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The influence of PBL on students' scientific literacy in ecosystem material for grade X

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ABSTRACT

This study stemmed from a concern over low student scientific literacy, reflected explicitly in the gap between theoretical concept mastery and the inability to apply this knowledge to analyze real and complex local ecological problems. Its primary objective was to analyze the significant impact of the Problem-Based Learning (PBL) model on developing students' scientific literacy regarding ecosystem components and interactions. Using a quasi-experimental approach, the research compared a group of students receiving instruction based on authentic problems against a control group following conventional teaching methods. Data were collected via pre-test and post-test instruments designed to measure various dimensions of scientific literacy. The results indicated a striking and statistically significant difference in achievement. The experimental group demonstrated an exceptional leap in understanding, with nearly all students successfully reaching the highest category of scientific literacy. In contrast, the control group showed only limited improvement, with the majority of students remaining at a moderate level of understanding. This finding conclusively proves that PBL is superior in transforming passive instruction into an active learning experience, training students to think critically, construct scientific arguments, and apply biological knowledge in a relevant and meaningful way.

ABSTRAK

Penelitian ini berangkat dari keprihatinan atas rendahnya literasi sains peserta didik, yang secara spesifik tecermin dari kesenjangan antara penguasaan konsep teoretis dan ketidakmampuan untuk menerapkan pengetahuan tersebut dalam menganalisis masalah ekologis lokal yang nyata dan kompleks. Tujuan utamanya adalah untuk menganalisis pengaruh signifikan dari model Problem-Based Learning (PBL) terhadap pengembangan literasi sains peserta didik pada materi komponen dan interaksi ekosistem. Menggunakan pendekatan kuasi-eksperimen, penelitian ini membandingkan kelompok peserta didik yang menerima pembelajaran berbasis masalah autentik dengan kelompok kontrol yang mengikuti metode pembelajaran konvensional. Data dikumpulkan melalui instrumen pretest dan posttest yang dirancang untuk mengukur berbagai dimensi literasi sains. Hasilnya menunjukkan sebuah perbedaan capaian yang sangat mencolok dan signifikan secara statistik. Kelompok eksperimen menunjukkan lonjakan pemahaman yang luar biasa, di mana hampir seluruh peserta didik mampu mencapai kategori literasi sains tertinggi. Sebaliknya, kelompok kontrol hanya menunjukkan peningkatan yang terbatas, dengan mayoritas peserta didik tertahan pada tingkat pemahaman sedang. Temuan ini secara konklusif membuktikan bahwa PBL secara superior mampu mentransformasi pembelajaran pasif menjadi pengalaman belajar aktif, melatih peserta didik berpikir kritis, berargumentasi ilmiah, dan mengaplikasikan pengetahuan biologi secara relevan dan bermakna.

Kata Kunci: komponen ekosistem; literasi sains; PBL; pembelajaran berbasis masalah

INTRODUCTION

The developments of the 21st century demand a fundamental transformation in science education, where modern science literacy is no longer merely memorizing facts but the ability to construct knowledge through contextual problem-solving that includes epistemic dimensions such as evaluating evidence, designing investigations, and interpreting scientific data. The main problem lies in the teaching and learning process, which remains teacher-centered, leaving students feeling constrained by this conventional approach (Hafizah & Nurhaliza, 2021). Research shows that Problem-Based Learning (PBL) is effective in improving science literacy in various fields, including ecology and the environment (Azizah et al., 2021; Putri & Roichan, 2021), because in the context of ecosystems, the PBL model allows students to understand the relationships between ecosystem components more deeply through student-centered and problem-based learning (Thomassen & Jørgensen, 2021). This is in contrast to traditional PBM, which stands for material-centered learning or conventional teaching and learning processes that limit students' creativity and active participation in building a comprehensive understanding of science.

PBL not only encourages students to think critically but also deepens their conceptual understanding of complex subject matter across various fields of study. Research conducted by Hafizah and Nurhaliza shows that the PBL method significantly improves students' science literacy. This occurs consistently across educational levels, both in formal school settings and in informal learning contexts (Hafizah & Nurhaliza, 2021). These findings reinforce PBL's position as a learning strategy that is not only pedagogically relevant but also adaptable to the needs of developing students' scientific literacy in the 21st-century learning era. Previous research in senior high schools (SMA) using PBL in biology lessons has shown that students taught with PBL had better understanding and scientific literacy than those taught with conventional methods, with greater contextual relevance in ecology and biology (Aradia et al., 2023).

