experimental group demonstrated better skills in describing experimental procedures, analyzing data, and interpreting findings, in line with inquiry-based learning theory [38].

However, no significant difference was found in the conclusion section, indicating that synthesizing research findings into concise and integrative conclusions remains a challenge for students in both groups. This result is consistent with previous studies [24][39], which suggest that conclusion writing requires higher-order synthesis skills that may require explicit instruction and guided practice beyond inquiry-based PBL activities.

3.3 Scientific Presentation Skills in Experimental-Based Problem-Based Learning

Students' scientific presentation skills were also assessed following the instructional intervention. Descriptive statistics for presentation skills in the experimental and control groups are presented in Table 2.

Table 2. Descriptive Statistics of Scientific Presentation Skills

	Group	N	Mean	Std. Deviation	Std. Error Mean
Presentation Skills	Control	36	14.19	0.525	0.087
	Experimental	37	19.38	0.492	0.081

As shown in Table 2, the experimental group achieved a higher mean score ($M = 19.38$, $SD = 0.49$) than the control group ($M = 14.19$, $SD = 0.53$). Because the data did not meet the normality assumption, a Mann–Whitney U test was conducted to compare presentation skills between groups. The results of the Mann–Whitney U test indicated statistically significant differences between the experimental and control groups across all presentation skill indicators, including contribution, collaboration, confidence, content mastery, and communication ($p = 0.000$). Figure 2 presents the comparison of scientific presentation skills between the two groups.

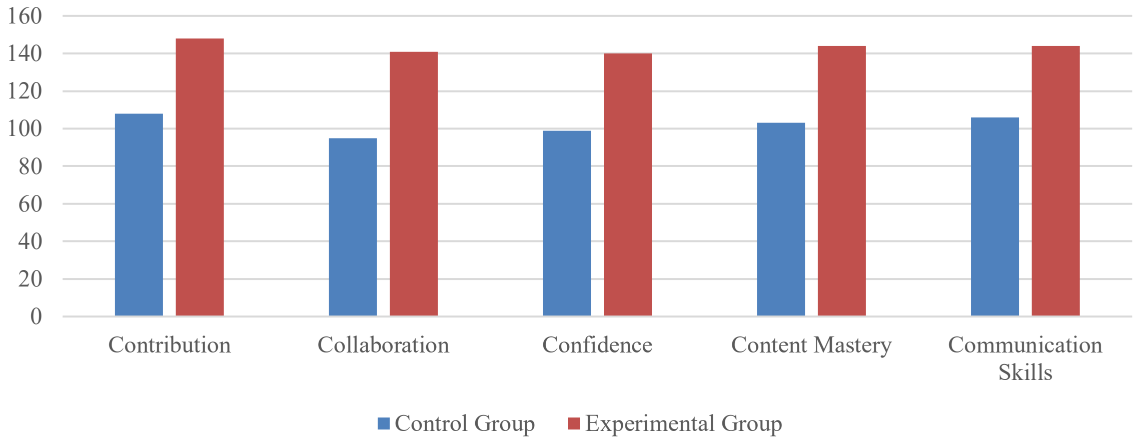

Figure 2. Comparison of Scientific Presentation Skills Between the Experimental and Control Groups

Overall, the results indicate that students who participated in experimental-based PBL demonstrated higher scientific presentation performance than those who received conventional instruction. These findings indicate that experimental-based PBL significantly enhances students' scientific presentation performance. The collaborative nature of PBL encourages active participation and shared responsibility during experimental work, which contributes to higher levels of engagement and confidence. Presenting findings derived from self-conducted experiments allows students to communicate scientific ideas more clearly and convincingly, as their understanding is grounded in direct experience rather than passive learning.

