FUTURITY
Education

DOI: https://doi.org/10.57125/FED.2026.09.04

How to cite: Yolida, B., Nur Safitri, S., Wiono, W. J., Maulina, D., & Priadi, M. A. (2026). Enhancing high school students' scientific literacy through socio-scientific issue-based problem-based learning (SSI-PBL): The case of Bukit Barisan Selatan National Park (BBSNP). *Futurity Education, 6*(3), 53–67. https://doi.org/10.57125/FED.2026.09.04

Enhancing High School Students' Scientific Literacy through Socio-Scientific Issue-Based Problem-Based Learning (SSI-PBL): The Case of Bukit Barisan Selatan National Park (BBSNP)

Berti Yolida*

Associate Professor, Biology Education, Faculty of Teacher Training and Education, University of Lampung, Lampung, Indonesia, https://orcid.org/0000-0001-6458-8630

Syakinah Nur Safitri

Bachelor of Education in Biology, Biology Education, Faculty of Teacher Training and Education, University of Lampung, Lampung, Indonesia, https://orcid.org/0009-0004-6210-446X

Wisnu Juli Wiono

Assistant Professor, Biology Education, Faculty of Teacher Training and Education, University of Lampung, Lampung, Indonesia, https://orcid.org/0000-0003-2626-9983

Dina Maulina

Associate Professor, Biology Education, Faculty of Teacher Training and Education, University of Lampung, Lampung, Indonesia, https://orcid.org/0000-0002-6102-1927

Median Agus Priadi

Assistant Professor, Biology Education, Faculty of Teacher Training and Education, University of Lampung, Lampung, Indonesia, https://orcid.org/0009-0000-5053-1289

***Corresponding author:** *berti.yolida@fkip.unila.ac.id.*

Received: April 22, 2026 | **Accepted:** August 1, 2026 | **Available online:** August 25, 2026

Abstract: Developing scientific literacy requires learning experiences that connect scientific concepts with authentic environmental problems, yet science instruction often remains detached from students' local contexts. This study examined the effectiveness of Socio-Scientific Issue-based Problem-Based Learning (SSI-PBL) using conservation issues from Bukit Barisan Selatan National Park (BBSNP) to improve high school students' scientific literacy. A quasi-experimental pretest- posttest control group design was implemented with 72 tenth-grade students. Scientific literacy was assessed using an OECD PISA 2022-based essay test, and the data were analysed using normalised gain, an independent-samples t -test, and Cohen's d effect size. Students in the SSI-PBL experimental class achieved higher scientific literacy than the control class, with significantly greater learning gains ($p = 0.006$) and a moderate educational effect ($d = 0.67$). Improvement was evident across all scientific literacy competencies, with the strongest gains observed in interpreting scientific data and evidence, followed by evaluating scientific inquiry and explaining scientific phenomena. Learning through authentic conservation issues enabled students to apply scientific knowledge, evaluate evidence, and justify decisions within meaningful environmental contexts rather than relying solely on conceptual understanding. These findings demonstrate that integrating locally relevant conservation issues into SSI-PBL strengthens scientific literacy while providing a practical approach for contextual science learning in biodiversity-rich regions.

Keywords: scientific literacy, socio-scientific issues, problem-based learning, contextual science learning, biodiversity conservation.

Introduction

Scientific evidence increasingly shapes decisions about environmental sustainability, public health, biodiversity conservation, and natural resource management(Cooke et al., 2023; Kattumuri, 2018). As environmental challenges become more complex, societies need citizens who can critically evaluate scientific information rather than rely on opinions or misinformation. These demands have made scientific literacy a central goal of contemporary science education because it equips students to explain scientific phenomena, interpret evidence, and make informed decisions when confronted with socio-environmental problems (Guerrero et al., 2024; Tijani & Adeduyigbe, 2026). As a result, improving scientific literacy has become an international priority reflected in educational reforms and assessment frameworks such as the OECD Program for International Student Assessment (PISA) (Sadler & Zeidler, 2009; She et al., 2018; Xie & Yusuf, 2026).

Despite this growing emphasis, developing scientific literacy in schools remains challenging (Dragoş & Mih, 2015; Vaino et al., 2026). Results from international assessments continue to indicate that many students struggle to transfer scientific knowledge to authentic situations requiring evidence-based reasoning and decision-making. In many classrooms, science instruction still prioritises conceptual mastery and factual recall, providing relatively few opportunities for students to investigate complex environmental problems that mirror those encountered outside school. This mismatch between instructional practice and the expected competencies of scientifically literate citizens has encouraged researchers to explore learning approaches that integrate scientific inquiry with real-world contexts.

Recent studies have identified Socio-Scientific Issues (SSI) as a promising approach for strengthening scientific literacy because they engage students with controversial and authentic issues that involve scientific, environmental, and societal dimensions. Through SSI-based learning, students are encouraged to evaluate evidence, consider multiple perspectives, and justify their decisions using scientific reasoning (Alcaraz-Dominguez, 2024; Arifin et al., 2026; Eryasar & Kilinc, 2022; Kinskey, 2026; Shan & Jain, 2026). At the same time, Problem-Based Learning (PBL) has consistently been reported to enhance inquiry skills by involving students in collaborative investigations and evidence-based problem-solving (Al-Thani & Ahmad, 2025; Hidayatullah & Setiawan, 2024; Pluta et al., 2013). Together, these approaches create learning environments that promote active knowledge construction rather than passive information acquisition, making them well-suited to developing scientific literacy.

