



Problem-based learning on wetland socio-scientific issue: A pathway to enhance scientific literacy and collaborative skill

Nurul Hidayati Utami *, Kaspul, Aminuddin Prahatama Putra, Bunda Halang, Amalia Rezeki

Study Program of Biology Education, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Banjarmasin,
South Kalimantan, Indonesia

* Corresponding Author Email: nh.utami@ulm.ac.id

Article Information	Abstract
Keyword: Problem-based learning; Socio-scientific issue; Wetland; Scientific literacy; Collaborative skill Kata Kunci: Pembelajaran berbasis masalah; Isu sosio-saintifik; Lahan basah; literasi sains; Keterampilan kolaborasi History: Received : 17/03/2025 Revised : 14/06/2025 Accepted : 20/06/2025 Published : 26/06/2025	Addressing the demands of 21st-century competencies, this study analyzed the influence of integrating Problem-Based Learning (PBL) with Socio-scientific Issues (SSI) on students' cognitive learning outcomes in Biology and examined its effectiveness in enhancing students' collaboration skills, particularly within the context of South Kalimantan's wetland ecosystems. Employing a quasi-experimental pretest-posttest design involving 120 students from MAN 2 and SMA 11 Banjarmasin, data were collected using validated instruments. Results from the Wilcoxon Signed-Rank test indicated a significant improvement in scientific literacy ($p < 0.001$), while the Mann-Whitney U test revealed a significant enhancement in collaboration skills ($p < 0.001$) within the PBL-SSI group compared to direct instruction. These findings affirm that PBL-SSI effectively addresses the limitations of traditional models in developing essential 21st-century competencies. This approach specifically fosters active learning, teamwork, and concurrently enhances student engagement and environmental awareness. It is concluded that integrating SSI into PBL creates a more meaningful and impactful learning experience, equipping students to tackle complex socio-scientific problems in the future. <i>Abstrak. Menjawab tuntutan kompetensi abad ke-21, penelitian ini menganalisis pengaruh integrasi Problem-Based Learning (PBL) dengan Socio-scientific Issues (SSI) terhadap hasil belajar kognitif siswa dalam Biologi dan menguji efektivitasnya dalam meningkatkan keterampilan kolaborasi siswa, khususnya dalam konteks ekosistem lahan basah Kalimantan Selatan. Menggunakan desain kuasi-eksperimen pretest-posttest dengan 120 siswa dari MAN 2 dan SMA 11 Banjarmasin, data dikumpulkan melalui instrumen tervalidasi. Hasil uji Wilcoxon Signed-Rank menunjukkan peningkatan signifikan pada literasi sains ($p < 0.001$), sementara uji Mann-Whitney U mengindikasikan peningkatan signifikan pada keterampilan kolaborasi ($p < 0.001$) dalam kelompok PBL-SSI dibandingkan instruksi langsung. Temuan ini menegaskan bahwa PBL-SSI secara efektif mengatasi keterbatasan model tradisional dalam mengembangkan kompetensi abad ke-21. Pendekatan ini secara spesifik mendorong pembelajaran aktif, kerja tim, serta meningkatkan keterlibatan siswa dan kesadaran lingkungan. Disimpulkan bahwa integrasi SSI ke dalam PBL menciptakan pengalaman belajar yang lebih bermakna dan berdampak, menyiapkan siswa menghadapi masalah sosio-ilmiah kompleks di masa depan.</i>

A. Introduction

Problem-Based Learning is an instructional design that can be applied in biology education. Various supporting developments for PBL have been introduced, including e-modules, LMS, worksheets, and Augmented Reality (Fidan & Tuncel, 2019; Pramana et al., 2020; Putra et al., 2023; Yana et al., 2021). The implementation of PBL aims to enhance knowledge acquisition efficiently, contextually, and in an integrated manner with real-world applications. Additionally, students are actively engaged in problem-solving processes that reflect real-life situations. PBL serves as a method to broaden students' perspectives on real-world issues while providing guidance, resources, and problem-solving skills (Dibyantini et al., 2021; Nisak & Istiana, 2017; Valdez & Bungihan, 2019).

