



The Effect of Integrated Problem-Based Learning SDG Point 6 on Improving Sustainability Literacy of High School Students

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Abstract: This study aimed to examine the effect of Problem-Based Learning (PBL) integrated with SDG point 6 on students' sustainability literacy related to water pollution. A quasi-experimental method with a non-equivalent control group pretest-posttest design was employed involving two tenth-grade classes at a senior high school in Garut, selected through convenience sampling. The research instrument consisted of 15 essay questions measuring three aspects of sustainability literacy: knowledge, skills, and mindset. The instrument was validated by experts and demonstrated high reliability (Cronbach's $\alpha = 0.92$). Data were analyzed through normality and homogeneity tests followed by an Independent Samples T-test. The results indicated that there was no statistically significant difference in total post-test scores between the experimental class using SDG-integrated PBL and the control class using discovery learning (two-tailed Sig. = 0.07). However, the experimental class showed greater mean improvements, particularly in the skills and mindset aspects, compared to the control class. In conclusion, PBL integrated with SDG 6 shows a tendency to enhance students' sustainability literacy, especially in terms of skills and mindset, although its overall effect was not statistically significant. The findings imply the need for better alignment between assessment instruments and learning contexts, student habituation to PBL, longer intervention periods, and further analyses to more sensitively evaluate instructional effectiveness.

Abstrak: Tujuan penelitian ini adalah menganalisis pengaruh pembelajaran berbasis masalah (Problem-Based Learning/PBL) yang diintegrasikan dengan SDG poin 6 terhadap literasi keberlanjutan siswa pada materi pencemaran air. Penelitian menggunakan metode kuasi-eksperimen dengan desain non-equivalent control group pretest-posttest yang dilaksanakan pada dua kelas X di salah satu SMA di Kota Garut melalui teknik sampling kemudahan. Instrumen penelitian berupa 15 soal esai yang mengukur tiga aspek literasi keberlanjutan, yaitu pengetahuan, keterampilan, dan mindset, yang telah divalidasi oleh ahli dan menunjukkan reliabilitas tinggi ($\alpha = 0,92$). Data dianalisis menggunakan uji normalitas, homogenitas, dan Independent Samples T-test. Hasil analisis menunjukkan bahwa tidak terdapat perbedaan yang signifikan secara statistik antara kelas eksperimen dan kelas kontrol pada skor post-test total (Sig. 2-tailed = 0,07). Namun demikian, kelas eksperimen menunjukkan peningkatan rata-rata yang lebih tinggi, terutama pada aspek keterampilan dan mindset, dibandingkan kelas kontrol. Kesimpulannya, PBL terintegrasi SDG 6 memiliki kecenderungan meningkatkan literasi keberlanjutan siswa, khususnya pada aspek keterampilan dan pola pikir, meskipun belum terbukti signifikan secara statistik. Implikasi penelitian ini menekankan pentingnya penyelarasan instrumen dengan konteks pembelajaran, pembiasaan siswa terhadap PBL, serta durasi intervensi dan analisis lanjutan untuk menguji efektivitas secara lebih komprehensif.

A. Introduction

Current environmental problems are increasingly worrying and pose a serious threat to life on Earth. Water pollution has profound impacts on ecosystems, human life, and climate change (Maruf, 2021). Water pollution occurs when pollutants enter water, including gases, chemicals, and particulates (Gusmarti et al., 2020). Based on data from the KLHK (2020), the West Java region experienced water pollution with a IKA (Water Quality Index) status that was polluted in the parameters of Dissolved Oxygen (DO), Biochemical Oxygen Demand (BDO), Chemical Oxygen Demand (COD), Fecal Coliform, and Total Coliform at values that exceeded the recommended quality standards (Liyanto et al., 2022).

In 2015, on September 25th, 193 countries belonging to the United Nations (UN) declared and agreed jointly on the targets of *the Sustainable Development Goals* (SDGs) which were expected to be achieved by 2030 (Adam, 2021). The agreement resulted in 17 SDGs goals, one of which was SDG point 6 related to the availability of clean water and sanitation. SDG point 6 aims to ensure the availability of sustainable water and sanitation, as well as the ease and security of people to obtain access to safe water (Elysia, 2018). Efforts to realize SDG point 6 can be done through education, education plays an important role in the formation of knowledge, attitudes, ways of thinking and awareness of students in acting in the future, this can make students agents of change in sustainable development (Putri et al., 2023).

