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Deep Conceptual Learning in Physics Learning: A STEM-Based Waterwheel Project for High School Students' Scientific Literacy

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Abstract

Scientific literacy is a crucial competency in 21st-century education, encompassing students' ability to understand scientific concepts, apply them in real-life contexts, and make evidence-based decisions. Despite various curriculum reforms, assessments such as PISA 2022 reveal that Indonesian students' scientific literacy remains below the international average. Prior studies have applied Project-Based Learning (PjBL) and STEM approaches separately, yet few have explicitly integrated these with the Engineering Design Process (EDP) and local environmental contexts to systematically enhance scientific literacy. Addressing this gap, this quasi-experimental study examines the effectiveness of a PjBL-STEM model, contextualized by a waterwheel project utilizing local river flow, in fostering students' deep conceptual learning and scientific literacy on the topic of Work and Energy. The study involved two purposively selected 11th-grade classes (N=60) at SMA Negeri 1 Samalanga: an experimental class taught with the PjBL-STEM-EDP approach and a control class taught conventionally. Instruments were validated (Cronbach's alpha=0.926) and data were analyzed using t-tests, N-Gain, and effect size (Cohen's d=2.25). Results showed the experimental group achieved significantly higher scientific literacy (mean post-test = 84.83 vs. control = 65.67; N-Gain = 0.83 vs. 0.49; $t(58) = -8.71$, $p < 0.001$, 95% CI [-23.6, -14.7]), with the strongest improvement in designing scientific investigations. The novelty of this study lies in aligning PjBL syntax, EDP stages, and OECD scientific literacy indicators within a local-context project. While deep conceptual learning (DCL) is used here as a theoretical framing rather than a measured outcome, the findings highlight the potential of contextual, interdisciplinary learning to foster scientific literacy, creativity, and critical thinking, supporting the goals of the Merdeka Curriculum and Education for Sustainable Development.

Keywords: Scientific Literacy; STEM Education; Project-Based Learning; Deep Conceptual Learning; Merdeka Curriculum; Physics Education

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INTRODUCTION

Scientific literacy is recognized as a key competency in 21st-century education (González-Pérez & Ramírez-Montoya, 2022; Kilag et al., 2023; Ploj Virtič, 2022). It encompasses students' ability to understand scientific concepts, apply knowledge in real-life contexts, and make evidence-based decisions (Jamil et al., 2024; Kumar et al., 2024; Okada et al., 2025). PISA (Programme for International Student Assessment) defines scientific literacy as the ability to use scientific knowledge, identify questions, and draw evidence-based conclusions to understand nature and the changes caused by human activities (Oliver et al., 2021; Suárez-Mesa & Gómez, 2024; Zhai & Pellegrino, 2023). Unfortunately, various study results, including PISA 2022, show that Indonesian students' scientific literacy skills are still below the international average. OECD (2023) data notes that only 34% of Indonesian students are at level two or above in scientific literacy, while the rest are below that level. The results of the Minimum Competency Assessment (AKM) also indicate low levels of literacy among students in many schools (Handayani et al., 2021; Rohmah et al., 2022; Shara & Silalahi, 2022). These findings underscore an urgent need to improve scientific literacy, particularly within physics education, which is often perceived as abstract and disconnected from students' lived experiences.

The low level of scientific literacy is caused by various factors, such as teacher-centered learning approaches and the lack of real-life contexts in learning (Çalik & Wiyarsi, 2025; Purwasih et al., 2025; Radišić et al., 2021). Therefore, innovation in learning strategies is needed—strategies that not only teach concepts but also involve students actively, collaboratively, and contextually (Bhardwaj et al., 2025; Marini et al., 2025; Pratama et al., 2025). One approach that is believed to address this challenge is the Project Based Learning (PjBL) model based on the STEM (Science, Technology, Engineering, and Mathematics) approach (Baran et al., 2021; Rahmania, 2021; Sumarni et al., 2023). The PjBL model provides space for students to learn through relevant real-world projects, encouraging collaboration, creativity, and problem-solving (Al-Thani & Ahmad, 2025; Chang et al., 2022; Yu, 2024). Meanwhile, the STEM approach enables interdisciplinary integration in solving real problems through scientific thinking and technical skills (Abdurrahman et al., 2023; Chiang et al., 2022; Sheth & Pathak, 2023; Wahono et al., 2021).

Several previous studies have shown that the STEM approach and the PjBL model are effective in improving scientific literacy (Muzana et al., 2021; Anwar et al., 2021; Sukackė et al., 2022; Sumarni et al., 2023; Winarni et al., 2022). For instance, Sumarni et al. (2023) applied PjBL-STEM but did not explicitly map instructional phases to scientific literacy indicators, while Lin et al. (2021) emphasized engineering design thinking without contextualizing learning in local environments. However, most still focus on general projects that lack a connection to local potential and have not explicitly mapped the relationship between the stages of the PjBL syntax, the engineering process in the Engineering Design Process (EDP), and the OECD scientific literacy indicators in an integrated manner. This creates a gap in the development of contextual, meaningful, and holistic learning.