Based on the Focus Group Discussion (FGD) with biology teachers, several key concerns in biology education were identified: (1) Implementation of PBL: While PBL has been applied in classrooms, science literacy has not yet been specifically measured as part of the learning process. (2) Teaching Media: The instructional materials commonly used include PowerPoint presentations, accompanied by student worksheets and other supplementary textbooks. (3) Biology Learning Approaches: Classroom discussions are typically conducted on environmental topics; however, there is a need to integrate more interactive student activities. (4) Student Activities: Activities such as creating posters and mind mapping have been implemented but have not yet been incorporated into class discussions. It is crucial to develop problem-solving-based learning. It enables students especially learners to analyze and find solutions, particularly in addressing learning-related problems (Abidin & Utami, 2023). Biology subjects, part of science lessons, are concepts for studying various scientific problems (Putra et al., 2021; Utami et al., 2023).

Problem-Based Learning fosters active, independent inquiry by initiating learning with real-world problems. This approach facilitates comprehensive knowledge construction, linking subject matter to relevant issues while developing higher order thinking skills like analysis, evaluation, and solution creation (Suharlan et al., 2023). Various studies on PBL have been conducted, including its implementation in online classrooms, which has been shown to improve students' academic performance (Aslan, 2021; Putra et al., 2024). The academic improvement facilitated by PBL is significant, as this approach encourages students to engage more interactively through group formation and active involvement in problem-solving. PBL is primarily designed to enhance students' critical thinking, problem-solving abilities, and intellectual skills, fostering deeper understanding and active learning (Arends, 2012).

Integrating PBL with SSI demonstrably deepens students' biological understanding. This approach effectively bridges abstract scientific concepts with tangible, real-world social challenges, thereby making biology instruction profoundly more relevant and meaningful. This pedagogical synergy holds in South Kalimantan, specifically Banjarmasin, where students are routinely exposed to pressing local environmental dilemmas like pollution and recurrent land fires, especially within critical wetland ecosystems. Beyond merely imparting biological knowledge, this integrated framework actively cultivates critical thinking skills, enhances socio-scientific literacy, and fosters a robust sense of environmental awareness, all of which are pivotal for significantly strengthening overall scientific literacy. Furthermore, embedding scientific literacy specifically within the context of wetland ecosystems during the learning process is instrumental in facilitating the construction of novel knowledge within biology education. While the precise problem-solving capabilities of students vary across educational tiers, observations generally indicate that senior high school (SMA) and Islamic senior high school (MA) students typically exhibit moderate proficiency in this crucial skill. This underscores the need for instructional strategies, such as PBL-SSI, that are specifically designed to elevate these essential competencies (Hidayatulloh et al., 2020; Putra et al., 2024).

In the learning process, students collect relevant PBL, as an active learning approach, significantly enhances students' problem-solving. It empowers them to collect information, critically analyze issues, and develop systematic solutions. Centralized on student-focused, interactive group work, PBL fosters essential problem-solving skills understanding, strategizing, implementing, and evaluating crucial for robust learning outcomes (Hestiana & Rosana, 2020; Sutarno et al., 2017). This study the following objectives were addressed (1) analyze the influence in PBL integrate SSI on scientific literacy (2) Examine the effectiveness of the PBL integrated with SSI model in enhancing students' collaboration skills.

B. Material and method

This research using a quasi-experimental research design, specifically the Nonequivalent Control Group Pretest-Posttest Design. In this design, the treatment group undergoes a pretest, receives the intervention (Problem-Based Learning), and then takes a posttest to measure scientific literacy. Simultaneously, a nonequivalent control group is given a pretest but does not receive the intervention, and later takes the posttest to compare the effects of the treatment. This approach allows for an evaluation of the impact of

PBL on scientific literacy and collaboration skills by assessing differences in performance between the experimental and control groups Table 1.

Table 1 The research design illustration

Group	Pretest	X	Posttest
Experimental	O ₁	X ₁	O ₂
control	O ₃	X ₂	O ₄

Description:

- O₁ = Pretest result of the experimental group
O₂ = Posttest result of the experimental group
X₁ = Learning using PBL integrated with SSI
X₂ = Learning using Direct Instruction
O₃ = Pretest result of the control group
O₄ = Posttest result of the control group

Participants in this study were 10th-grade students from MAN 2 Banjarmasin and SMAN 11 Banjarmasin who met specific selection criteria. The sample was selected using cluster random sampling, comprising 120 students from 2023/2024 academic year. This study was conducted in three main stages: preparation, implementation, and completion. In the preparation stage, initial observations were conducted, the research population was identified, and lesson plans, student worksheets, and research instruments were developed. The implementation stage involved the realization of the planned instructional materials, including modules, worksheets, lesson plans, observation sheet and evaluation instruments.