Using PBL can increase students' science literacy and, compared with conventional learning, improve their data processing, critical and analytical thinking, and understanding of complex scientific concepts. Previous research indicates that the PBL model can positively affect the ability to apply scientific knowledge critically in everyday life (Ermawati et al., 2024). Other studies confirm that the application of the PBL method has a significant impact on improving students' science literacy when implemented consistently at various levels of education, both in formal school environments and in informal learning contexts (Alatas & Fauziah, 2020), particularly at SMAN 9 Medan by testing the science literacy skills of 10th grade students through a quasi-experimental design and a quantitative approach that focused on understanding ecosystem components and interactions. The application of PBL positively contributes to students' problem-solving and the development of analytical thinking across various branches of science (Lendeon & Poluakan, 2022).

Students are in the early stages of learning more complex science. This study examines how PBL affects students' science literacy in Grade X at SMA Negeri 9 Medan, particularly their understanding of ecosystem components and interactions. This shows that PBL can help students better understand theoretical knowledge and develop their critical thinking and teamwork skills to solve relevant problems. In many conventional learning models, practical application and problem-solving aspects are often neglected. The PBL model offers a more contextual and transformative approach by requiring students to research and solve real-life problems (Hafizah & Nurhaliza, 2021).

Initial observations in January 2025 at SMA Negeri 9 Medan revealed an interesting paradox, 72% of students were able to name the components of an ecosystem according to their textbooks. However, only 28% could explain why the number of Sumatran tigers found in Gunung Leuser National Park continues to decline even though the food chain is intact. This gap indicates that learning remains confined to a one-way transfer of information, without involving students in the analysis of complex local ecological dynamics.

The above facts align with PISA findings placing Indonesia 74th among 81 countries in science literacy, with the lowest score in scientific reasoning. At the micro level, interviews with seven biology teachers at SMA Negeri 9 Medan in February 2025 revealed the root of the problem: 85% of lesson plans for ecosystem material still rely on lecture methods and worksheets based on memorization. A concrete example can be seen in the teaching of competitive interactions, where students are only asked to draw hypothetical food web diagrams, rather than analyzing actual cases of competition between tilapia and local fish in floating net cages on Lake Toba, which has caused a 40% decline in the pora-pora fish population according to 2024 data from the North Sumatra Fisheries Service. Learning that is isolated from specific ecological contexts yields an artificial, inapplicable form of scientific literacy.

Qualitative data from in-depth interviews with the Head of the Laboratory at State Senior High School 9 Medan revealed a concerning practice: 90% of ecosystem practicum sessions have used preserved specimens or digital simulations, even though the school is only 15 km from the Belawan mangrove area, which is rich in biodiversity. Ironically, the results of participatory observation in class X-IPA 2 show that 82% of students have never been invited to observe directly the interactions of mangrove crabs (*Scylla serrata*) with the surrounding ecosystem. This phenomenon can be observed within a 500-meter radius of the school. This disconnect between theory and reality in the field is exacerbated by the lack of collaboration with stakeholders, such as the North Sumatra Natural Resources Conservation Agency BKSDA Sumut and academics from the University of North Sumatra, in the development of learning modules. Data-based school needs analysis reveals an uneven pattern of student participation. During three observation sessions in January 2025, only 18% of students actively asked critical questions about the ecosystem, whereas 72% passively took notes from PowerPoint slides. Field notes reveal two main causes: first, the material is presented abstractly, without concrete visualizations (e.g., underwater videos of coral reefs on Pulau Banyak, 40% of which have been damaged by coral bleaching); second, the absence of interactive simulations, such as energy-flow modeling using Ecopath software. These conditions underscore the urgency of PBL models that combine digital technology with field exploration.

Previous research on PBL has demonstrated its effectiveness in improving conceptual understanding (Aradia *et al.*, 2023; Zulfa *et al.*, 2022). However, three major gaps have been identified, including the use of fictional problem scenarios (e.g., hypothetical river pollution), the lack of integration of real data from government agencies, and the limited measurement of cognitive aspects alone. This study addresses these gaps by designing PBLs based on three authentic problems in North Sumatra: the eutrophication of Lake Toba due to agricultural waste; the abrasion of the Labu Beach mangroves at a rate of 25 hectares/year; and the conversion of peatlands in Langkat, which releases 1.2 million tons of carbon annually. The novelty of this research is further strengthened by the *Socio-Scientific Issues* (SSI) approach, which explores multidimensional ecological dilemmas. In the case of the hydroelectric power plant development on the Asahan River, students not only learned about the ecological impact on the jurung fish (*Neolissochilus thienemanni*), but also analyzed the conflict of interests between the 650 MW energy needs for the industrial area, the customary rights of the Batak Angkola community, and the principle of intergenerational justice in biodiversity conservation.