In achieving sustainable development, sustainability literacy is an important indicator that needs to be developed in students, primarily through education (Sanchez et al., 2025). Sustainability literacy provides an overview of students' knowledge, understanding, and actions in making decisions about sustainability for the future. These actions are part of preparing themselves to face challenges and make decisions, such as those related to environmental crises and climate change (Sanchez et al., 2025; Chinedu et al., 2023; UNESCO, 2017). According to Décamps et al (2017), sustainability literacy comprises three aspects: knowledge, skills, and mindset.

The knowledge aspect describes an individual's ability to apply knowledge to real situations, including collaboration, problem-solving, and decision-making (Sani et al., 2025). The skills aspect includes the ability to apply sustainability concepts in everyday life through efficient, practical actions (Sani et al., 2025). The mindset aspect includes changes that support a responsible attitude and foster awareness of the importance of sustainability in achieving future solutions (Sani et al., 2025; Kokkarinen & Cotgrave, 2013).

Sustainability literacy is important for students to understand and be aware of the concept of sustainability, which is crucial for future life and for developing knowledge, skills, and mindsets to build a sustainable future (Umbara & Handayani, 2023). Sustainability literacy, integrated with the concept of water pollution due to human activities, is expected to provide students with an understanding of the importance of adequate water and sanitation. Clean water and sanitation are related to the health and quality of life of individuals (Zulkarnain et al, 2023). In this case, sustainability literacy integrated with SDG 6, in the context of real water pollution problems caused by human

activities, is expected to be an effort to prepare, maintain, and foster students' awareness of the importance of maintaining the quality of life through the availability of clean water and good sanitation.

Based on several studies, students' sustainability literacy, especially in Indonesia, is low (Putri et al., 2023; Sani et al., 2025; Amalia et al., 2025). Developing students' sustainability literacy can be achieved through contextual learning, direct observation methods, training, stimulation, and the practice of sustainable behaviors (Adam, 2021). Learning strategies that can be implemented to support contextual learning include problem-based learning (PBL) models.

In this study, the PBL stages used are divided into seven stages, namely: (1) Problem identification, (2) Formulating the problem, (3) Planning the investigation, (4) Carrying out the investigation, (5) Analyzing data, (6) Drawing conclusions, and (7) Implementation (Widodo, 2021). In this case, PBL is oriented towards knowledge built and supported through experience, problem-solving, and independent social and environmental interactions (Syamsidah & Suryani, 2018; Amalia et al., 2025). The context of the problem in PBL is a real-life problem relevant to everyday life and, if left unsolved, will have a negative impact (Syamsidah & Suryani, 2018; Widodo, 2021; Amalia et al., 2025). In this study, the problem discussed and solved is water pollution in the Cimanuk tributary caused by human activities, such as the disposal of household, industrial, and agricultural waste and garbage.

The PBL model is one of the innovative learning strategies in realizing *Educational Sustainable Development* (ESD) in schools (Evans, 2019). The application of the PBL model can develop sustainability competencies in students, such as systems thinking, anticipatory thinking, collaborative thinking, critical thinking, normative thinking, strategic thinking, problem-solving skills, and student self-awareness (Llach & Bastida, 2022; Lozano et al., 2022). The use of PBL in learning, specifically integrated with the SDGs, is expected to develop students' sustainability literacy, focusing on the individual's role in achieving the SDGs. This is also in line with research by Llach et al (2022), which reported results from the implementation of integrated PBL. The SDGs can foster sustainability competencies and educate students to act as agents of change in addressing global issues. The PBL model can also foster students' knowledge development through in-depth inquiry and reflection as part of the problem-solving process (Lim, 2023). In addition, PBL can improve students' critical thinking, collaboration, and creativity skills (Lim, 2023).