The research instruments include (1) worksheets containing questions based on scientific

literacy indicators, which are designed to address wetland-related issues and incorporate SSI. These worksheets have been validated by experts, ensuring their feasibility and reliability for use.

Wetland ecological literacy, representing scientific literacy specifically focused on wetlands, is assessed through a comprehensive set of cognitive and behavioral indicators. These indicators, adapted from established environmental and scientific literacy frameworks and tailored to wetland ecosystems, reflect an individual's understanding, skills, attitudes, and actions concerning wetlands and their sustainability. For this study, the key indicators include students' ability to: (a) identify problems and (b) recognize environmental issues within wetlands; (c) analyze the impacts of human activities on these ecosystems; (d) interpret and (e) integrate relevant data and findings; and (f) effectively communicate these findings during class discussions

Collaboration skill were assessed through classroom observation using validated instrument, and reflecting dimension of effective teamwork. This observation sheet measured ability to (1) Actively contribute to group tasks and discussions (2) Engage in productive cooperation to achieve shared objectives (3) Exhibit mutual respect and appreciation for diverse perspectives (4) Work collaboratively towards a shared goal of problem-solving, ensuring tasks are completed on time.

This framework outlines student and teacher activities across five steps, emphasizing the integration of SSI within a PBL approach, specifically focusing on wetland ecosystems in Table 2.

Table 2 PBL-SSI framework for student and teacher activities

Step	Student activities	Teacher activities
Step 1: Orienting students to open-ended problem based on SSI in Wetland Areas	Students are introduced to complex, ill-structured problems directly linked to SSI in wetlands. Examples include the impact of wetland fires on local biodiversity	The teacher introduces the real-world SSI context, explains learning objectives, and motivates students to actively engage in problem-solving using diverse scientific data and ethical considerations.
Step 2: Organizing students into groups	Students are organized into heterogeneous groups to collaboratively address the assigned SSI-driven problems and complete related tasks.	The teacher ensures effective group formation, establishing roles and outlining expectations for collaborative problem-solving.
Step 3: Guiding individual and group investigations	Students actively gather and critically evaluate information based on factual socio-scientific issues specific to wetlands. They identify scientific concepts, societal implications, and potential ethical dimensions of the problem.	The teacher acts as a facilitator, assisting students in sourcing information from peer-reviewed and other reliable resources relevant to SSI. The teacher prompts students to consider multiple perspectives
Step 4: Developing and presenting findings	Students collaboratively plan and prepare comprehensive reports or presentations. They are expected to propose well-reasoned solutions or positions on the SSI, supported by scientific evidence.	The teacher guides students in planning and preparing their reports, in the SSI. The teacher encourages students to anticipate counter-arguments and justify their proposed solutions
Step 5: Analyzing and evaluating the problem-solving process & SSI in wetlands	Students collectively evaluate their learning outcomes and present their findings and proposed solutions. They reflect on the complexities of the SSI and the scientific reasoning used.	provides constructive feedback on students' scientific understanding, socio-scientific reasoning skills

This integrated PBL-SSI framework in wetland contexts for fostering essential 21st-century skills. The resulting student outputs and observational data will undergo rigorous analysis. Specifically, scientific literacy and collaboration skill data will first be tested for normality using the Kolmogorov-Smirnov test and for homogeneity via Levene's test in SPSS 25.0. Subsequently, non-parametric statistical methods will be employed for hypothesis testing, aligning with the outcomes of these preliminary assumption checks.

C. Results and discussion

Before analyze the influence in PBL integrated SSI on scientific literacy a pre prerequisite test was carried

out in Table 3 and Table 4. Based on the Table 3, both scientific literacy and collaborative skills fall into the non-normal category. Subsequently, the homogeneity test for the scientific literacy variable was conducted using Levene's statistic, with the results presented in Table 4. The homogeneity test for the scientific literacy variable using Levene's statistic indicated that it falls within the homogeneous category. Based on the results of both prerequisite tests, the data were found to be non-homogeneous and non-normal. Consequently, hypothesis testing was conducted using non-parametric tests, specifically the Wilcoxon test for the scientific literacy variable and the Mann-Whitney test for the collaborative skill variable.