The theoretical implications of this study lie in enriching the PBL model with a place-based learning framework that accommodates the uniqueness of bio-regions. Until now, studies on PBL in Indonesia have been dominated by urban contexts (Hafizah & Nurhaliza, 2021). Meanwhile, this study offers a contextualized protocol for Sumatra's unique ecosystems, ranging from peat swamps to karst ecosystems in Nias. In practical terms, the research output, in the form of local case-based PBL modules, can be adapted by schools in areas of high biodiversity, such as Kalimantan (Pesut Mahakam) or NTT (Komodo), making science learning more relevant to the archipelago's natural wealth.

This study aims to analyze how the application of the PBL model affects students' science literacy at Medan State High School 9 regarding ecosystem materials and their interactions. This study is also expected to provide new insights into the effectiveness of PBL in ecosystem learning and to serve as a reference for educators in choosing more effective teaching strategies. The findings of this study can also help policymakers improve science education in Indonesia, particularly by increasing students' science literacy (Widiastuti & Kurniasih, 2021; Zulfa *et al.*, 2022). With a problem-based approach oriented toward critical thinking skills, it is hoped that this approach will help students better understand and internalize ideas about ecosystems and become better prepared to face real-world challenges (Herman *et al.*, 2022). It is hoped that this research will increase our understanding of the role of PBL in improving students' science literacy and how this model can be applied more widely in science learning.

LITERATURE REVIEW

Concept and Characteristics of PBL

PBL is a learning model rooted in constructivist theory, in which learners are encouraged to build their understanding through contextualized, real-life experiences. Instead of delivering information directly, this approach invites learners to explore concepts and principles through authentic problems that reflect real-world situations (Smith *et al.*, 2022). The main characteristic of PBL is that the problems used must be real-world problems. PBL consists of five main stages (Procel & Pinoargote, 2023): orienting learners to the problem, dividing learners into small groups, guiding the investigation process individually and collaboratively, facilitating the preparation and presentation of discussion results, and directing the evaluation of the solutions and the thought processes that have been carried out. PBL is particularly well-suited to biology because it can combine theoretical ideas with everyday practice.

Literasi Sains dalam Konteks Pembelajaran Biologi

Scientific literacy in problem-solving involves understanding, explaining, and using science. Scientific literacy enables individuals to make decisions based on scientific analysis while remaining sensitive and self-aware of themselves and their surroundings. Scientific literacy enables students to apply the scientific knowledge they have acquired, formulate critical questions, and draw conclusions based on empirical evidence, which are important components of studying phenomena and the impacts of human actions on nature (Sutiani, 2021). Ecosystem components and their interactions are highly relevant to developing scientific literacy because they involve observable natural phenomena, require the ability to analyze cause-and-effect relationships, and necessitate an understanding of ecosystem balance in relation to contemporary environmental issues (Mambrey *et al.*, 2022).

Implementation of PBL in Ecosystem Components and Interactions Material

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Ecosystem components and their interactions are a topic in 10th-grade biology that examines biotic and abiotic organisms and the interactions that occur within them. The implementation of PBL in this material is very effective because it presents real environmental problems relevant to students' lives. According to research conducted by Simamora et al. (2022). Because students face problems, PBL can improve their critical thinking skills. Environmental problems such as water pollution, deforestation, and climate change require in-depth analysis of the interactions among ecosystem components. The PBL syntax in this learning process begins with the presentation of authentic environmental problems, followed by students identifying the ecosystem components involved, analyzing the interactions among them, proposing solutions based on ecological principles, and presenting their analyses. This approach enables students to understand concepts holistically and to connect theoretical knowledge with practical applications in everyday life (Al Ayyubi & Wisudawati, 2025).