Furthermore, the improvement in presentation skills complements the development of scientific writing skills, as both forms of scientific communication require clarity of thought, logical organization, and mastery of scientific content. The findings also show that experimental-based PBL positively affects students' scientific presentation skills. Students in the experimental group performed better than those in the control group across all presentation indicators, including contribution, collaboration, confidence, content mastery, and communication [40]. These results can be explained by the collaborative and inquiry-based nature of PBL. Group experimental activities encourage students to actively participate, work collaboratively, and take responsibility for presenting their findings. Presenting results obtained from their own experimental work helps students develop better understanding of the content and increases their confidence in communicating scientific ideas [41]-[43]. This finding is in line with previous studies reporting that PBL supports the development of scientific communication and presentation skills by promoting active learning and critical thinking. The improvement in presentation skills also supports the development of scientific writing, as both skills are closely related in scientific communication [44]-[46].

3.4 Overall Impacts of Experimental-Based Problem-Based Learning on Scientific Communication Skills

The findings of this study indicate that experimental-based Problem-Based Learning (PBL) has a positive overall impact on students' scientific communication skills, particularly in scientific writing and scientific presentation. From a learning theory perspective, this result is consistent with constructivist theory, which emphasizes knowledge construction through active engagement and meaningful experiences. Through problem identification, experimentation, and reflection, students actively construct scientific understanding, which supports the development of coherent, evidence-based scientific writing. In addition, inquiry-based learning theory explains the significant improvement in methodology and results and discussion sections, as students directly engage in data collection, analysis, and interpretation [47], [48]. The collaborative learning theory further supports these findings, as group-based problem solving and presentation activities enhance students' ability to articulate ideas clearly, organize arguments logically, and communicate scientific concepts confidently in both written and oral forms [49].

Despite these positive impacts, the findings also suggest that higher-order synthesis skills, particularly in writing scientific conclusions, remain challenging for students. Writing effective conclusions requires advanced cognitive processes such as abstraction and synthesis, which may not be fully developed through inquiry-based activities alone [50]. Moreover, this study has several limitations, including the use of a posttest-only design and data collection from a single institution. Therefore, future research is recommended to involve larger and more diverse samples across multiple institutions and to apply longitudinal research designs to examine the long-term development of students' scientific writing and presentation skills, especially higher-order synthesis abilities such as scientific conclusion writing.

4. CONCLUSION

The results of this study indicate that Problem-Based Learning integrated with experimental activities effectively enhances students' scientific writing and presentation skills in Basic Physics learning. Students who participated in experimental-based PBL demonstrated more structured scientific writing and stronger presentation performance than those who received conventional instruction. The integration of problem-solving and experimental inquiry supports empirical reasoning and scientific communication development. Overall, experimental-based PBL provides a strong pedagogical basis for improving scientific literacy in higher education and may be applied in broader learning contexts. Future studies are recommended to involve larger and more diverse samples to further validate these findings.

ACKNOWLEDGEMENTS

The authors would like to express sincere gratitude to all parties who contributed to and supported the completion of this research, including the instructors, students, and colleagues who provided guidance, assistance, and valuable feedback throughout the study.

AUTHOR CONTRIBUTIONS

Conceptualization, Lutfiana Ditta Sari; Methodology, Lutfiana Ditta Sari; Validation, Sudarti and Bea Hana Siswati; Formal Analysis, Lutfiana Ditta Sari; Investigation, Lutfiana Ditta Sari; Resources, Lutfiana Ditta Sari; Data Curation, Lutfiana Ditta Sari; Writing-Original Draft Preparation, Lutfiana Ditta Sari; Writing-Review & Editing, Sudarti and Bea Hana Siswati; Visualization, Lutfiana Ditta Sari; Supervision, Sudarti and Bea Hana Siswati; Project Administration.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

[1] G. Muñoz Alvarez, I. M. Greca, and I. Arriassecq, "Problem-based learning as a strategy for teaching physics in technical–professional higher education: A case study in Chile," *Education Sciences*, vol. 15, no. 8, pp. 941, 2025, doi: 10.3390/educsci15080941.