Table 3 Homogeneity test variable independent

Data	Class	Statistic	Sig	Conclusion
Pretest scientific literacy	Control	0,146	0,003	Not normal
	Experimental	0,134	0,008	Not normal
Posttest scientific literacy	Control	0,175	0,000	Not normal
	Experimental	0,188	0,000	Not normal
Collaborative skill	Control	0,193	0,000	Not normal
	Experimental	0,245	0,000	Not normal

Table 4 Lavene statistic

Data	Levene statistic	N	Sig	Conclusion
Pretest	0,232	120	0,631	Homogen
Posttest	0,154	120	0,696	Homogen

Scientific literacy

Table 5 indicates the following findings regarding students' scientific literacy after the implementation of PBL integrated with SSI. Scientific literacy outcomes in wetland contexts were analyzed, revealing overall improvements. The ranks analysis indicated 102 students (positive ranks) showed increased scientific literacy scores after the PBL-SSI intervention, while 8 students experienced a decline

(negative ranks), and 10 showed no change (ties). This positive trend suggests the intervention's effectiveness. Furthermore, the experimental group (PBL-SSI) demonstrated a significantly higher mean rank of 66.45 compared to the control group (Direct Instruction) with 56.42. This supports the efficacy of PBL-SSI in enhancing scientific literacy. The statistical significance of this improvement was confirmed using the Wilcoxon Signed-Rank Test in Table 6.

Table 5 Mean ranks in scientific literacy

Variable		N	Mean rank
Post & pre Scientific literacy	Negative ranks	8a	43.38
	Positive rank	102b	56.42
	Ties	10c	
	Total	120	

Description: (a) post < pre, (b) post > pre, (c) post = pre

Table 6 Wilcoxon signed-rank test

Z	Asymp. Sig. (2- tailed)	Conclusion
8,102b	0,000	Significant difference

Hypothesis:

Ha: There is a significant effect of scientific literacy when applying PBL-SSI

Ho: There is no significant effect of scientific literacy when applying PBL-SSI

The study revealed significant differences in student problem-solving abilities between the PBL-SSI experimental group and the direct instruction control group. The Wilcoxon test confirmed a significant positive effect of PBL-SSI on cognitive learning outcomes, with an Asymp. Sig. (2-tailed) value of 0.000. As this value is less than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted, confirming PBL-SSI's significant impact on scientific literacy. These findings align with prior research demonstrating PBL's effectiveness in enhancing problem-solving skills. (Putra et al., 2024). Furthermore, the study supports the claim that students taught using the PBL model demonstrate improved learning Biology.

Several studies conclude that PBL significantly influences students' biology learning outcomes. PBL in experimental settings consistently shows a greater impact on students' cognitive learning gains compared to conventional teaching methods, a finding consistent with the results of this study (Argaw et al., 2017; Aslan, 2021; Aufa et al., 2021; Hidajat, 2023).

PBL presents complex real-world issues, such as wetland ecosystems that are rich in biodiversity but environmental challenges. These factors make wetlands an engaging and relevant topic for biology learning (Praimee et al., 2022). Integrating PBL with SSI in biology education provides more contextual and meaningful learning experience. This approach enables students to engage in problem-solving as an essential part of the learning process (Rahmah et al., 2021). The combination of PBL-SSI not only enhances scientific literacy and cognitive skills but also fosters students critical thinking and awareness of real-world environmental issues.

The implementation PBL-SSI not only helps students understand scientific concepts but also develops their ability to make informed and responsible decisions, particularly on topics related to wetland ecosystems. In this approach, students are presented with controversial SSI based on scientific evidence, such as the impact of climate change on wetlands. This method fosters a deeper engagement with both scientific content and real-world problem-solving.

Several steps support the success of PBL. When implementing PBL, students tend to be more active and motivated in learning because the lessons are connected to real-world problems that are highly relevant to their daily lives, particularly in topics.

In PBL, students work in groups to collaborate and solve problems, which enhances their understanding and application of the material they learn. Several instructional steps (syntax) demonstrate greater student engagement compared to traditional teaching methods, where the teacher acts mainly as a facilitator. As a result, PBL-based classes often achieve higher learning outcomes than control groups. Key Steps in PBL Implementation are

(1) Problem Orientation Step such Students watch a video presenting a real-world problem and formulate research questions based on the problem then stimulate critical thinking and increase students' enthusiasm for problem-solving.