Although the educational value of SSI and PBL has been widely documented, important limitations remain in existing literature. Most studies have implemented these approaches using broad themes such as climate change, renewable energy, or waste management (Hernández-Ramos et al., 2021; Sanchez et al., 2024), while relatively few have examined how locally relevant conservation issues influence students' scientific literacy. As a result, empirical evidence remains limited on whether learning becomes more effective when socio-scientific issues originate from environmental problems that students recognise in their own communities. This limitation is particularly apparent in biodiversity-rich regions, where protected areas provide authentic contexts for connecting scientific concepts with environmental decision-making.

Bukit Barisan Selatan National Park (BBSNP), one of Indonesia's most important biodiversity conservation areas (Kahler, 2018; McCarthy et al., 2015; O'Brien & Kinnaird, 1996; Weiskopf et al., 2019), offers a distinctive setting for addressing this gap. Conservation challenges within the park—including habitat degradation, biodiversity loss, and human–wildlife conflict—represent authentic socio-scientific issues that require scientific understanding and consideration of ecological and social consequences. Embedding these issues within SSI-based Problem-Based Learning (SSI-PBL) gives students opportunities to investigate environmental problems directly relevant to their local surroundings while applying scientific evidence to support their conclusions. Examining this approach is timely because it not only contributes to improving scientific literacy but also expands current understanding of how place-based conservation contexts can strengthen the effectiveness of science learning.

Research conducted in different educational settings also reveals considerable variation in how scientific literacy has developed. Literature reviews worldwide have largely influenced scientific argumentation, inquiry, and decision-making through contemporary issues such as climate change and public health (Allchin & Zemplén, 2020; Salsabila Allissa Fitri & Ma'arif, 2025). In many Asian countries, however, greater attention has focused on curriculum reform, STEM integration, and improving students' performance in international assessments (Lee et al., 2023; Wahono et al., 2020; Yamada, 2023). Research from developing countries has increasingly highlighted the importance of contextual learning by incorporating local environmental problems and indigenous knowledge into science education. Despite these different approaches, relatively few studies have explored protected conservation areas as authentic socio-scientific learning environments, particularly in regions with exceptionally high biodiversity.

The existing literature also presents several methodological and conceptual limitations. Most investigations have adopted short-term quasi-experimental designs that primarily measure overall scientific literacy, providing limited information about how different learning approaches influence individual competencies such as explaining scientific phenomena, evaluating scientific inquiry, and interpreting scientific evidence. In addition, authentic conservation contexts remain underrepresented in SSI-PBL research, even though they offer opportunities for students to examine scientific, ecological, and social issues simultaneously. As a result, it remains unclear whether learning situated in biodiversity conservation areas can strengthen scientific literacy beyond what has been reported in more general environmental contexts.

This study addresses these limitations by integrating SSI-PBL with conservation issues from Bukit Barisan Selatan National Park, a UNESCO World Heritage tropical rainforest recognised for its exceptional biodiversity and complex conservation challenges. Rather than presenting environmental issues through hypothetical classroom scenarios, students investigate ecological problems that exist within their own region and are closely connected to biodiversity conservation and ecosystem sustainability. This approach extends previous research by positioning local conservation issues not simply as learning examples but as the foundation for scientific inquiry, evidence evaluation, and decision-making. In doing so, the study offers new empirical evidence on how place-based socio-scientific learning can strengthen scientific literacy in secondary science education.

Research Problem

Scientific literacy is increasingly essential for preparing students to address complex environmental challenges through evidence-based reasoning. However, science instruction still predominantly emphasises conceptual knowledge rather than engaging students with authentic socio-scientific issues. This gap limits students' ability to apply scientific understanding to real-world environmental problems, highlighting the need for contextual learning that strengthens both scientific literacy and environmental responsibility. Although SSI-PBL have been widely reported to improve scientific literacy, most studies focus on global issues such as climate change and waste management. At the same time, authentic local conservation contexts remain underexplored. Moreover, evidence on how such contexts develop the three OECD PISA scientific literacy competencies is still limited. This study addresses these gaps by examining SSI-PBL using conservation issues from Bukit Barisan Selatan National Park (BBSNP), providing new evidence on the value of place-based science learning for improving scientific literacy.

Research Focus

This study examines how SSI-PBL, implemented through authentic conservation issues from Bukit Barisan Selatan National Park, supports the development of high school students' scientific literacy. The study focuses on the three scientific literacy competencies defined in the OECD PISA framework—explaining scientific phenomena, evaluating and designing scientific inquiry, and interpreting scientific data and evidence—because these competencies are essential for addressing contemporary environmental challenges through scientific reasoning.

Research Aim and Research Questions

The study aims to examine the effectiveness of SSI-PBL using the conservation context of Bukit Barisan Selatan National Park in improving high school students' scientific literacy and to determine how authentic local environmental issues contribute to contextual science learning. Guided by this objective, the study addresses the following research questions:

1. Does SSI-PBL significantly improve high school students' scientific literacy compared with conventional science instruction?
2. How does SSI-PBL influence students' ability to explain scientific phenomena, evaluate and design scientific inquiry, and interpret scientific data and evidence?
3. How does the integration of authentic conservation issues from Bukit Barisan Selatan National Park contribute to the development of students' scientific literacy?
4. To what extent does contextualised SSI-PBL address the need for more authentic science learning environments that support scientific literacy?

Literature Review

Scientific literacy has evolved from emphasising mastery of scientific concepts to developing students' ability to interpret evidence, evaluate scientific claims, and make informed decisions in situations involving science and society (Dibner & Snow, 2016; Osborne, 2023; Roberts & Bybee, 2014; Zeidler & Sadler, 2023). Recent studies consistently report that these competencies are more likely to develop when students participate in inquiry-oriented learning that connects science with authentic environmental issues rather than isolated classroom exercises (Kopbayeva et al., 2026). This shift reflects a broader movement in science education toward preparing learners to respond to increasingly complex environmental and sustainability challenges. Nevertheless, many students continue to struggle to transfer scientific knowledge to real-life situations, suggesting that contextual learning remains an important challenge in science education.