This study addresses these gaps by integrating PjBL and STEM through the Engineering Design Process (EDP) framework and explicitly aligning each phase with OECD scientific literacy indicators. Uniquely, the study contextualizes learning within a local environmental resource: students designed and built a mini waterwheel using the flow of the Samalanga River near their school. This approach aims to foster deep conceptual learning, where students actively construct knowledge, engage in scientific inquiry, and apply concepts to authentic, community-relevant problems.

The novelty of this research lies in three dimensions: (1) explicit alignment of PjBL syntax, EDP stages, and OECD scientific literacy indicators; (2) integration of local ecological resources to increase relevance and engagement; and (3) focus on deep conceptual learning as envisioned in Indonesia's Merdeka Curriculum and Education for Sustainable Development (ESD). This combination creates a structured and context-rich learning experience that not only helps students understand physics concepts theoretically but also apply them practically in real-life settings relevant to their community.

Furthermore, by explicitly mapping each phase of the PjBL model to EDP stages and scientific literacy indicators, this study introduces a systematic pedagogical framework that addresses gaps identified in previous research, such as the lack of local context integration and partial alignment with literacy competencies. Therefore, this study aims to examine the effectiveness of a local-context STEM-based PjBL model in improving high school students' scientific literacy on the topic of Work and Energy. It also seeks to contribute to the literature by demonstrating how structured alignment of pedagogical models and local context can systematically enhance scientific literacy, critical thinking skills, and students' engagement with real-world scientific issues.

METHOD

Research Design

This study employed a quasi-experimental design with a pretest-posttest control group design to examine the effectiveness of a local-context STEM-based Project-Based Learning (PjBL) model in improving scientific literacy. The research was conducted at SMA Negeri 1 Samalanga, a public high school located near the Samalanga River in Aceh, Indonesia. Two 11th-grade classes (total N=60) were purposively selected: one as the experimental group (n=30) and the other as the control group (n=30). Purposive sampling was chosen to ensure both classes had comparable prior achievement in physics, similar class size, and equal access to local environmental resources relevant to the project. The school context is characterized by mixed socio-economic backgrounds and prior exposure to conventional physics instruction.

Learning Design and Procedure

In the experimental class, learning was conducted through a mini hydropower waterwheel project based on the Engineering Design Process (EDP) approach, according to Jolly (2024) which includes seven stages: (1) Define the Problem, (2) Imagine, (3) Plan, (4) Create, (5) Test and Evaluate, (6) Redesign and (7) Communicate; presented in Figure 1.

The project integrated the physics topic of Work and Energy within a local context, namely the use of water flow from the Samalanga River as a potential renewable energy source. Students were guided to design a simple device capable of converting the kinetic energy of flowing water into electrical energy. The waterwheel was built using recycled materials, such as plastic spoons for the blades, ice cream sticks for the frame, and plastic tubing to channel water in a circular flow from top to bottom. A small light bulb was included to serve as an indicator of successful energy conversion.

The sketch (Figure 2) illustrates a basic system in which water is directed from above through a hose to spin a turbine made from plastic spoons. This turbine rotates a shaft connected to a small dynamo, generating electricity to power a light bulb. The used water is collected below and pumped back to the top using a simple pump, creating a closed-loop water circulation system.

Figure 1. Engineering Design Process (adapted from Jolly, 2024).

This design not only emphasizes the application of Work and Energy concepts but also fosters scientific thinking, problem-solving, creativity, and environmental awareness. The project provides a deep learning experience aligned with 21st-century education principles and the Pancasila Student Profile outlined in the Merdeka Curriculum. The control group received conventional instruction through lectures and textbook exercises on the same topic.