Based on previous studies, research on Problem-Based Learning (PBL) has predominantly emphasized general learning outcomes or sustainability awareness, while limited attention has been given to examining how PBL contributes to the development of each specific aspect of sustainability literacy, namely knowledge, skills, and mindset (Kieu et al., 2016; Décamps et al., 2017; Putri et al., 2023; Sani et al., 2025). Moreover, empirical evidence on the integration of PBL with specific Sustainable Development Goals, particularly SDG point 6 concerning clean water and sanitation, remains scarce in secondary education contexts. This gap indicates a need for more focused investigations that assess not only overall sustainability literacy but also its multidimensional aspects within authentic

environmental problem settings. Addressing this gap, the present study offers novelty by empirically examining the effectiveness of PBL integrated with SDG point 6 in fostering students' sustainability literacy across its core dimensions in the context of water pollution. Accordingly, this study seeks to answer the research question of whether and to what extent SDG-integrated PBL influences students' sustainability literacy, both overall and by aspect. The objective of this research is therefore to analyze the effect of SDG point 6-integrated PBL on students' sustainability literacy related to water pollution, while providing insights into sustainable learning strategies grounded in real-world environmental issues to support the development of students' awareness and responsibility toward environmental protection.

B. Method

The method used in this study was a *quasi-experimental, pre-posttest, non-equivalent control group design* (Creswell, 2019). This design used non-randomly selected experimental and control groups. The experimental class was taught using the problem-based learning (PBL) model integrated with SDG 6, and the control class was taught using the conventional *discovery learning* model. The research design is presented in the table below.

Table 1. Research Design Used

Group	Pre-test	Treatment	Post-test
Experimental Group	O ₁	X	O ₂
Control Group	O ₁	-	O ₂

Information:

- O₁ : Administering a Sustainability Literacy Pre-test
- O₂ : Administering a Sustainability Literacy Post-test
- X : Problem-based learning (PBL) integrated with SDG point 6
- : Conventional learning

This research was conducted from May to April 2025 at one of the Senior High Schools in Garut City, with the sample population consisting of all class X students. The sampling technique used was *convenience sampling* based on the considerations of teachers and school management as the research location. The sample consisted of two classes: an experimental class receiving an integrated PBL learning treatment on SDG point 6 and a control class using conventional learning.

The instrument used in this study was a sustainability literacy essay question sheet, with sustainability literacy indicators adopted from *the Sustainability Literacy Test* (Sulites) according to Décamps et al (2017), covering three main aspects: knowledge, skills, and mindset. The sustainability literacy instrument used was also adjusted to the SDG learning objective 6, according to UNESCO (2017). The sustainability literacy instrument comprised 15 essay questions: 8 on the knowledge aspect, three on the skills aspect, and four on the

mindset aspect. The assessment used a Likert scale with a score range of 0-3. Both groups were given an initial test (pre-test) and a final test (post-test) of sustainability literacy to determine students' sustainability literacy abilities before and after the treatment. The following is presented. The indicators of the sustainability literacy instruments used in the research are shown in Table 2.