Socio-scientific Issues (SSI) and Problem-Based Learning (PBL) have emerged as complementary approaches for addressing this challenge (Hernández-Ramos et al., 2021). SSI encourages students to examine scientific issues from multiple scientific, ethical, and social perspectives (Badeo & Duque, 2022; Herman et al., 2021; Lymbouridou, 2025), whereas PBL provides a structured process through which evidence is gathered, evaluated, and applied to solve authentic problems (Blumberg, 2005; Sukackė et al., 2022). Studies conducted in different educational contexts have shown that combining these approaches promotes scientific reasoning, argumentation, and evidence-based decision-making more effectively than conventional science instruction. Even so, most published research has relied on global themes such as climate change, renewable energy, or environmental pollution, leaving locally relevant conservation issues relatively unexplored.

Growing interest in place-based science education has highlighted the educational value of local environmental contexts. Learning activities situated in ecosystems students recognise from their surroundings allow them to explore scientific concepts through direct observation of ecological processes and human–environment interactions(Eberbach & Crowley, 2009; Hall, 2017). Protected areas are particularly valuable because they bring together biodiversity conservation, ecosystem management, and competing social interests within a single learning context. Despite these advantages, conservation areas have rarely been incorporated into SSI-PBL research, especially in biodiversity-rich developing countries where such settings could provide highly authentic opportunities for scientific inquiry.

These limitations indicate that further evidence is needed from learning environments where socio-scientific issues emerge naturally from students' local surroundings. Bukit Barisan Selatan National Park provides such a context because its conservation challenges combine ecological, scientific, and societal dimensions that are directly relevant to secondary school science. Investigating SSI-PBL within this setting extends current research beyond commonly used environmental topics. It offers an opportunity to examine how locally grounded conservation issues support the development of scientific literacy. This perspective positions contextual relevance as an integral element of effective science learning rather than merely a background for classroom activities.

Materials and Methods

A quasi-experimental study using a pretest-posttest control group design examined the effectiveness of SSI-PBL in improving high school students' scientific literacy. Random assignment of individual students was not feasible because the study was implemented within existing classroom settings. As a result, one class was assigned as the experimental group and received SSI-PBL using conservation issues from BBSNP. In contrast, another class served as the control group and followed the school's PBL without SSI content. Students in both groups completed the same scientific literacy test before and after the intervention, allowing changes in learning outcomes to be compared under comparable instructional conditions.

Sample and Participants

The study involved 72 tenth-grade students from State Senior High School 1 Pesisir Selatan, Lampung Province, Indonesia. Participants were selected through purposive sampling to ensure that both classes had comparable academic characteristics and followed the same biology curriculum. The sample was determined through purposive sampling based on equal average values, consisting of 36 grade X E4 students as the experimental class who received SSI-PBL and 36 grade X E5 students as the control class who used PBL without SSI content.

Instrument and Procedure

Scientific literacy was assessed using ten essay questions developed according to the scientific competency framework of OECD PISA 2022. The instrument measured three competencies: explaining scientific phenomena, evaluating and designing scientific inquiry, and interpreting scientific data and evidence. Content validity was established through expert review by university lecturers specialising in biology education, with all items meeting the expected validity criteria. Students' responses were evaluated using an analytical scoring rubric aligned with each competency indicator, enabling examination of both overall scientific literacy and individual competency performance.

The intervention was implemented over six instructional sessions. During the first session, both groups completed a pretest to establish their initial level of scientific literacy. Students in the experimental group then participated in SSI-PBL using authentic conservation issues from BBSNP, including biodiversity conservation, habitat degradation, human–wildlife conflict, and ecosystem management. Learning followed the core phases of Problem-Based Learning: introducing authentic socio-scientific problems, identifying key issues, conducting collaborative investigations, evaluating scientific evidence, proposing evidence-based solutions, and reflecting on the learning process. Throughout these activities, students examined environmental issues from scientific and societal perspectives before drawing evidence-supported conclusions. In contrast, the control group studied the same biology content through the school's used PBL without SSI content, which relied primarily on teacher explanations, textbook discussions, and guided classroom exercises without explicit integration of socio-scientific issues.

Data Analysis

Students' scientific literacy performance was analysed using both descriptive and inferential statistics. Descriptive analysis included calculating mean scores, standard deviations, and normalised gain (N-gain) to describe learning improvement in each group. Before hypothesis testing, the data were examined for normality and homogeneity to ensure the assumptions for parametric analysis were met. Differences between the experimental and control groups were then analysed using an independent-samples *t*-test with a significance level of 0.05. Finally, Cohen's *d* effect size was calculated to estimate the practical magnitude of the SSI-PBL intervention on students' scientific literacy.

Results

This section reports the findings obtained from the study after the implementation of the SSI-PBL. To facilitate interpretation, the results are presented in a logical sequence, starting with descriptive statistics and continuing with hypothesis testing. Together, these analyses provide evidence of the model's contribution to improving students' scientific literacy in the context of the BBNSP heritage area.