During the Organizing and Guiding Group Investigations step, students collaboratively address the given problem by conducting group investigations and completing structured worksheets to organize their findings. The use of real-world, relatable problems ensures students develop a deeper understanding of the material and formulate effective solutions. This structured PBL approach fosters meaningful and applicable learning, ultimately enhancing students' critical thinking, collaboration, and real-world problem-solving skills. Student worksheet are presented in Figure 1 and Figure 2.

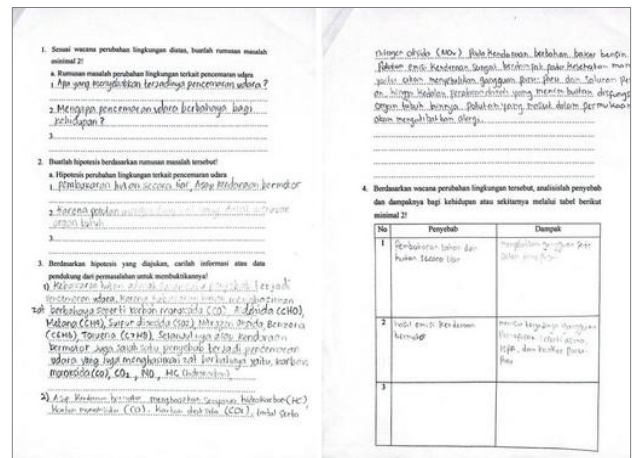


Figure 1
Student activities in worksheet (in Indonesian)

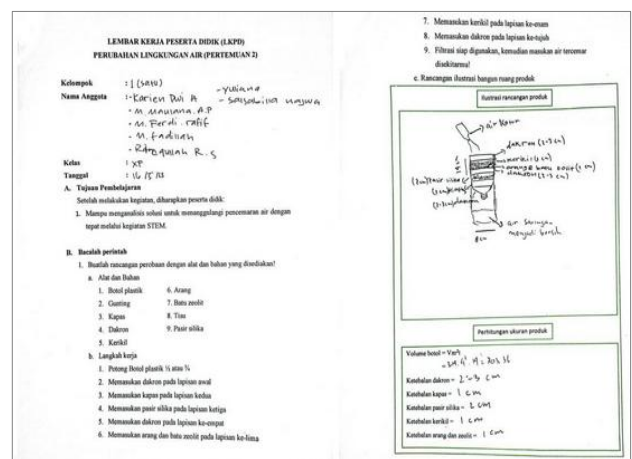


Figure 2
student activities about water pollution and environmental change (in Indonesian)

These figures about implementation of the PBL approach, which actively engages students in addressing environmental issues, particularly related to water pollution. In the first image, students are

tasked with analyzing water pollution problems by formulating solutions aimed at mitigating pollution impacts and identifying the factors affecting water quality. Through this task, students are encouraged to think critically and apply theoretical knowledge of environmental science to understand and propose solutions to the issues at hand. Meanwhile, the second image presents a more technical activity, where students work in groups to design and test a water filtration device as a solution to water pollution. They are required to compile experimental reports, sketch product designs, and perform calculations related to the designs they create, thereby deepening their understanding of scientific concepts in environmental management.

This PBL approach emphasizes active student involvement, both individually and collaboratively, in solving real-world problems faced by society. Additionally, students are trained to collaborate, conduct hands-on experiments, and analyze collected data to generate practical and innovative solutions. Furthermore, incorporating the concept of SSI into this learning process adds another dimension to

students' understanding. SSI refers to complex, controversial societal issues that have a scientific component, such as environmental concerns, health crises, or technological advancements. By addressing SSI, students are not only learning scientific concepts but are also engaging with the ethical, social, and political implications of scientific issues, thereby fostering their ability to make informed decisions and contribute meaningfully to society.

Collaborative skill

Table 7 presents the findings on students' collaboration skills following the implementation of PBL integrated with SSI. The control group exhibited a mean rank of 29.14 in collaborative learning, significantly lower than the experimental group's mean rank of 89.88. This disparity indicates the experimental group achieved substantially higher levels of collaboration. The significant difference in mean ranks and sum of ranks between the groups (detailed in Table 8) confirms that the intervention applied to the experimental group effectively enhanced collaborative learning.