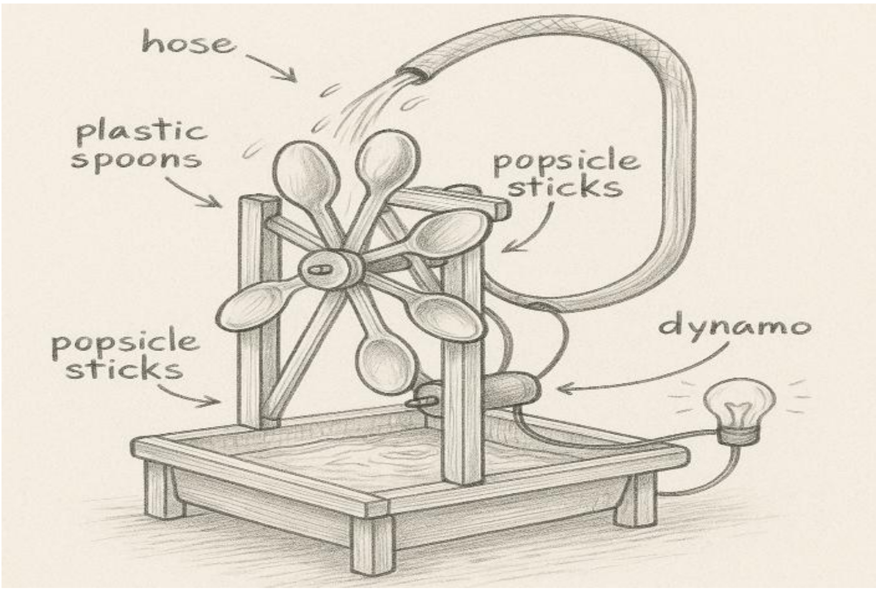

Figure 2. Student-designed sketch of the waterwheel system during the Plan phase of EDP

Instruments and Data Analysis Techniques

Research instruments included: (1) Teaching modules based on PjBL-STEM, (2) Student worksheets (LKPD), (3) Observation sheets for learning implementation, and (4) A scientific literacy test covering three core indicators (OECD, 2025), presented in Figure 3.

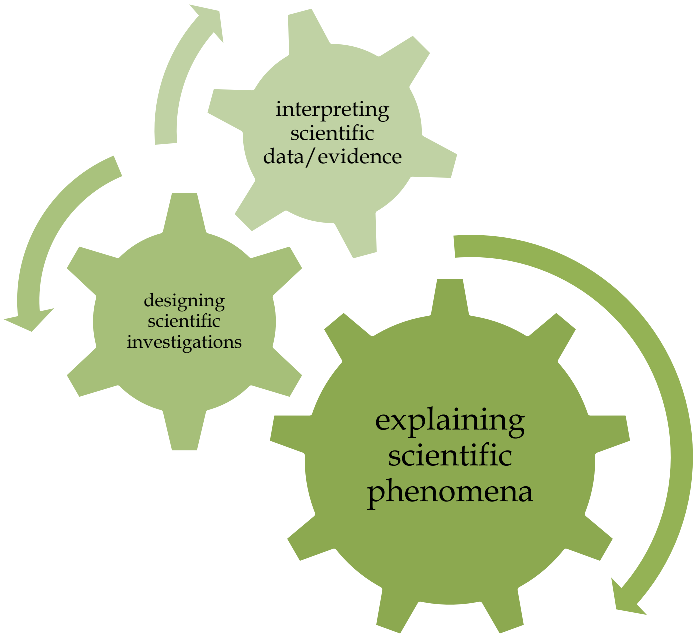

Figure 3. Scientific Literacy Indicators (adapted from OECD, 2025)

Instruments were developed following expert consultation and literature review, then validated by two experts in physics education and STEM pedagogy. The scientific literacy test was piloted with 30 students outside the sample to analyze reliability, difficulty, and discrimination indices. Cronbach's alpha was calculated to assess internal consistency, yielding a reliability coefficient of 0.926 (very high). Items showed moderate to high difficulty and good discrimination, confirming the test's suitability.

Data were analyzed using IBM SPSS Statistics version 25. Normality and homogeneity tests were performed to verify the assumptions for inferential analysis. An independent-samples t-test determined the statistical significance of differences between experimental and control groups. N-Gain analysis measured improvement in each scientific literacy indicator, and effect size (Cohen's d) was calculated to evaluate practical significance.

Integration of PjBL, STEM (EDP), and Scientific Literacy

The integration of PjBL syntax, EDP stages, and OECD (2025) scientific literacy indicators was systematically mapped, as shown in Table 1. Teachers ensured that each phase of the PjBL model corresponded to the targeted literacy skills: explaining scientific phenomena, designing scientific investigations, and interpreting data and evidence.

Table 1. The Integration of PjBL Syntax, STEM EDP Stages, and Scientific Literacy Indicators

PjBL Syntax	STEM EDP Stage (Jolly, 2024)	Scientific Literacy Indicator (OECD, 2025)
Determining fundamental questions	Define the problem	Explaining scientific phenomena

PjBL Syntax	STEM EDP Stage (Jolly, 2024)	Scientific Literacy Indicator (OECD, 2025)
Designing a plan	Research and imagine; Plan	Evaluating and designing scientific investigations
Creating a schedule	Plan	Interpreting data and scientific evidence
Monitoring students	Create; Test and evaluate	Explaining phenomena and interpreting data based on observation
Testing results	Redesign; Communicate	Evaluating and revising based on scientific evidence
Evaluating experience	Communicate	Explaining scientific phenomena and reflecting on testing results

This approach enables more meaningful learning as it links scientific concepts to real local contexts, such as utilizing water energy from Krueng Samalanga (a local river) through a waterwheel replica project as a medium for learning the concept of work and energy.