[2] Mlundi, S. (2025). Enhancing scientific writing skills among postgraduate students: evaluating the impact of academic writing training at the institute of accountancy Arusha, Tanzania. *Ampersand*, pp. 100251, 2025, doi: 10.1016/j.amper.2025.100251.

[3] G. Rahman, M. S. Zaigham, and M. Umer, "A study of cohesive devices in students' academic writing," *Qlantic Journal of Social Sciences and Humanities*, vol. 4, no. 4, pp. 372-384, 2023, doi: 10.55737/qjssh.897009451.

[4] H. D. Assem, L. Nartey, E. Appiah, and J. K. Aidoo, "A review of students' academic performance in physics: Attitude, instructional methods, misconceptions and teachers qualification," *European Journal of Education and Pedagogy*, vol. 4, no. 1, pp. 84-92, 2023, doi: 10.24018/ejedu.2023.4.1.551.

[5] A. R. S. Tambunan, W. Andayani, W. S. Sari, and F. K. Lubis, "Investigating EFL students' linguistic problems using Grammarly as automated writing evaluation feedback," *Indonesian Journal of Applied Linguistics*, vol. 12, no. 1, pp.

16-27, 2022, doi: 10.17509/ijal.v12i1.46428.
[6] P. Chauhan, "Fundamentals of academic writing: A literature review," *Journal of NELTA*, vol. 27, no. 1-2, pp. 161-180, 2022, doi: 10.3126/nelta.v27i1-2.53201.
[7] W. K. Sari, N. Hasanah, and E. I. Nada, "The effect of problem-based learning on scientific argumentation skills in the merdeka belajar curriculum," *PAEDAGOGIA*, vol. 28, no. 2, pp. 347–354, 2025, doi: 10.20961/paedagogia.v28i2.102722.
[8] A. Z. Khairunnissa, D. Eka, N. Fitriana, I. Rifqiawati, N. Maryani, and U. S. Ageng, "Enhancing Student 's Communication Skills in Writing Biology Practical Reports Using Flashcards," *Biodidaktika: Jurnal Biologi dan Pembelajarannya*, vol. 19, no. 2, pp. 79–89, 2024, doi: 10.30870/biodidaktika.v19i2.24455.
[9] D. Oetomo, S. Widoretno, M. Ramli, B. A. Prayitno, B. Sugiarto, and C. A. Prabowo, "Analysis of students' scientific writing skills in the biology education study program at Sebelas Maret University," *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 11, no. 1, pp. 253-261, 2025, doi: 10.22219/jpbi.v11i1.37437.
[10] T. D. Presley, N. A. Harp, L. S. Holt, D. Samuel, and J. J. Harp, "Incorporating physics principles in general biology to promote integrative learning and thinking," *International Journal of Innovative Teaching and Learning in Higher Education (IJITLHE)*, vol. 2, no. 1, pp. 1–19, 2021, doi: 10.4018/IJITLHE.20210101.oa5.
[11] A. Ridwan, C. Fatimah, T. Hadinugrahaningsih, and Y. Rahmawati, "Development of 21 st Century Skills in Acid-Base Learning Through STEAM Projects," *JTK (Jurnal Tadris Kimiya)*, vol. 1, pp. 121–134, 2022, doi: 10.15575/jtk.v7i1.4913.
[12] E. R. I. Khotimah, and A. Iswanto, "The effectiveness of problem-based learning method towards student's critical thinking skills in argumentative essay writing," *Innovative: Journal Of Social Science Research*, vol. 4, no. 3, pp. 14884-14894, 2024, doi: 10.31004/innovative.v4i3.11513.
[13] S. Sutopo, N. Hidayah, H. Wisodo, and D. Haryoto, "Improving students' understanding of kinematics concepts through multi-representational learning," In *AIP Conference Proceedings* (Vol. 2215, No. 1, p. 030026). AIP Publishing LLC, 2020, doi: 10.1063/5.0004063.
[14] S. N. M. Royani, S. Sutopo, A. Hidayat, and P. Parno, "Research trends in physics learning strategies: A systematic literature review addressing students' conceptual understanding difficulties in kinematics," *Jurnal Penelitian Pendidikan IPA*, vol. 11, no. 3, pp. 1-10, 2025, doi: 10.29303/jppipa.v11i3.10047.