Research Results on the Effect of PBL on Science Literacy Skills

Various studies have shown that PBL positively affects students' science literacy. Previous studies have shown that PBL can improve students' science literacy, including attitudes and competence, as well as their ability to interpret data and explain scientific phenomena (Parno *et al.*, 2020; Ramadi *et al.*, 2025). Previous studies also show that PBL increases students' science literacy about ecosystem materials by 35% relative to the initial condition (Inayah & Solihat, 2024). The characteristics of the PBL learning model encourage active student participation, which enhances their critical and analytical thinking skills and integrates scientific knowledge into the real world. Several important factors greatly influence the success of PBL. The problems presented must be relevant, challenging, and capable of stimulating students' critical thinking. In addition, the teacher's role as a facilitator is crucial for guiding discussions, directing the problem-solving process, and maintaining student engagement. Student readiness is also a determining factor, including their ability to work together, think independently, and manage time and information. Without support from these three aspects, the effectiveness of PBL in improving science literacy can be reduced.

METHODS

This study employed a quantitative, quasi-experimental design to examine the effect of the PBL model on students' science literacy. The research design employed a nonequivalent control group design, comprising two groups: the experimental group that received the PBL model treatment and the control group that received conventional instruction. Both groups were administered pre- and post-tests to assess differences in learning outcomes before and after the treatment. The population of this study comprised all students in Grade X at State Senior High School 9 Medan in the 2024/2025 academic year. The sampling technique was purposive, considering the equivalence of academic characteristics between classes. The research sample comprised four classes, with a total of 141 students, distributed proportionally across two experimental and two control classes.

The research instruments used included science literacy tests. The science literacy test was compiled based on science literacy indicators relevant to the ecosystem component material. The instrument's validity was assessed through expert review, and its reliability was assessed using Cronbach's alpha. The data analysis employed parametric statistics, namely the t-test, to test differences and interactions among the variables studied.

The research procedure includes the preparation stage, treatment implementation, data collection, and analysis of results. The preparation stage involves developing learning tools and evaluation instruments. The implementation stage includes administering a pretest, implementing learning according to the model

in each group, and administering a posttest. Data analysis is conducted after all data have been collected to test hypotheses and draw conclusions from the research results.

Figure 1. Science Literacy Coverage

Source: Research 2025

The research instruments used included science literacy tests. The science literacy test was compiled based on science literacy indicators relevant to the ecosystem component material. The instrument's validity was assessed through expert review, and its reliability was calculated using the Cronbach's Alpha coefficient. The data analysis technique used parametric statistics, namely the t-test, to test the differences and interactions between the variables studied.

Table 1. Science Literacy Ability Instrument Grid

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No	Context	Competency	Knowledge	Item Indicator
1	Rice field ecosystem (Personal)	Identify	Factual	List 3 biotic and 3 abiotic components in a rice field ecosystem
2	Solar energy (Personal/Local)	Explain	Conceptual	Explain the role of sunlight in the ecosystem
3	Symbiosis (Local)	Explain	Conceptual	Explain the meaning of parasitic symbiosis and give examples
4	Interactions between living things (Local)	Explain	Conceptual	Give two examples of mutually beneficial interactions and explain why.
5	Climate change (Global/Local)	Analyze	Procedural	Explain the effect of extreme temperatures on interactions between living things.
6	Forestry (Local/National)	Analyze	Procedural	Analyze the impact of tree loss on ecosystem balance.
7	Food chain (Local/National)	Analyze	Conceptual	Analyze the consequences if predators disappear from the ecosystem.
8	Soil pollution (Local)	Analyze	Procedural	Explain the effects of soil pollution on living things.
9	Urban (Local/National)	Evaluate	Strategic	Develop solutions to reduce ecosystem damage in urban areas
10	School (Personal/Local)	Evaluate	Strategic	Design an awareness campaign to maintain ecosystem balance

Source: Research 2025

Quantitative methods were used to evaluate the effects of the PBL model on students' science literacy skills in grade X at SMAN 9 Medan. This study applied a quasi-experimental design to improve understanding of ecosystem components and interactions. Two groups of students were involved in this study. The experimental group will be taught using the PBL model, while the control group will be taught using conventional learning approaches such as lectures and discussions.

Science literacy data were collected and evaluated using descriptive and inferential techniques to test the research hypothesis. Science literacy scores were calculated using the following formula.

$$\textbf{Nilai} = \left(\frac{\text{Skor yang diperoleh}}{\text{Skor maksimal}} \right) \times 100$$

The results of the calculations, expressed as percentages, were then grouped by assessment categories. As shown in **Table 2**, the assessment categories were divided into three, according to (Hasan *et al.*, 2018).