Table 2. Sustainability Literacy Indicators

KNOWLEDGE ASPECT
<p>Knowledge About Humanity and Sustainable Ecosystems on Planet Earth:</p> <ol style="list-style-type: none"> 1. Ecosystems: Biosphere, global and local ecosystems, interdependent and diverse communities of life, life-supporting cycles, closed (material)/open (energy) systems, etc. 2. Humanity: Individual human needs, diversity, social structures, culture, the local and global world, etc. 3. Sustainability: Definition of Sustainability / Sustainable Development. 4. Ecological perspective: where we are and why sustainability is both an urgency and an opportunity 5. Social perspective: where we are (demographics, inequality, gender equality, education), and sustainability becomes an urgency and an opportunity
<p>Knowledge About Global and Local Systems Built by Humans to Answer Society's Needs:</p> <ol style="list-style-type: none"> 6. Social and global governance structures: paradigms, favorable outcomes, negative impacts, laws, organizational functioning, land use, gender equality, etc. 7. Local and global social structures and governance, discussing: education and culture 8. Local and global economic systems: paradigms; positive outcomes and negative impacts; production, distribution, consumption of goods and services; life cycles; value chains; finance; etc. 9. In local and global economic systems, focus on: water, energy, and food
<p>Knowledge About Sustainable Transition:</p> <ol style="list-style-type: none"> 10. How to initiate, strengthen, and accelerate system change 11. Initiatives towards sustainability are more from the institutional/international level (such as UN MDGs, Global Compact, GIEC, GRI, ISO 26000, ESD, etc.) 12. Concepts, tools, frameworks, more from individual NGOs or smaller networks (such as Natural Capitalism, The Natural Step, Ecological Footprint, etc.) 13. Examples and ideas to learn from: case studies of success or failure; technological, strategic, or social innovation.
<p>Knowledge About the Role of Shaping/Maintaining Individual and System Change:</p> <ol style="list-style-type: none"> 14. How does one become aware of one's own role and impact? 15. How one acts efficiently to create individual and systemic change
SKILL ASPECT
<p>Personal Skills:</p> <ol style="list-style-type: none"> 16. Ability to reflect/evaluate oneself and in groups; Ability to continuously renew energy; Ability to continuously learn/develop; Creativity; Critical thinking 17. Ability to empathize, compassion, and solidarity; Future-oriented and strategic thinking. 18. Dealing with complexity and uncertainty; Practical problem-solving/management/planning skills.
<p>Collaboration Skills:</p> <ol style="list-style-type: none"> 19. Networking, communication skills, and building effective coalitions for systemic change 20. Catalyzing/managing change; Inspiring a shared vision; Enabling/motivating others to act/participate.

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21. Teamwork; Working in a multicultural and interdisciplinary (diverse) environment; Participatory skills, decision-making; Conflict resolution/consensus building skills; Focus on process, dialogue, listening.
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Skills in Thinking and Acting Systematically

22. Ability to apply systems thinking concepts in practice; identify and use leverage points.
 23. The ability to zoom in and out on time and detail, and to keep in mind a desired future and global perspective.
 24. Ability to understand formal and informal structures, power dynamics, and interactions
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MINDSET

Mindset in Sustainability Issues

25. Respect and care for the community of life, now and in the future
 26. Humans are part of nature and not separate from it.
 27. Holistic versus mechanistic worldview
 28. The golden rule (treat others as you would like to be treated)
 29. The belief that one can initiate and strengthen personal and systemic change towards sustainability
 30. Active commitment to solving sustainability issues
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The research procedure began with the creation of a descriptive question sheet instrument on sustainability literacy based on a grid that corresponds to the aspects and indicators of sustainability literacy, containing water pollution content. The validation of the question sheet was conducted by three experts from the Biology Education Study Program at Universitas Pendidikan Indonesia. The sustainability literacy question sheet was also piloted with a sample of 11th-grade students to determine its reliability, validity, and difficulty level.

Reliability tests are conducted to assess the consistency of the instruments used. Reliable instruments have relatively similar measurement results. Validity testing is conducted to assess an instrument's validity, i.e., whether it measures what it should (Arikunto, 2013). Based on the results of the test of the question instrument, the reliability value obtained was 0.92, which falls into the high criteria; the validity of the questions is in the sufficient and high criteria; the level of difficulty of the questions is in the moderate criteria, and the discriminatory power is in the sufficient and reasonable criteria. The results of the reliability and validity tests for the instrument are presented in Table 3.

Table 3. Results of the Reliability and Validity Test of the Sustainability Literacy Instrument

No Question	Reliability	Validity	
		Mark	Interpretation
1.	0.92 (Reliable)	0.46	Valid
2.		0.57	Valid
3.		0.49	Valid
4.		0.45	Valid
5.		0.54	Valid
6.		0.69	Valid
7.		0.48	Valid
8.		0.71	Valid
9.		0.55	Valid

No Question	Reliability	Validity	
		Mark	Interpretation
10.		0.65	Valid
11.		0.66	Valid
12.		0.57	Valid
13.		0.57	Valid
14.		0.55	Valid
15.		0.74	Valid

The data from *the pretest-posttest* of sustainability literacy were then analyzed quantitatively using *the Independent Samples T-test* T SPSS version 27. Before conducting the test of the difference in the average using the *Independent Sample t-Test* in the experimental and control classes, a prerequisite test was conducted using normality and homogeneity tests to ensure the data met the parametric assumptions. The following presents the research flow shown in Figure 1.