[15] E. E. Fa'iqoh, W. Waris, and R. S. D. Gita, "The influence of the problem-based learning (PBL) model on the creativity and problem-solving skills of elementary school students," *Jurnal Pedagogi dan Pembelajaran*, vol. 8, no. 2, pp. 413-422, 2025, doi: 10.23887/jp2.v8i2.99092.
[16] F. Fathurrohman, S. Suparlan, L. Nurohmah, and N. Nurhayati, "The implementation of problem-based learning (PBL) model to improve critical thinking ability of class iv students in civics subjects at school," *Jurnal Prima Edukasia*, vol. 13, no. 2, pp. 225–233, 2024, doi: 10.21831/jpe.v13i2.84394.
[17] D. Cinthia, A. Yulastri, M. Giatman, D. Irfan, and H. Effendi, "Evaluating the effectiveness of problem-based learning (PBL) in schools : A comprehensive meta-analysis," *AL-ISHLAH: Jurnal Pendidikan*, vol. 17, pp. 5683–5695, 2025, doi: 10.35445/alishlah.v17i3.7008.
[18] H. D. Ayu, D. A. Chusniyah, M. P. Kurniawati, and P. F. Purwanti, "Problem-based learning (PBL) as an effective solution to enhance understanding of physics concepts : A systematic literature review," *Journal of Environment and Sustainability Education*, vol. 2, no. 2, pp. 86–105, 2024, doi: 10.62672/joease.v2i2.29.
[19] R. Novalia, A. Marini, T. Bintoro, and U. Muawanah, "Project-based learning: For higher education students' learning independence," *Social Sciences & Humanities Open*, vol. 11, pp. 101530, 2025, doi: 10.1016/j.ssaho.2025.101530.
[20] R. Ariefka and S. Sari, "The effect of problem based-learning based on science edutainment on students' logical thinking," *EDUCARE: Journal of Primary Education*, vol. 4, no. 1, pp. 55–66, 2024, doi: 10.35719/EDUCARE.V4I1.199.
[21] E. Yupeni and D. Futra, "Development of PBL-Based student worksheets to improve problem-solving skills and collaborative skills of 11th grade students in reaction rate material," *AL-ISHLAH: Jurnal Pendidikan*, vol. 17, no. 1, pp. 1424–1439, 2025, doi: 10.35445/alishlah.v17i1.6234.
[22] R. A. Linsih, Y. Soepriyanto, and H. Praherdhiono, "The effect of collaborative inquiry-based learning model and learning motivation on critical thinking skills of elementary school," *JKTP: Jurnal Kajian Teknologi Pendidikan*, vol. 8, no. 2, pp. 118–127, 2025, doi: 10.17977/um038v8i22025p118.
[23] L. C. Nguyen, N. Van Ngo, N. Thi, and L. Ngoc, "Impact of problem-based learning on critical thinking: An exploration with middle school students," *International Journal of Innovative Research and Scientific Studies*, vol. 8, no. 2, pp. 2809–2819, 2025, doi: 10.53894/ijirss.v8i2.5819.
[24] S. Pratiwi and T. Utami, "Utilization of artificial intelligence technology in an academic writing class : How do Indonesian students perceive ?," *Contemporary Educational Technology*, vol. 15, no. 4, 2023, doi: 10.30935/cedtech/13419.
[25] M. Khalifa, and M. Albadawy, "Using artificial intelligence in academic writing and research: An essential productivity tool," *Computer Methods and Programs in Biomedicine Update*, vol. 5, pp. 100145, 2024, doi: 10.1016/j.cmpbup.2024.100145.
[26] L. Zhang and Y. Ma, "A study of the impact of project-based learning on student learning effects: a meta-analysis study.," *Front. Psychol.*, vol. 14, p. 1202728, 2023, doi: 10.3389/fpsyg.2023.1202728.
[27] A. Ni'mah, E. S. Arianti, S. Suyanto, S. H. P. Putera, and A. Nashrudin, "Problem-Based Learning (PBL) methods within an independent curriculum (A Literature Review)," *Sintaksis: Publikasi Para ahli Bahasa dan Sastra Inggris*, vol.2 , no. 4, 2024, doi: 10.61132/sintaksis.v2i4.859.
[28] A. A. Rafiq, M. B. Triyono, and I. W. Djatmiko, "The Integration of Inquiry and Problem-Based Learning and Its Impact on Increasing the Vocational Student Involvement," *International Journal of Instruction*, vol. 16, no. 1, pp. 659–684, 2023, doi: 10.29333/iji.2023.16137a.