Table 7 Table ranks on collaborative skill

	Ranks		
	Treatment	Mean rank	Sum of ranks
Collaborative skills	Control	29.14	1661.00
	Experiment	89.88	5842.00
	Total		

Table 8 Man-Whitney test

Z	Asymp. Sig. (2- tailed)	Conclusion
9,576b	0,000	Significant difference

Hypotheses:
Ha: There is an effect on collaborative skills when implementing PBL-SSI.
Ho: There is no effect on collaborative skills when implementing PBL-SSI.

The Mann-Whitney test revealed a statistically significant difference ($p < 0.05$) in collaborative learning, indicating that the PBL-SSI approach consistently yielded higher levels of collaboration compared to the control group. This significant difference, specifically in mean ranks and sum of ranks. Therefore, wider application of the PBL-SSI method or further validation research is recommended. Collaborative skill, in this context, underscores active group member contributions towards shared goals, with individual responsibility for both personal and collective achievement. Collaborative learning shows the contribution of group members to achieving common learning goals, while each learner is responsible for understanding and assessing both individual and group achievements (Filmi et al., 2024; Nestiyarum & Widjianti, 2023; Sarjani et al., 2023; Utami & Amintarti, 2020)

Integrating PBL with SSI enables students to: (1) comprehend scientific concepts in real-world contexts, (2) cultivate critical thinking and decision-making skills, (3) consider social, economic, and environmental problem facets, and (4) heighten awareness of pertinent environmental and social issues. This approach fosters a critically thinking, socially, and ecologically responsible generation by equipping students to apply scientific knowledge to real-life challenges (Nabila et al., 2023). Student activities during this process are illustrated in Figure 3. This figure illustrates student activities during the initial steps of PBL integrated with SSI. The top image depicts students actively engaged in problem orientation, where they are introduced to real-world socio-scientific issues concerning wetlands, such as the impact of land fires. The bottom image shows students collaboratively working in small groups during the investigation step, gathering and analyzing data to address the given

problems. These activities are integral to developing students' biological conceptual understanding, critical thinking, socio-scientific literacy, and collaboration skills within the context of wetland ecosystems.



Figure 3 Classroom activities during the problem orientation

Collaborative skills in PBL develop through social interaction, teamwork, communication, and joint problem-solving all of which are highly relevant for addressing complex socio-scientific issues. The collaborative process in learning includes: (1) Students working in small groups to identify the main issues related to wetland ecosystems, (2) students collaborating to analyze wetland issues and integrating the various perspectives they uncover during the investigation, (3) students working together to determine the best solution that takes into account both scientific and social aspects, (4) students presenting the discussion outcomes regarding the wetland issues, followed by reflective analysis of the discussion (Utami et al., 2021).

The scientific impact of this research is highly significant for the future of education, particularly Biology education. Firstly, it empirically reinforces that integrating PBL with SSI effectively moves beyond mere conceptual learning. This demonstrates that students not only acquire biological knowledge but also develop crucial 21st-century competencies: critical thinking, socio-scientific literacy, and profound environmental awareness. Secondly, by contextualizing learning within South Kalimantan's wetland ecosystems, this study provides a specific model for localizing biology education, empowering

students to engage directly with their community's environmental challenges. This is vital for cultivating a generation that is not only scientifically literate but also socially and ecologically responsible.

D. Conclusion

This study conclusively demonstrates the significant impact of PBL integrated with SSI on students' scientific literacy and collaboration skills in Biology. The Wilcoxon Signed-Rank test revealed a significant enhancement in scientific literacy ($p < 0.001$), particularly regarding wetland-related socio-scientific issues. Concurrently, the Mann-Whitney U test confirmed that PBL-SSI significantly improved students' collaborative skills ($p < 0.001$) compared to conventional instruction. This integrated approach effectively fosters essential competencies, enabling students to communicate, share ideas, and cooperate productively in addressing complex socio-scientific problems.

E. Acknowledgement

The author expresses sincere gratitude to Lambung Mangkurat University for its invaluable support in facilitating this research. Appreciation is also extended to all parties who have contributed, directly or indirectly, to the completion of this study.