Table 1

Descriptive Statistics of Students' Scientific Literacy Skills

Class	Score	$\bar{X}$ ± sd
Experiment	*Pretest*	28.7 ± 7.72
	Posttest	68.8 ± 8.91
Control	*Pretest*	31.9 ± 7.60
	Posttest	62.5 ± 8.95

$\bar{X}$; Everage, Sd; standard deviation

Table 2

Distribution of Students' Scientific Literacy N-Gain Scores

Class	N-Gain Criterion	Number of students	Percentage of *N-Gain (%)*
Experiment	High	6	16.67
	Medium	29	80.55
	Low	1	2.78
Control	High	1	2.78
	Medium	29	80.55
	Low	6	16.67

Based on Tables 1 and 2, students in the experimental group demonstrated greater improvement in scientific literacy than those in the control group. The N-gain analysis revealed that 80.55% of students in the experimental group achieved a moderate level of improvement, while 16.67% reached the high category. In contrast, only one student in the control group attained the high category. Most students (80.55%) showed moderate improvement, while the remaining 16.67% fell into the low category. These findings indicate that the SSI-PBL model was more effective than the conventional learning approach in enhancing students' scientific literacy.

To examine the effect of the SSI-PBL model on students' scientific literacy, an independent-samples *t*-test was conducted. Before hypothesis testing, the data were assessed for normality and homogeneity to ensure the *t*-test assumptions were met. Table 3 presents the results of these prerequisite tests.

Table 3

Results of the Assumption Tests and Independent Samples t -Test

Score	Class	Normality Test	Homogeneity Test	Independent Samples t-Test
N- Gain	Experiment	Sig. 0.131 > 0.05	Sig. 0.354 > 0.05	Sig. (2- tailed) 0.006 < 0.05
	Control	Sig. 0.126 > 0.05		

As shown in Table 3, the normality test indicated that the data were normally distributed (p > 0.05), while the homogeneity test confirmed that the variances were homogeneous (p > 0.05). Since these assumptions were satisfied, an independent-samples t-test was performed. The analysis yielded $p = 0.006$, which was lower than the significance level of 0.05. Therefore, the null hypothesis was rejected, indicating that the SSI-PBL model had a statistically significant effect on students' scientific literacy. To better understand this improvement, students' scientific literacy was further analysed across each literacy indicator. The results of this analysis are presented in Table 4.

Table 4

N-Gain Scores for Each Scientific Literacy Indicator

No	Scientific Literacy Indicator	*N- Gain*			
		Experiment	Category	Control	Category
1	Explain scientifically	0.43	Medium	0.27	Low

2	Evaluate and design scientific inquiry	0.52	Medium	0.36	Medium
3	Interpret data and evidence scientifically	0.68	Medium	0.63	Medium

As shown in Table 4, all scientific literacy indicators in the experimental group showed moderate improvement. The highest N-gain score was observed for the Interpret data and evidence scientifically indicator (0.68), followed by Evaluate and design scientific inquiry (0.52) and Explain phenomena scientifically (0.43). In contrast, the control group achieved only a low level of improvement (0.27) on the Explain phenomena scientifically indicator, highlighting a clear difference between the two groups.

To further examine the magnitude of the intervention's impact, an effect size analysis was conducted. This analysis provides additional evidence regarding the strength of the SSI-integrated Problem-Based Learning (SSI-PBL) model in improving students' scientific literacy. Table 5 presents the results of the effect size analysis.

Table 5

Effect Size Analysis Results for Students' Scientific Literacy

Class	$\bar{X}$ N- Gain	Standard deviation	Effect Size	Category
Experiment	0.55	0.13	0.67	Medium
Control	0.45	0.16		

As shown in Table 5, the effect size value of 0.67 indicates that the SSI-PBL model had a moderate effect on students' scientific literacy in learning ecosystem concepts.

Discussion

Students who participated in SSI-PBL consistently achieved better scientific literacy outcomes than those who learned using the PBL model without SSI (Table 1). This difference indicates that learning organised around authentic conservation issues creates richer opportunities for students to apply scientific knowledge, rather than learning focused primarily on conceptual explanations (Jacobson et al., 2015; Trilling & Fadel, 2013). Rather than treating environmental problems as textbook examples, students examined conservation challenges from BBSNP as situations that required scientific reasoning and evidence-based judgment. These experiences helped bridge the gap between classroom learning and environmental issues in their own region, providing empirical support for using locally grounded socio-scientific contexts to strengthen scientific literacy.

The improvement observed in the experimental class can be understood from the way SSI-PBL positions students as active participants in knowledge construction (Table 2). Throughout the learning process, students explored conservation problems, evaluated different sources of scientific evidence, discussed alternative viewpoints, and justified their proposed solutions. These activities required them to integrate conceptual understanding with inquiry and reasoning rather than rely on memorised information. At the same time, the local conservation context made the learning experience more relevant because the environmental issues being discussed were closely connected to students' surroundings (Ardoin et al., 2020; Baylon & Cabasan, 2026; Hsu, 2025; Purwasih et al., 2025). This combination of PBL and SSI relevance appears to have strengthened both students' understanding of science and their ability to use scientific knowledge in practical situations (Çalik & Wiyarsi, 2025; Hernández-Ramos et al., 2021; Högström et al., 2025; Purwasih et al., 2025).

The analysis of individual scientific literacy competencies provides a clearer picture of how students benefit from SSI-PBL (Table 4). The largest improvement occurred in interpreting scientific data and evidence, suggesting that frequent engagement with authentic ecological information enhanced students' ability to analyse and evaluate evidence before concluding. Students also showed noticeable gains in evaluating scientific investigations, reflecting greater confidence in identifying appropriate methods, assessing the quality of evidence, and considering alternative explanations for environmental problems. Although scientifically explaining the phenomenon produced the smallest gain among the three competencies, the improvement in scientific literacy using SSI-PBL was greater than that with PBL without SSI (Ayuwaningsih et al., 2025; Purnamasari et al., 2025). This pattern indicates that conceptual understanding developed alongside problem solving and evidence evaluation, rather than in isolation, allowing students to build a more integrated form of scientific literacy (Busch & Rajwade, 2024; Istyadji, 2023; Osborne, 2023; Schwartz et al., 2023).