[29] R. Zhang, J. Shi, and J. Zhang, “Research on the quality of collaboration in project-based learning based on group awareness,” *Sustainability*, vol. 15, no. 15, pp. 11901, 2023, doi: 10.3390/su151511901.
[30] T. Cahyaningrum and A. Widyantoro, “Effect of project-based learning and problem-based learning on the students ’ writing achievement,” *LingTera*, vol. 7, no. 1, pp. 72–83, 2020, doi: 10.21831/lt.v7i1.13700.
[31] L. Song, C. Wang, and J. Jiang, “The impact of project-based learning on university physics education: enhancing cognitive skills and core competencies,” *Frontiers in Psychology*, vol. 16, pp. 1495105, 2025, doi: 10.3389/fpsyg.2025.1495105.
[32] T. R. Cahyani, B. K. Prahani, and S. Admoko, “The effect of problem based learning (PBL) model on students’ critical thinking ability in sound wave material,” *Studies in Philosophy of Science and Education*, vol. 4, no. 3, pp. 112-122, 2023, doi: 10.46627/sipose.v4i3.281.
[33] K. Nisa, S. Ramadhan, and H. E. Thahar, “Implementing a problem-based learning model in writing scientific articles for undergraduate students,” *Journal of Language Teaching & Research*, vol. 14, no. 5, 2023, doi: 10.17507/jltr.1405.21.
[34] N. Nurkhamidah, “Investigating the lecturers’ challenges in implementing project-based learning in writing class,” *Jurnal Sustainable*, vol. 6, no. 1, pp. 1-10, 2023, doi: 10.32923/kjmp.v6i1.3083.
[35] C. Martinez, “Developing 21st century teaching skills: A case study of teaching and learning through project-based curriculum,” *Cogent Education*, vol. 9, no. 1, pp. 2024936, 2022, doi: 10.1080/2331186X.2021.2024936.
[36] Y. S. Mooduto, “The effectiveness of the problem-based learning model in enhancing critical thinking skills in science education,” *Journal La Edusci*, vol. 6, no. 1, pp. 95-106, 2025, doi: 10.37899/journallaedusci.v6i1.2177.
[37] N. Aripin, H. Alberida, Y. Ahda, and F. Mufit, “The impact of problem-based learning on science learning to improve students’ critical thinking and problem-solving skills: A meta-analysis,” *Jurnal Penelitian Pendidikan IPA*, vol. 11, no. 6, pp. 45–57, 2025, doi: 10.29303/jppipa.v11i6.10051.
[38] Y. I. Sari, D. H. Utomo, and I. K. Astina, “The effect of problem based learning on problem solving and scientific writing skills,” *International Journal of Instruction*, vol. 14, no. 2, pp. 11-26, 2021, doi: 10.29333/iji.2021.1422a.
[39] M. F. Teng, and M. Yue, “Metacognitive writing strategies, critical thinking skills, and academic writing performance: A structural equation modeling approach,” *Metacognition and Learning*, vol. 18, no. 1, pp. 237-260, 2023, doi: 10.1007/s11409-022-09328-5.
[40] E. R. Widiyanti, and S. Suyanto, “Does the PBL-STEM model improve students' deductive, inductive, and reasoning skills in biology?,” *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 11, no. 2, pp. 638-648, 2025, doi: 10.22219/jpbi.v11i2.41084.