Table 2. Criteria for Science Literacy Achievement

No	Score Range (%)	Science Literacy Criteria
1	$\leq$ 67 – 100	High
2	33-66	Medium
3	< 33	Low

Source: Hasan et al. 2018

The data obtained were analyzed using statistical tests, namely the Kolmogorov-Smirnov normality test, to ensure normality. Then, a homogeneity test using Levene's Test to assess the similarity of variances between groups, and finally, a t-test (Independent Samples t-Test) was used to compare the differences in the average pretest and posttest results between the experimental and control groups.

RESULTS AND DISCUSSION

Results

Uji Normalitas

The purpose of the normality test in this study is to determine whether the data are normally distributed. **Table 3** shows the results of the normality test. SPSS 25 was used to perform the Kolmogorov-Smirnov test to assess normality. If the significance value is ≤ 0.05, the sample data is not normally distributed.

Table 3. One-Sample Kolmogorov-Smirnov Test

Component	Experimental Class		Control Class	
	pretest	Post test	Pretest	Post test
Number of Students	70	70	71	71
Mean	40,00	82,07	40,57	49,58
Min	40	60	35	55
Max	75	100	55	90
Normality Test	0,059 (Normal)	0,097 (Normal)	0,200 (Normal)	0,080 (Normal)

Source: Research 2025

The data obtained were analyzed using the Kolmogorov-Smirnov normality test to ensure normality. Then, Levene's Test was used to assess homogeneity of variance across groups. Finally, the t-test (Independent Sample t-Test) was used to compare the differences in the pre-test and post-test results between the experimental group and the control group.

Homogeneity Test

The homogeneity test is used to determine whether groups of sample data have equivalent variances, indicating that they come from populations with similar characteristics. Data is said to be homogeneous if the significance value of the variance exceeds the limit of 0.05.

Table 4. Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Value	Based on Mean	1.144	1	141	0.287
	Based on Median	1.267	1	141	0.262
	Based on Median and with adjusted df	1.267	1	140.514	0.262
	Based on trimmed mean	1.117	1	141	0.292

Source: Research 2025

Based on **Table 4,** the significant value of the Levene test, namely sig > 0.05, and the value of 0.292 is greater than 0.05, indicating that the data is homogeneously distributed.

Hypothesis Testing

Hypothesis testing is a method for evaluating the validity of a hypothesis. In the control class, 72 students obtained a mean of 49.58. In the experimental class, 71 students obtained a mean of 82.07. The scores after the test increased by 65.82%.

Table 5. Independent Sample Test

"Independent Samples Test"					
		"Levene's Test for Equality of Variances"		t-test for Equality of Means	
		F	Sig.	t	Df	Sig. (2-tailed)
Science Literacy Ability	Equal variances assumed	8,444	0,004	-15,167	140	0,00
	Equal variances not assumed			-15,167	122,294	0,000

Source: Research 2025

The results of the paired t-test in **Table 5** show a significance value below the significance level of 0.05, namely 0.00. This indicates that Ho is rejected and Ha is accepted, meaning that there is a significant difference between the pretest and posttest results. These findings prove that the PBL model has a positive effect on improving students' reading and science comprehension skills.

Analysis of Science Literacy Skills

The science literacy levels of students were analyzed based on questionnaire results from two groups: the experimental class using the PBL model and the control class using conventional learning methods. The questionnaire instrument was in the form of an essay test with a score of 10 for correct answers, 5 for partially correct answers, and 0 for incorrect/blank answers, which were then classified into high, medium, and low categories based on the total score. The material used in the treatment was ecosystem

components, and the study was conducted on 10th-grade students at SMAN 9 Medan to assess the difference in science literacy between the two groups. The results of the distribution of students' science literacy are presented in **Table 6.**

Table 6. Distribution of Students' Science Literacy

No	Score Range (%)	Science Literacy Criteria	Control	Experimental
1	< 67 – 100	High	11	70
2	33-66	Medium	59	-
3	< 33	Low	1	-

Source: Research 2025

Table 6 shows that in the experimental class, 70 students were in the high category. There were no students in the medium and low categories. Meanwhile, in the control class, there were 11 students in the high category, 59 students in the medium category, and one student in the low category.