Using BBSNP as the learning context also changes the way students interact with scientific concepts (Table 5). Many previous studies have incorporated socio-scientific issues related to climate change, renewable energy, or waste management (Colmenares-Quintero et al., 2023; Dawana & Setiani, 2023; Løkke et al., 2023; Monroe et al., 2019; Praimee & Boonserm, 2021; Sekhon et al., 2021), whereas this study focused on conservation challenges that students recognised from their own environment. Discussing biodiversity loss, habitat degradation, and human–wildlife interactions enables students to view science as a tool for understanding issues that directly affect their communities. This contextual connection adds to existing evidence that the effectiveness of SSI-PBL depends not only on the instructional model itself but also on the relevance of the learning context. Embedding science learning within authentic local conservation issues therefore offers a practical way to strengthen scientific literacy while fostering greater awareness of environmental responsibility (Fajri et al., 2026; Purwasih et al., 2025).

The present results align with earlier studies showing that SSI and PBL improve scientific literacy by encouraging inquiry, collaboration, and evidence-based reasoning(Çalik & Wiyarsi, 2025; Khairrunisa et al., 2025; Lin, 2026). However, most previous research has examined these approaches using broad environmental themes or classroom-based scenarios. In contrast, the learning activities in this study were embedded in conservation issues from BBSNP, allowing students to work with problems that reflected the ecological conditions of their own region. This difference is important because familiarity with local environmental challenges appears to make scientific concepts easier to understand and apply. The findings therefore extend current knowledge by showing that the value of SSI-PBL lies not only in its inquiry-oriented learning process but also in students' ability to connect science learning with environmental contexts recognised as part of their everyday lives.

Another point emerging from this study is that scientific literacy cannot be separated from the context in which learning takes place. Scientific literacy activities encourage students to ask questions, analyse evidence, and justify conclusions. However, these competencies become more meaningful when developed through issues students perceive as real and relevant. Using conservation problems from BBSNP enabled students to integrate scientific concepts with ecological and social considerations while evaluating possible solutions from multiple perspectives (Kahler, 2018; Lin, 2026; Ruyani & Matthews, 2017; Wulandari et al., 2023). This finding broadens current understanding of SSI-PBL by indicating that contextual relevance should be regarded as an essential component of scientific literacy instruction rather than simply as an additional feature of classroom activities.

The educational implications extend beyond the classroom. Science teachers can make greater use of locally relevant socio-scientific issues to encourage students to investigate environmental problems through scientific inquiry, rather than relying primarily on textbook explanations. Likewise, curriculum developers may consider incorporating local conservation resources into science learning so that students gain experience applying scientific knowledge in authentic situations (Ballard et al., 2017; Kimmerer, 2012; Sorensen et al., 2018). While this study showed positive results, the intervention was conducted over a relatively short period and in a single school. Further research is needed to examine whether similar results can be maintained across different science topics; the use of biology learning resources within the student's immediate environment, the number of schools used, educational level, and geographic environment are suggested limitations of this study. Such research would provide a broader understanding of how contextualised SSI-PBL can support the development of long-term scientific literacy.

Conclusion

Studi ini menunjukkan bahwa integrasi SSI-PBL dalam konteks konservasi BBSNP secara efektif meningkatkan literasi ilmiah siswa sekolah menengah. Siswa mencapai peningkatan yang signifikan tidak hanya dalam literasi ilmiah secara keseluruhan, tetapi juga dalam kemampuan mereka untuk menjelaskan fenomena ilmiah, mengevaluasi investigasi ilmiah, dan menafsirkan bukti ilmiah dalam konteks lingkungan yang autentik. Dengan melibatkan siswa dalam isu-isu konservasi autentik, pendekatan ini memperdalam pemahaman konseptual sekaligus mendorong penalaran kritis serta rasa tanggung jawab lingkungan yang lebih kuat. Akibatnya, siswa mengembangkan literasi ilmiah sebagai kompetensi praktis yang dapat diterapkan untuk menangani isu-isu lingkungan di luar kelas. Selain mengonfirmasi efektivitas SSI-PBL, studi ini menunjukkan bagaimana konteks konservasi lokal dapat memperkuat hubungan antara konsep ilmiah, praktik penyelidikan, dan pengambilan keputusan berbasis bukti. Temuan ini menggarisbawahi bahwa pembelajaran sains yang sukses tidak hanya bergantung pada pilihan model pembelajaran tetapi juga pada relevansi konteks pembelajaran. Ketika siswa menyelidiki isu-isu lingkungan yang secara langsung memengaruhi komunitas mereka, pengetahuan ilmiah menjadi lebih bermakna dan lebih mudah diterapkan dalam situasi kehidupan sehari-hari. Studi di masa mendatang dapat meneliti dampak jangka panjang SSI-PBL pada berbagai topik sains, tingkat pendidikan, dan lingkungan geografis untuk menentukan penerapan pendekatan ini secara lebih luas.

Suggestions for Future Research

This study demonstrates that SSI-PBL using authentic conservation issues can effectively improve students' scientific literacy. Future research could examine whether similar outcomes are achieved in other science topics, educational levels, and regions with different environmental characteristics. Such studies would help determine the broader applicability of contextualised SSI-PBL across diverse learning settings. Further research could also explore how field-based learning, digital technologies, or partnerships with conservation organisations enrich students' learning experiences. In addition to scientific literacy, future studies should examine outcomes such as environmental responsibility, decision-making, and conservation behaviour to provide a more comprehensive understanding of the educational impact of contextualised science learning.