[41] M. Taiebine, C. Nejjari, S. Bounou, and I. Youlyouz-marfak, “Five-day experience in scientific production: Write together, motivate each other and achieve success,” *Soc. Sci. Humanit. Open*, vol. 11, pp. 101373, 2025, doi: 10.1016/j.ssaho.2025.101373.
[42] W. R. Wan Yusof, M. Kimi, W. S. H. Wan Zullkiplee, M. A. Zailani, M. Shahabudin, A. A. H. Ismail, S. M. A. A. Abdullah, I. N. A. Ismail, and D J. R. Gopal, “Assessment of practical and scientific writing skills for pre-university students through project-based learning,” *Journal of Chemical Education*, vol. 99, no. 2, pp. 715-722, 2021, doi: 10.1021/acs.jchemed.1c00843.
[43] S. A. Nasihah, I. Isnawati, and H. Subekti, “Profile and validity of PBL-SETS interactive multimedia to train learners’ science literacy,” *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 10, no. 3, pp. 1059-1071, 2024, doi: 10.22219/jpbi.v10i3.35861.
[44] A. A. Ximenes and B. R. Huka, “The implementation of problem based learning approach to improve students’ writing skills,” *International Journal of Multicultural and Multireligious Understanding*, vol. 12, no. 3, pp. 25–34, 2025, doi: 10.18415/ijmmu.v12i3.6593.
[45] B. D. Wale, and Y. N. Bogale, “Using inquiry-based writing instruction to develop students’ academic writing skills. *Asian-Pacific Journal of Second and Foreign Language Education*, *6*(1), 4, 2021, doi: 10.1186/s40862-020-00108-9.
[46] Yee, Y. L., & Karpudewan, M. (2022). Science Writing Heuristics Improve Pre-University Students' Understanding of Energy Transfer in an Ecosystem and Argumentation Ability. *Journal of Turkish Science Education*, *19*(1), 82-96, 2022, doi: 10.36681/tused.2022.111.
[47] M. Petro, I. Sallata, G. Senatore, and Y. N. Biryukova, “Practical skills in pre-university education in Albania: The challenge for an effective and contemporary education,” *Journal of Education Culture and Society*, vol. 16, no. 1, pp. 843-857, 2025, doi: 10.15503/jecs2025.2.843.857.
[48] S. W. Utomo, S. Joyoatmojo, S. Yutmini, and N. Suryani, “Problem-based learning model with a scientific approach to improve higher order thinking skills,” *International Journal of Learning and Change*, vol. 14, no. 1, pp. 87-100, 2022, doi: 10.1504/IJLC.2022.119515.
[49] A. Arifuddin, W. Wahyudin, S. Prabawanto, M. Yasin, and D. Elizanti, “The effectiveness of augmented reality-assisted scientific approach to improve mathematical creative thinking ability of elementary school students,” *Al Ibtida: Jurnal Pendidikan Guru MI*, vol. 9, no. 2, pp. 444-455, 2022, doi: 10.24235/al.ibtida.snj.v9i2.11647.
[50] E. Ahman, D. Dahlan, and D. Supendra, “Identifying key factors influencing the development of higher order thinking skills (HOTS) in Students : A systematic literature review,” vol. 17, no. 2010, pp. 5242–5257, 2025, doi: 10.35445/alishlah.v17i3.6627.