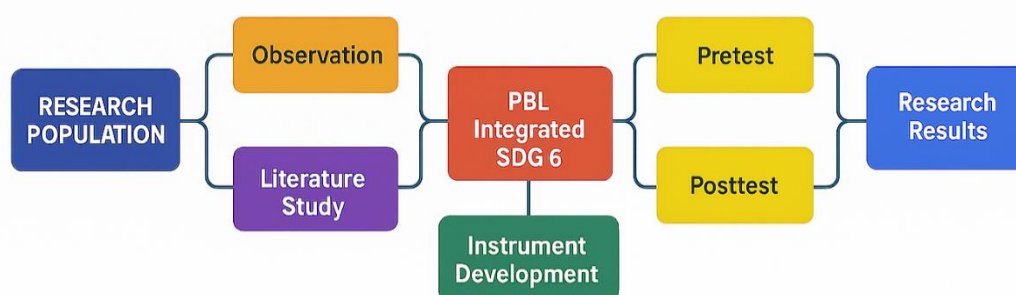


Figure 1. Research Flow

Figure 1 illustrates the sequence of the quasi-experimental research process, beginning with the selection of the experimental and control groups, followed by the administration of a sustainability literacy pre-test. The experimental group then received Problem-Based Learning integrated with SDG point 6, while the control group was taught using discovery learning. After the instructional intervention, both groups completed a post-test to measure changes in sustainability literacy. The research flow concludes with prerequisite testing (normality and homogeneity) and statistical data analysis using the Independent Samples T-test to determine the effect of the intervention.

C. Result

Data analysis was conducted to determine the effect of integrated problem-based learning (PBL) on students' sustainability literacy in line with SDG 6. The data were obtained based on pre-test and post-test *results*. Sustainability literacy of students in the experimental class using integrated PBL learning based on SDG 6 and the control class using *discovery learning*: pre-test data and post-test. The sustainability literacy test results from the experimental and control classes were then subjected to prerequisite tests for normality and homogeneity. The results of the normality and homogeneity tests are presented in Table 4.

Table 4. Results of Normality and Homogeneity Tests**1. Normality Test**

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Experimenta l pre-test	.105	36	.200 *	.973	36	.519
Pre-test control	.094	34	.200 *	.946	34	.095
Experimenta l post-test	.129	36	.134	.956	36	.163
Post-test control	.115	34	.200 *	.949	34	.118

2. Homogeneity Test

		Levene Statistics	df1	df2	Sig.
Pre-test Results	Based on Mean	.009	1	68	.924
	Based on Median	.006	1	68	.940
	Based on Median and with adjusted df	.006	1	66,915	.940
	Based on the trimmed mean	.014	1	68	.906
		Levene Statistics	df1	df2	Sig.
Post- test Results	Based on Mean	.174	1	68	.678
	Based on Median	.174	1	68	.678
	Based on Median and with adjusted df	.174	1	67,291	.678
	Based on the trimmed mean	.147	1	68	.703

The results of the normality and homogeneity tests for *the* pre-test and post-test data on sustainability literacy for the experimental and control classes showed a significance value (Sig.) > 0.05%, indicating that the *pretest-posttest data* were normal and homogeneous. The data are normal so that further testing can use parametric tests. The data is homogeneous, meaning that the data obtained have the same diversity between the experimental and control class students. Furthermore, the pre-test and post-test data of the sustainability literacy of the experimental class students who used integrated PBL learning SDG point 6 and the control class who used *discovery learning* were tested for average differences using the *Independent Sample T -test*. The average difference test was used to determine whether pre-test scores differed. And a post-test of sustainability literacy in the experimental and control classes. The results of the *Independent Sample T-test* are presented in Table 5, as follows.