Acknowledgements

The researchers thank the principal for permission to conduct research at the sample school.

Conflict of interest

None.

Funding

None.

References

íAlcaraz-Dominguez, S. (2024). SSI as An Educational Innovation in Spain: Easier Said Than Done. In *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues* (pp. 245–268). Springer.

Allchin, D., & Zemplén, G. Á. (2020). Finding the place of argumentation in science education: Epistemics and Whole Science. *Science Education*, *104*(5), 907–933. https://doi.org/10.1002/sce.21589

Al-Thani, N. J., & Ahmad, Z. (2025). The scope of problem-based learning and integrated research education for primary learners. In *Teaching and Learning with Research Cognitive Theory: Unlocking Curiosity and Creativity for Problem-Solving Skills* (pp. 25–43). Springer.

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation*, *241*, 108224. https://doi.org/10.1016/j.biocon.2019.108224

Arifin, Z., Sukarmin, S., & Saputro, S. (2026). Culturally sustaining inquiry learning integrated with socioscientific issues as a conceptual framework for equitable and sustainable science education. *Discover Sustainability*. https://doi.org/10.1007/s43621-026-03624-9

Ayuwaningsih, M. S., Marianti, A., Irsadi, A., Dewi, N. R., & Widiyatmoko, A. (2025). Development of E-LKPD Ecology and Biodiversity Using PBL-SSI to Enhance Secondary Students' Environmental Literacy. *Jurnal Bioedukatika*, *13*(1).

Badeo, J. M., & Duque, D. A. (2022). The effect of Socio-Scientific Issues (SSI) in teaching science: A meta-analysis study. *Journal of Technology and Science Education*, *12*(2), 291–302. https://doi.org/10.3926/jotse.1340

Ballard, H. L., Dixon, C. G. H., & Harris, E. M. (2017). Youth-focused citizen science: Examining the role of environmental science learning and agency for conservation. *Biological Conservation*, *208*, 65–75. https://doi.org/10.1016/j.biocon.2016.05.024

Baylon, R. J., & Cabasan, M. T. N. (2026). Biodiversity conservation narratives and its integration in environmental education: A systematic review. *Biological Conservation*, *321*, 111978. https://doi.org/10.1016/j.biocon.2026.111978

Blumberg, P. (2005). Assessing students during the problem-based learning (PBL) process. *Journal of the International Association of Medical Science Educators*, *15*(2), 92–99.

Busch, K. C., & Rajwade, A. (2024). Conceptualizing community scientific literacy: Results from a systematic literature review and a Delphi method survey of experts. *Science Education*, *108*(5), 1231–1268. https://doi.org/10.1002/sce.21871

Çalik, M., & Wiyarsi, A. (2025). The effect of socio-scientific issues-based intervention studies on scientific literacy: A meta-analysis study. *International Journal of Science Education*, *47*(3), 399–421. https://doi.org/10.1080/09500693.2024.2325382

Colmenares-Quintero, R. F., Caicedo-Concha, D. M., Rojas, N., Stansfield, K. E., & Colmenares-Quintero, J. C. (2023). Problem based learning and design thinking methodologies for teaching renewable energy in engineering programs: Implementation in a Colombian university context. *Cogent Engineering*, *10*(1), 2164442. https://doi.org/10.1080/23311916.2022.2164442

Cooke, S. J., Cook, C. N., Nguyen, V. M., Walsh, J. C., Young, N., Cvitanovic, C., Grainger, M. J., Randall, N. P., Muir, M., & Kadykalo, A. N. (2023). Environmental evidence in action: On the science and practice of evidence synthesis and evidence-based decision-making. *Environmental Evidence*, *12*(1), 10. https://doi.org/10.1186/s13750-023-00302-5

Dawana, I. R., & Setiani, R. (2023). Validity of Teaching Modules with Problem-Based Learning (PBL) Model Assisted by E-Book to Improve Problem-Solving Skills on Renewable Energy Material and Implementation of Independent Learning Curriculum. *Journal of Physics: Conference Series*, *2623*(1), 012015.

Dibner, K. A., & Snow, C. E. (2016). *Science literacy: Concepts, contexts, and consequences*.

Dragoş, V., & Mih, V. (2015). Scientific literacy in school. *Procedia-Social and Behavioral Sciences*, *209*, 167–172. https://doi.org/10.1016/j.sbspro.2015.11.273

Eberbach, C., & Crowley, K. (2009). From everyday to scientific observation: How children learn to observe the biologist's world. *Review of Educational Research*, *79*(1), 39–68. https://doi.org/10.3102/0034654308325899

Eryasar, A. S., & Kilinc, A. (2022). The coherence between epistemologies and SSI teaching: A multiple-case study with three science teachers. *Science & Education*, *31*(1), 123–147. https://doi.org/10.1007/s11191-021-00200-7

Fajri, N., Arnyana, I. B. P., Adnyana, P. B., Made, D., Fajri, S. R., Sarnita, F., & Fitriani, H. (2026). Integration of local potential and innovative learning methods to improve environmental awareness: A systematic literature review. *Journal of Turkish Science Education*.

Guerrero, G., Rojas-Avilez, L., González-Weil, C., Ibaceta-Guerra, N., Martínez-Pérez, L., & Rosas-Pari, L. M. (2024). Science education for students' critical scientific and environmental literacies: Experiences from Latin America. In *Rethinking Science Education in Latin-America: Diversity and Equity for Latin American Students in Science Education* (pp. 23–42). Springer.