F. References

- Abidin, M. Z., & Utami, N. H. (2023). Profile of science generic skills in biology learning materials for students in class X. *Vidya Karya*, 38(1), 57–65. DOI: <https://doi.org/10.20527/jvk.v38i1.15507>
- Arends, R. (2012). From learning to teaching. In *Learning to teach in the primary school* (pp. 116–129). Routledge. DOI: <https://doi.org/10.4324/9781315453736-9>
- Argaw, A. S., Haile, B. B., Ayalew, B. T., & Kuma, S. G. (2017). The effect of problem based learning (PBL) instruction on students' motivation and problem solving skills of physics. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(3), 857–871. DOI: <https://doi.org/10.12973/eurasia.2017.00647a>
- Aslan, A. (2021). Problem-based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers and Education*, 171(May), 104237. DOI: <https://doi.org/10.1016/j.compedu.2021.104237>
- Aufa, M. N., Rusmansyah, R., Hasbie, M., Jaidie, A., & Yunita, A. (2021). The effect of using e-module model problem based learning (PBL) based on wetland environment on critical thinking skills and environmental care attitudes. *Jurnal Penelitian Pendidikan IPA*, 7(3), 401–407. DOI: <https://doi.org/10.29303/jppipa.v7i3.732>
- Dibyantini, R. E., Suyanti, R. D., & Silaban, R. (2021, March). The effectiveness of problem based

- learning model through providing generic science skill in organic chemistry reaction subject. In *Journal of Physics: Conference Series* (Vol. 1819, No. 1, p. 012073). IOP Publishing. DOI: <https://doi.org/10.1088/1742-6596/1819/1/012073>
- Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers and Education*, 142(July), 103635. DOI: <https://doi.org/10.1016/j.compedu.2019.103635>
- Filmi, R. F., Ibrohim, I., & Prabaningtyas, S. (2024). The effect of the problem-oriented project-based learning (POPBL) model on high school students' collaboration skills on metabolic and cell division materials. *BIO-INOVED: Jurnal Biologi-Inovasi Pendidikan*, 6(1), 98-104. DOI: <https://doi.org/10.20527/bino.v6i1.18148>
- Hestiana, H., & Rosana, D. (2020). The effect of problem based learning based sosio-scientific issues on scientific literacy and problem-solving skills of junior high school students. *Journal of Science Education Research*, 4(1), 15-21. DOI: <https://doi.org/10.21831/jsr.v4i1.34234>
- Hidajat, F. A. (2023). A comparison between problem-based conventional learning and creative problem-based learning on self-regulation skills: Experimental study. *Heliyon*, 9(9), e19512. DOI: <https://doi.org/10.1016/j.heliyon.2023.e19512>
- Hidayatulloh, R., Suyono, S., & Azizah, U. (2020). Analisis keterampilan pemecahan masalah siswa sma pada topik laju reaksi. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 10(1), 1899-1909. DOI: <https://doi.org/10.26740/jpps.v10n1.p1899-1909>
- Nabila, A., Soendjoto, M. A., & Winarti, A. (2023). Effectiveness of e-book "Ethno-ecology study of Magnoliopsida in Desa Kiram" to train students' critical thinking skills. *BIO-INOVED: Jurnal Biologi-Inovasi Pendidikan*, 5(3), 321-327. DOI: <https://doi.org/10.20527/bino.v5i3.16584>
- Nestiyarum, Y., & Widjajanti, E. (2023). Differentiated project based learning to improve collaboration skills and cognitive learning outcomes of high school students on colloidal system material. *Jurnal Penelitian Pendidikan IPA*, 9(12), 11441-11447. DOI: <https://doi.org/10.29303/jppipa.v9i12.4867>
- Nisak, K., & Istiana, A. (2017). Pengaruh penerapan problem based learning terhadap kemampuan pemecahan. *Jurnal Kajian Pendidikan Matematika*, 3(1), 91-98. Retrieved from <https://journal.lppmunindra.ac.id/index.php/jkpm/article/download/2540/2203>
- Praimee, U., Wongchantra, P., Sookngam, K., Ongon, S., Junkaew, L., Ritsumdaeng, P., Kaeongam, S., Pronyusri, T., Wongchantra, K., Phothibat, P., Bunnaen, W., Sailabat, P., & Thongnetr, W. (2022). Environmental education learning for enhancing wetlands management in the Northeast of Thailand using cooperative-based learning. *Journal of Education and Learning*, 11(4), 161-173. DOI: <https://doi.org/10.5539/jel.v11n4p161>
- Pramana, M. W. A., Jampel, I. N., & Pudjawan, K. (2020). Meningkatkan hasil belajar biologi melalui e-modul berbasis problem based learning. *Jurnal Edutech Undiksha*, 8(2), 17-32. DOI: <https://doi.org/10.23887/jeu.v8i2.28921>
- Putra, A. P., Utami, N. H., & Kaspul, K. (2023). Effect of CLWD-Flipped classroom on student learning outcomes: A quasi-experimental study. *Jurnal Penelitian Pendidikan IPA*, 9(11), 10426-10432. DOI: <https://doi.org/10.29303/jppipa.v9i11.4411>
- Putra, A. P., Utami, N. H., & Kaspul, K. (2024, January). Implementasi CLDW berbasis PBL untuk meningkatkan keterampilan pemecahan masalah pada sistem koordinasi manusia. In *Prosiding Seminar Nasional Lingkungan Lahan Basah* (Vol. 9, No. 1, pp. 175-182). Retrieved from <https://snllb.ulm.ac.id/prosiding/index.php/snllb-lit/article/view/995>
- Putra, A. P., Utami, N. H., Kaspul, K., & Huldani, H. (2021). CLDW: Worksheet application for developing science generic skills and learning outcomes. *Review of Interantional Geographical Educationtional Geographical Education*, 11(9), 1226-1233. DOI: <https://doi.org/10.48047/rigeo.11.09.105>
- Rahmah, A., Arifin, Y. F., & Putra, A. P. (2021). Profile of student ability in solving critical problems in the concept of human physiology. *BIO-INOVED: Jurnal Biologi-Inovasi Pendidikan*, 3(3), 150-154. DOI: <https://dx.doi.org/10.20527/bino.v3i3.10590>
- Sarjani, L. P. W., Suastra, I. W., & Subagia, I. W. (2023). The influence of project-based learning models on collaboration skills and science learning outcome for junior high school. *Jurnal Penelitian Pendidikan IPA*, 9(SpecialIssue), 1284-1292. DOI: <https://doi.org/10.29303/jppipa.v9ispecialissue.7243>
- Suharlan, L. S., Arsyad, M., & Palloan, P. (2023). Influence of problem based learning and self directed learning models on students' problem solving abilities. *Jurnal Penelitian Pendidikan IPA*, 9(12), 11386-11393. DOI: <https://doi.org/10.29303/jppipa.v9i12.4730>
- Sutarno, S., Setiawan, A., Kaniawati, I., & Suhandi, A. (2017, September). Pre-service physics teachers' problem-solving skills in projectile motion concept. In *Journal of Physics: Conference Series* (Vol. 895, No. 1, p. 012105). IOP Publishing. DOI: <https://doi.org/10.1088/1742-6596/895/1/012105>
- Utami, N. H., Aminah, S., & Abidin, Z. (2023). Mastery of generic science skills in biology learning in high school level students. *Practice of The Science of Teaching Journal: Jurnal Praktisi Pendidikan*, 2(2), 99-104. DOI: <https://doi.org/10.58362/hafecspost.v2i2.43>