Table 5. Results of the Independent Sample T- test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Results Pre-test	Equal variances assumed	.009	.924	.523	68	.603	1.40553	2.68649	-3.95528	6.76634
	Equal variances not assumed.			.524	67,998	.602	1.40553	2.68160	-3.94551	6.75657
Results Post-test	Equal variances assumed	.174	.678	1,841	68	.070	5.12285	2.78198	-.42849	10.67420
	Equal variances not assumed.			1,846	67,925	.069	5.12285	2.77464	-.41396	10.65967

Based on the results of the average difference test using the *Independent Sample T - test* on the pre-test scores of the experimental and control classes, a significance value (*2-tailed Sign*) of 0.60 was obtained. These results indicate that there was no significant difference in students' sustainability literacy before the learning intervention. Furthermore, based on the results of the average difference test using the *Independent Sample t test* on the post-test scores of the experimental and control classes, a significance value (*2-tailed Sign*) of 0.07 was also obtained. This value is greater than 0.05, indicating that there is no statistically significant difference between the experimental class using SDG-integrated PBL learning and the control class using *discovery learning*. The significance value of the average difference test on the pre-test and post-test *results* of the experimental class using SDG-integrated PBL learning point 6 and the control class using conventional learning shows no significant difference in sustainability literacy achievement. This shows that the increase in sustainability literacy between the experimental and control classes is the same, so there is no effect of SDG-integrated PBL learning point 6 on students' sustainability literacy.

Further analysis was conducted by examining the average pre-test *and* post-test *scores* for each aspect of sustainability literacy, namely knowledge, skills, and mindset. Based

on average post-test scores for each aspect of sustainability literacy, achievement was higher in the experimental class that used integrated PBL on SDG 6 than in the control class that used *discovery learning*. The improvement in the experimental class that used integrated PBL learning on SDG point 6 was evident in skills and mindset.

The average pre-test and post-test scores for each aspect of sustainability literacy showed a significant improvement in the experimental class that used integrated PBL learning on SDG point 6, compared with the control class that used conventional *discovery learning*. In the experimental class, the achievement in increasing sustainability literacy was 13 in the knowledge aspect, 16 in the skill aspect, and 9 in the mindset aspect. In the control class, the achievement in increasing sustainability literacy was 9 in the knowledge aspect, 14 in the skill aspect, and 8 in the mindset aspect. The following data show the average increase in value of the Sustainability literacy pre-test and post-test for each aspect in both the experimental and control classes, presented in the line diagram in Figure 2.