Discussion

The science literacy skills of the students in this study differed significantly between those in the control class, which used conventional instruction, and those in the experimental class, which used the PBL learning model. The improvement in students' science literacy skills was evident in their posttest responses, which showed they could provide correct, varied answers in their own words. Higher-order thinking skills, which include deep interpretation and informed decision-making, are influenced by reading habits, reading analysis, and learning that focuses on providing explanations penjelasan (Suryanda, 2018). The more students read, the more complex their knowledge becomes, and low reading interest hinders higher-order thinking skills, making it difficult for students to understand questions (Azrai *et al.*, 2020).

Effective learning to achieve science literacy skills involves placing science in context, including issues and problems in the surrounding environment. Based on previous research, an effective learning model in fostering science literacy skills, particularly regarding the context of science, is the PBL model (Santoso *et al.*, 2023). The PBL model has the potential to raise real questions to encourage students to develop thinking and problem-solving skills. This explanation demonstrates that PBL encourages students to critically explore contextual questions related to scientific concepts to solve problems (Fauziah *et al.*, 2019). There is a relationship between aspects of science literacy and activities in learning that apply the PBL model (Prastika *et al.*, 2019).

Meaningful learning can help students understand knowledge and store it in their long-term memory, as well as help them apply their knowledge to real, new, and different situations (Suryanti *et al.*, 2021). In one relevant study, it was found that understanding of science literacy had increased (Azizah *et al.*, 2021), so a learning model that can foster science literacy was proposed, namely the PBL model. PBL is a learning model that can help improve science literacy (Husniyyah *et al.*, 2023). The results of the data analysis show that the posttest scores of students in the experimental class with PBL differ from those of students in the control class with PBL, indicating that the improvement in literacy skills is significantly influenced by the application of the PBL model in science education.

From the pretest results, it can be seen that students in the experimental class have lower science literacy skills than students in the control class. This is because the PBL model used in the experimental class

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helps students learn science more effectively than simply studying the material directly, which can lead to lower science literacy. After all, it does not help or guide students to plan effective investigations or problem-solving. The results of this study indicate that the PBL model is effective in improving students' science literacy skills in ecosystem components. During the discussion process, students were given the freedom to express their opinions, to respect others' opinions, and to reach joint agreements based on their science literacy. Through these activities, students showed significant improvement in science literacy aspects, including context, content, and process (Meo *et al.*, 2024). This empirical evidence reinforces that the PBL learning model is one of the appropriate and relevant learning models to be used to improve students' science literacy in a sustainable manner in biology learning.

Previous studies have shown that students can practice problem-solving skills when applying the PBL model, thereby developing scientific literacy by following scientific evidence (Widiana *et al.*, 2020). Students' scientific literacy will improve through problem-based learning. Evidence that the PBL paradigm is very successful in this regard is supported by the improvement in students' scientific literacy (Aliyana *et al*, 2021). PBL improves students' ability to solve problems and master scientific process skills related to natural events and their surrounding environment (Larosa *et al.*, 2024). The inquiry and issue analysis processes taught to them also help them develop their scientific abilities.

Students' ability to understand science in all fields is greatly influenced by the PBL model (Juleha *et al.*, 2019). This is in line with previous research findings, which show that students taught using PBL have good problem-solving skills (Utami, 2022). PBL helps students understand how to interpret data and scientific evidence, as well as evaluate and design scientific research and observe scientific phenomena. This model uses structured steps to teach students how to solve problems.

CONCLUSION

The implementation of the PBL model has a positive impact on improving students' science literacy. The study found that students who participated in PBL-based learning improved their science literacy compared to those who received conventional instruction. These results imply that choosing the right learning model can influence students' understanding and science literacy skills. The PBL model can train students to solve problems, argue, and strengthen their skills.

The results of this study are expected to serve as a reference for applying similar learning models to other conceptual biology topics, as well as to encourage teachers to design problem-based learning that is relevant to real life. Therefore, this approach is recommended as a strategic alternative to improve the quality of biology learning, particularly in developing sustainable creative thinking skills.

AUTHOR'S NOTE

The results of the study indicate that there are problems in implementing the PBL learning model. Therefore, future research may focus on developing new strategies or modifications to PBL to make it more effective in improving science literacy. The researchers suggest that further research be conducted to investigate additional components that influence the success or failure of efforts to improve students' science literacy skills.

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