- Utami, N. H., & Amintarti, S. (2020, January). TPS improving student understanding and collaborative activity in topic blood circulation system. In *Journal of Physics: Conference Series* (Vol. 1440, No. 1, p. 012072). IOP Publishing. DOI: <https://doi.org/10.1088/1742-6596/1440/1/012072>
- Utami, N. H., Kaspul, K., Mispa, R., Aprilliana, I., & Jannah, N. (2021). Bimbingan teknis representasi visual pada pembelajaran biologi SMA secara kolaboratif. *Bubungan Tinggi: Jurnal Pengabdian Masyarakat*, 3(3), 255-261. DOI: <https://doi.org/10.20527/btjpm.v3i3.2513>
- Valdez, J. E., & Bungihan, M. E. (2019). Problem-based learning approach enhances the problem solving skills in chemistry of high school students. *Journal of Technology and Science Education*, 9(3), 282–294. DOI: <https://doi.org/10.3926/JOTSE.631>
- Yana, M., Zaini, M., & Dharmono, D. (2021). Validitas lembar kerja peserta didik biologi terhadap keterampilan berpikir kritis jenjang SMP. In *Proceeding Biology Education Conference: Biology, Science, Enviromental, and Learning* (Vol. 18, No. 1, pp. 13-18). Retrieved from <https://jurnal.uns.ac.id/prosbi/article/view/58051>