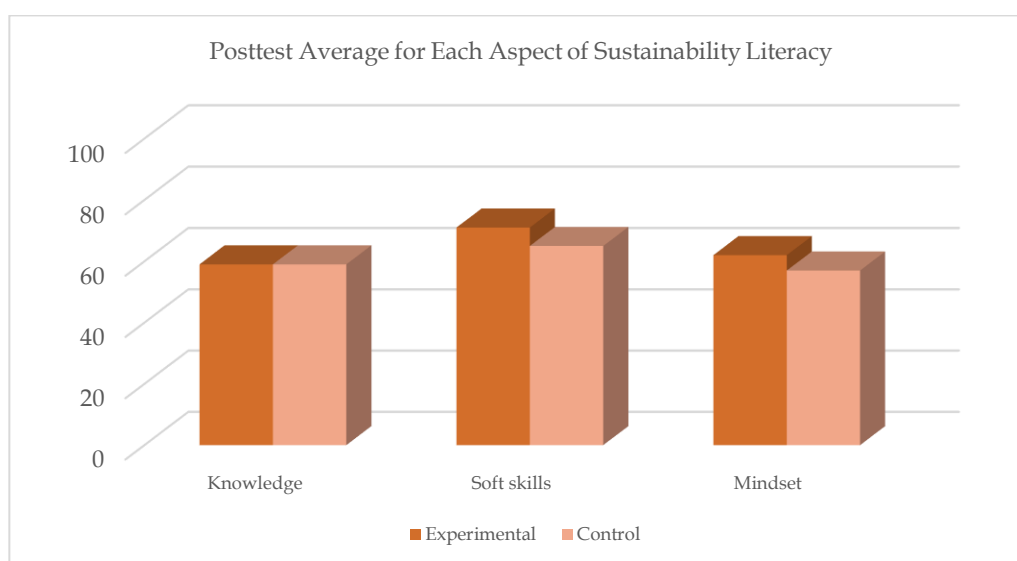


Figure 2. Average Achievement of Each Aspect of Sustainability Literacy

Figure 2 presents a comparison of the average improvement in students' sustainability literacy across three aspects knowledge, skills, and mindset, between the experimental class and the control class. The figure shows that both groups experienced increases in all aspects after the learning intervention. However, the experimental class that implemented Problem-Based Learning integrated with SDG point 6 achieved higher average gains than the control class, particularly in the skills and mindset aspects. The improvement in the knowledge aspect was also greater in the experimental class compared to the control class. Overall, the figure indicates that SDG-integrated PBL tends to enhance students' sustainability literacy, especially in developing practical skills and sustainability-oriented mindsets, even though the overall statistical difference between groups was not significant

D. Discussion

This study aimed to examine whether Problem-Based Learning (PBL) integrated with SDG point 6 influences students' sustainability literacy related to water pollution, both overall and across its core aspects of knowledge, skills, and mindset. The results of the Independent Samples T-test indicate that there was no statistically significant difference in total sustainability literacy scores between the experimental class using SDG-integrated PBL and the control class using discovery learning. This finding suggests that, at the inferential level, the implementation of PBL integrated with SDG 6 did not produce a significantly different overall outcome compared to discovery learning. Nevertheless, further analysis at the aspect level provides a more nuanced understanding of the learning effects.

Although the overall statistical difference was not significant, the experimental class demonstrated higher average improvements across all aspects of sustainability literacy, particularly in the skills and mindset dimensions. These findings indicate that SDG-integrated PBL tends to facilitate the development of competencies related to collaboration, problem-solving, critical thinking, and reflective awareness, which are central to sustainability education (Sani et al., 2025). This tendency aligns with previous studies highlighting that PBL promotes active engagement through authentic problems and collaborative inquiry, thereby supporting deeper learning processes (Djonomiarjo, 2020; Lim, 2023; Widodo, 2021)

The absence of a statistically significant difference between the experimental and control groups may be explained by several contextual and methodological factors. First, SDG point 6 was not exclusively embedded in the experimental class; rather, sustainability-related contexts were also introduced in the control class as part of the discovery learning process. According to UNESCO (2017), contextualizing learning within the SDGs can enhance students' engagement and understanding of sustainability concepts regardless of the instructional model. Consequently, the shared sustainability context across both groups may have reduced observable differences in overall outcomes.

Second, the school environment where the study was conducted had already implemented various sustainable practices, such as waste reduction initiatives, water-saving campaigns, and green facilities. Previous studies have shown that school environments supporting sustainable lifestyles can significantly influence students' pro-environmental attitudes and behaviors (Abbas et al., 2019; Liu et al., 2018; Pulimeno et al., 2020). Such conditions may have contributed to students' sustainability literacy development in both groups, thereby diminishing the relative impact of the instructional intervention.

Another factor relates to the sustainability literacy instrument used in this study. Although the instrument demonstrated high reliability and acceptable validity, it remained relatively general in scope, focusing on global issues of water pollution and sanitation. Meanwhile, the PBL activities emphasized localized and context-specific problem-solving processes. As suggested by (Putri et al., 2023), alignment between learning activities and assessment contexts is crucial for capturing students' sustainability literacy profiles more

accurately. This mismatch may have limited the sensitivity of the instrument in detecting differences attributable to the instructional model.

Despite these limitations, the higher gains observed in the skills and mindset aspects among students in the experimental class suggest that SDG-integrated PBL holds particular potential for fostering practical sustainability competencies and transformative thinking. PBL encourages students to engage in inquiry-based problem solving, collaboration, and reflection, which are essential for developing sustainability-oriented skills and attitudes (Ismail et al., 2024). Through engagement with real-world water pollution issues, students were encouraged to consider preventive actions and responsible behaviors related to clean water and sanitation, reinforcing the objectives of SDG point 6.