Hall, V. J. (2017). Exploring teacher–student interactions: Communities of practice, ecological learning systems–or something else? *Journal of Further and Higher Education*, *41*(2), 120–132. https://doi.org/10.1080/0309877X.2015.1070395

Herman, B. C., Newton, M. H., & Zeidler, D. L. (2021). Impact of place-based socioscientific issues instruction on students' contextualization of socioscientific orientations. *Science Education*, *105*(4), 585–627. https://doi.org/10.1002/sce.21618

Hernández-Ramos, J., Pernaa, J., Cáceres-Jensen, L., & Rodríguez-Becerra, J. (2021). The Effects of Using Socio-Scientific Issues and Technology in Problem-Based Learning: A Systematic Review. *Education Sciences*, *11*(10), 640. https://doi.org/10.3390/educsci11100640

Hidayatullah, & Setiawan, B. (2024). Empowering students' collaborative skills sustainability by utilizing problem-based learning as an instructional strategy in online learning. *Cogent Education*, *11*(1), 2362006. https://doi.org/10.1080/2331186X.2024.2362006

Högström, P., Gericke, N., Wallin, J., & Bergman, E. (2025). Teaching Socioscientific Issues: A Systematic Review: P. Högström et al. *Science & Education*, *34*(5), 3079–3122. https://doi.org/10.1007/s11191-024-00542-y

Hsu, C.-H. (2025). Outdoor environmental education as a nature-based solution for "education" and "environment": A new conceptual framework and its pilot application in a coastal community case study in Taiwan. *Journal of Coastal Conservation*, *29*(1), 13. https://doi.org/10.1007/s11852-025-01099-w

Istyadji, M. (2023). Conception of scientific literacy in the development of scientific literacy assessment tools: A systematic theoretical review. *Journal of Turkish Science Education*, *20*(2), 281–308. https://doi.org/10.36681/tused.2023.016

Jacobson, S. K., McDuff, M. D., & Monroe, M. C. (2015). *Conservation education and outreach techniques*. Oxford University Press.

Kahler, J. S. (2018). *The Situational Prevention of Wildlife Poaching in Bukit Barisan Selatan National Park, Sumatra, Indonesia*. Michigan State University.

Kattumuri, R. (2018). Sustaining natural resources in a changing environment: Evidence, policy and impact. In *Contemporary Social Science* (Vol. 13, Number 1, pp. 1–16). Taylor & Francis.

Khairrunisa, A. N., Yusup, I. R., & Paujiah, E. (2025). Improving students' scientific literacy through a problem-based learning model integrated with socio-scientific issues on ecosystem learning. *Biosfer*, *18*(2), 276–289. https://doi.org/10.21009/biosferjpb.55744

Kimmerer, R. W. (2012). Searching for synergy: Integrating traditional and scientific ecological knowledge in environmental science education. *Journal of Environmental Studies and Sciences*, *2*(4), 317–323. https://doi.org/10.1007/s13412-012-0091-y

Kinskey, M. (2026). Facilitating Socioscientific Reasoning Online: A Middle Grades Science Teacher's Engagement with Socioscientific Issues. *Journal of Science Teacher Education*, 1–19. https://doi.org/10.1080/1046560X.2026.2700929

Kopbayeva, M., Uspabayeva, A., & Atici, T. (2026). The effect of inquiry-based learning compared with traditional instruction on the learning outcomes of pre-service biology teachers: A systematic review. *Frontiers in Education*, *11*, 1854373.

Lee, Y.-F., Lee, L.-S., & Nguyen, H. B. N. (2023). A comparison of STEM education status and trends in five highly competitive countries in the Asia-Pacific region. *Journal of Asian Vocational Education and Training*, *16*(2).

Lin, S. (2026). Teaching Climate Change as a Socio-Scientific Issue: A Systematic Review of Strategies and Outcomes in Secondary Science Education (2021-2026). *OALib*, *13*(04), 1–14. https://doi.org/10.4236/oalib.1115169

Løkke, S., Nielsen, H. N., & Holgaard, J. E. (2023). Problem-Based Learning Approach Facilitating Sustainable Waste Management. *Journal of Problem Based Learning in Higher Education*, *11*(3), 119–129. https://doi.org/10.54337/ojs.jpblhe.v11i3.7828

Lymbouridou, C. (2025). Science for ethics in SSI discussions. *Cultural Studies of Science Education*, *20*(3), 389–429. https://doi.org/10.1007/s11422-025-10258-2

McCarthy, J. L., Wibisono, H. T., McCarthy, K. P., Fuller, T. K., & Andayani, N. (2015). Assessing the distribution and habitat use of four felid species in Bukit Barisan Selatan National Park, Sumatra, Indonesia. *Global Ecology and Conservation*, *3*, 210–221. https://doi.org/10.1016/j.gecco.2014.11.009

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., & Chaves, W. A. (2019). Identifying effective climate change education strategies: A systematic review of the research. *Environmental Education Research*, *25*(6), 791–812. https://doi.org/10.1080/13504622.2017.1360842

O'Brien, T. G., & Kinnaird, M. F. (1996). Birds and mammals of the Bukit Barisan Selatan national park, Sumatra, Indonesia. *Oryx*, *30*(3), 207–217. https://doi.org/10.1017/S0030605300021657

Osborne, J. (2023). Science, scientific literacy, and science education. In *Handbook of research on science education* (pp. 785–816). Routledge.

Pluta, W. J., Richards, B. F., & Mutnick, A. (2013). PBL and beyond: Trends in collaborative learning. *Teaching and Learning in Medicine*, *25*(sup1), S9–S16. https://doi.org/10.1080/10401334.2013.842917

Praimee, U., & Boonserm, W. (2021). The Effects of Learning Activities on Waste and Sewage Management Using Question and Problems-Based Learning for Undergraduate Students of Mahasarakham University, Thailand. *Journal of Educational Issues*, *7*(1), 72. https://doi.org/10.5296/jei.v7i1.18267

Purnamasari, A. P., Suma, K., & Rapi, N. K. (2025). The Effect of Problem-Based Learning within Socioscientific Contexts on Students' Scientific Literacy and Argumentation Skills. *Jurnal Penelitian Pendidikan IPA*, *11*(10), 707–716. https://doi.org/10.29303/jppipa.v11i10.11970

Purwasih, D., Wilujeng, I., Wiyarsi, A., & Zakwandi, R. (2025). The socio-scientific issue based on local potential in integrated learning instruction to improve student ecological literacy. *Science & Education*, 1–24.

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In *Handbook of research on science education, Volume II* (pp. 545–558). Routledge.

Ruyani, A., & Matthews, C. E. (2017). A Comparative Look at Informal Science Education and Environmental Education in Bengkulu Province, Indonesia and North Carolina, USA. In P. G. Patrick (Ed.), *Preparing Informal Science Educators: Perspectives from Science Communication and Education* (pp. 387–417). Springer International Publishing. https://doi.org/10.1007/978-3-319-50398-1_20

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *46*(8), 909–921.

Salsabila Allissa Fitri, H., & Ma'arif, A. (2025). Understanding how socio-scientific issues shape science education worldwide: A systematic review. *EPJ Web of Conferences*, *344*, 01051.

Sanchez, J. M. P., Picardal, M. T., Fernandez, S. R., & Caturza, R. R. A. (2024). Socio-Scientific Issues in Focus: A Meta-analytical Review of Strategies and Outcomes in Climate Change Science Education. *Science Education International*, *35*(2), 119–132. https://doi.org/10.33828/sei.v35.i2.6

Schwartz, R. S., Lederman, J. S., & Enderle, P. J. (2023). Scientific inquiry literacy: The missing link on the continuum from science literacy to scientific literacy. In *Handbook of research on science education* (pp. 749–782). Routledge.

Sekhon, N., Beach, T., Krause, S., & Eshleman, S. (2021). Understanding climate trends in Central America through practical problem-based learning. *Journal of Geography in Higher Education*, *45*(2), 298–318. https://doi.org/10.1080/03098265.2020.1833318

Shan, G., & Jain, J. A. (2026). Decision-Making Involving Socioscientific Issues: A Systematic. *Asian Journal of University Education (AJUE)*, *22*(1).

She, H. C., Stacey, K., & Schmidt, W. H. (2018). Science and mathematics literacy: PISA for better school education. *International Journal of Science and Mathematics Education*, *16*(Suppl 1), 1–5. https://doi.org/10.1007/s10763-018-9911-1

Sorensen, A. E., Corral, L., Dauer, J. M., & Fontaine, J. J. (2018). Integrating authentic scientific research in a conservation course–based undergraduate research experience. *Natural Sciences Education*, *47*(1), 1–10. https://doi.org/10.4195/nse2018.02.0004

Sukackė, V., Guerra, A. O. P. de C., Ellinger, D., Carlos, V., Petronienė, S., Gaižiūnienė, L., Blanch, S., Marbà-Tallada, A., & Brose, A. (2022). Towards active evidence-based learning in engineering education: A systematic literature review of PBL, PjBL, and CBL. *Sustainability*, *14*(21), 13955. https://doi.org/10.3390/su142113955

Tijani, B. E., & Adeduyigbe, A. M. (2026). Systematic review of science education approaches to climate change education and sustainable development goal 13. *Discover Environment*, *4*(1), 241. https://doi.org/10.1007/s44274-026-00771-8

Trilling, B., & Fadel, C. (2013). *21st century skills: Learning for life in our times*. Jossey-Bass.

Vaino, K., Korfiatis, K., Astapova, A., Popov, O., Valdmann, A., & Orru, H. (2026). Navigating Post-truth: Challenges and Opportunities for Science Education Through Evolving Scientific Literacy Visions. *Science & Education*, 1–38.

Wahono, B., Lin, P.-L., & Chang, C.-Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education*, *7*(1), 36. https://doi.org/10.1186/s40594-020-00236-1

Weiskopf, S. R., McCarthy, J. L., McCarthy, K. P., Shiklomanov, A. N., Wibisono, H. T., & Pusparini, W. (2019). The conservation value of forest fragments in the increasingly agrarian landscape of Sumatra. *Environmental Conservation*, *46*(4), 340–346. https://doi.org/10.1017/S0376892919000195

Wulandari, Nanda Kurniasari, Wulan Ayu Lestari, Arif Ilmayawan, Hari Kaskoyo, & Samsul Bakri. (2023). Function and effectiveness of Management of the Bukit Barisan Selatan National Park, Indonesia. *International Journal of Life Science Research Archive*, *4*(1), 189–197. https://doi.org/10.53771/ijlsra.2023.4.1.0033

Xie, Y., & Yusuf, A. (2026). Advancing scientific literacy: A systematic review of trends, pedagogies and challenges in the 21st century. *Review of Education*, *14*(1), e70140. https://doi.org/10.1002/rev3.70140

Yamada, A. (2023). STEM field demand and educational reform in Asia-Pacific countries. *The Oxford Handbook of Higher Education in the Asia-Pacific Region*, 189–209. https://doi.org/10.1093/oxfordhb/9780192845986.013.9

Zeidler, D. L., & Sadler, T. D. (2023). Exploring and expanding the frontiers of socioscientific issues. In *Handbook of research on science education* (pp. 899–929). Routledge.