Finally, challenges in implementing PBL, such as students' unfamiliarity with problem-based learning approaches and limited instructional time, may also have influenced the outcomes. Previous research indicates that effective PBL implementation requires sufficient habituation, scaffolding, and time for both preparation and learning processes (Rakhmawati, 2021). Without these conditions, the full potential of PBL may not be optimally realized.

Overall, the findings indicate that while SDG-integrated PBL did not result in a statistically significant improvement in overall sustainability literacy compared to discovery learning, it shows a meaningful tendency to enhance students' skills and mindsets related to sustainability. These results contribute to the growing body of research on sustainability education by highlighting the importance of contextual factors, assessment alignment, and instructional habituation in evaluating the effectiveness of PBL within SDG-oriented learning.

E. Implication

The findings of this study indicate that integrating Problem-Based Learning with SDG point 6 has the potential to enhance students' sustainability literacy, particularly in fostering sustainability-related skills and mindsets. The use of SDG-integrated PBL within real-world environmental contexts offers a pedagogical approach that supports the development of sustainability competencies alongside essential 21st-century skills, such as critical thinking, collaboration, and problem-solving. In this regard, sustainability-oriented learning in schools plays an important role in preparing students to respond to future environmental and social challenges.

However, this study also highlights several important considerations for effective implementation. The sustainability literacy instrument employed in this research primarily emphasized global perspectives on water pollution and clean water availability, while the PBL learning activities focused on localized, everyday environmental issues. This misalignment may have limited the ability of the assessment to fully capture the learning outcomes generated through SDG-integrated PBL. Additionally, students' limited familiarity with problem-based learning and the constrained duration allocated for

preparation and classroom implementation may have reduced the optimal impact of the intervention.

Therefore, future instructional practices should ensure a stronger alignment between learning activities and assessment instruments, particularly by contextualizing sustainability issues at both local and global levels. Moreover, adequate habituation to PBL approaches and sufficient time for instructional preparation and implementation are essential to maximize the effectiveness of SDG-integrated PBL in improving students' sustainability literacy.

F. Limitation and Suggestion for Further Research

This study has several limitations that should be considered when interpreting the findings. First, the implementation of Problem-Based Learning integrated with SDG point 6 was conducted within a limited instructional timeframe, and students were not fully accustomed to problem-based learning approaches. This limited habituation may have affected the optimal development of students' sustainability literacy. Second, the assessment instrument for sustainability literacy primarily emphasized outcome-based measurement and did not sufficiently capture students' learning processes during PBL activities, which may have constrained the sensitivity of the evaluation.

Based on these limitations, future research is recommended to place greater emphasis on instructional preparation and student habituation when implementing SDG-integrated PBL. Providing extended implementation periods and scaffolding strategies may allow students to engage more effectively with problem-based learning environments. In addition, further studies should develop and employ sustainability literacy assessment instruments that integrate both process- and outcome-oriented measures. Such instruments would enable a more comprehensive evaluation of students' sustainability literacy development and provide deeper insights into how SDG-integrated PBL supports learning across knowledge, skills, and mindset dimensions.

G. Conclusion

This study indicates that the implementation of Problem-Based Learning (PBL) integrated with SDG point 6 demonstrates a positive tendency in enhancing students' sustainability literacy related to environmental pollution. Although the statistical analysis revealed no significant difference between the experimental and control groups, a more detailed aspect-based analysis showed that students in the experimental class experienced greater improvements, particularly in the skills and mindset dimensions, when PBL was integrated with SDG 6. These findings suggest that SDG-integrated PBL supports the development of sustainability-oriented competencies by encouraging active engagement, critical thinking, and reflective awareness of real-world environmental issues. While the overall effect was not statistically significant, PBL shows potential as a pedagogical approach for fostering sustainability awareness and promoting meaningful learning experiences aligned with global sustainability goals. Therefore, this study recommends the

implementation of PBL integrated with the SDGs as part of instructional practices, particularly when applied over an extended period to allow students to become familiar with both the SDG framework and problem-based learning processes.

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