RESULTS AND DISCUSSION

This study aims to examine the effectiveness of a STEM-based Project-Based Learning (PjBL) model in enhancing students' scientific literacy on the topic of Work and Energy. The data on students' learning outcomes were analyzed using descriptive statistics, prerequisite tests (normality and homogeneity), an independent-samples t-test, N-Gain analysis to measure improvement, and effect size (Cohen's d) to evaluate practical significance.

Instrument Test Results

The research instrument, in the form of a scientific literacy test, was validated by two experts in physics and STEM education. Content validity was assessed using Aiken's V index, with values ranging from 0.43 to 0.70, exceeding the minimum threshold of 0.40 for moderate validity (Azwar, 2012). This indicates that all items met the criteria for acceptable content validity. Reliability testing through a trial with 30 students produced a Cronbach's alpha of 0.926, which falls into the *very high* category, confirming that the instrument is consistent and reliable. Table 2 summarizes the results of the validity analysis, item difficulty level, and discrimination index.

Table 2. Summary of the Results of the Validity Analysis, Difficulty Level, and Discrimination Index

No	Difficulty		Discrimination		Validity		Description
	Index	Category	Index	Category	Index	Category	
1	0.600	Moderate	0.875	Very Good	0.698	High	Good Item
2	0.633	Moderate	0.750	Very Good	0.434	Moderate	Good Item
3	0.600	Moderate	0.875	Very Good	0.698	High	Good Item
4	0.633	Moderate	0.750	Very Good	0.679	High	Good Item
5	0.633	Moderate	0.750	Very Good	0.679	High	Good Item
6	0.767	Easy	0.500	Good	0.505	Moderate	Good Item

All items were therefore considered valid, with difficulty indices ranging from *moderate* to *easy*, discrimination indices ranging from *good* to *very good*, and Aiken's V values above the recommended threshold, making them suitable for use in this study.

Descriptive Statistics

Based on pre-test and post-test data from both classes, descriptive statistics are presented in Table 3. From these results, it can be seen that before the treatment, the pre-test average scores of the control (32.17) and experimental (33.17) classes were relatively similar, indicating that both groups had comparable initial abilities.

Table 3. Descriptive Statistics of Pre-test and Post-test Scores

Class	Mean	Median	Std. Deviation	Max Score	Min Score
Ctrl. Pre-test	32.17	32.5	5.83	45	20
Ctrl. Post-test	65.67	65	9.07	80	50
Exp. Pre-test	33.17	35	6.88	45	20
Exp. Post-test	84.83	85	7.93	100	70

After the treatment, there was an increase in the average post-test scores in both classes. However, a significant improvement was observed in the experimental class, with an average score of 84.83, compared to only 65.67 in the control class. Furthermore, the maximum score in the experimental class reached 100, indicating that some students achieved full mastery of the material taught through the STEM-based PjBL model.

The standard deviation in the experimental class was 7.93, which was smaller than that of the control class at 9.07, indicating a more even distribution of student scores in the experimental class. This reflects that the applied learning intervention helped most students to understand the material better and more consistently.

Table 4. Tests of Normality

		Kolmogorov-Smimov[a]			Shapiro-Wilk		
	Class	Statistic	df	Sig.	Statistic	df	Sig.
Scientific Literacy	Exp. Pre-test	0.144	30	0.517	0.944	30	0.119
	Exp. Post-test	0.142	30	0.537	0.953	30	0.198
	Ctrl. Pre-test	0.187	30	0.218	0.937	30	0.076
	Ctrl. Post-test	0.134	30	0.608	0.941	30	0.097

*. This is a lower bound of the true significance; a. Liliefors Significance Correction

These results indicate that the implementation of the STEM-based PjBL model not only improves overall academic achievement but also enhances the equity of conceptual understanding among students (Jackson et al., 2021; Retno et al., 2025; Stephenson Reaves et al., 2022). Project-based learning enables students to actively engage in meaningful, problem-oriented learning processes integrated with real-world contexts—particularly through the waterwheel project relevant to the local school environment.

The normality test using Kolmogorov-Smirnov and Shapiro-Wilk showed that all data had significance values > 0.05, indicating normal distribution (Table 4). Moreover, the homogeneity test using Levene's test yielded a significance value of 0.504 (based on the mean), indicating that the data were homogeneous (Table 5).

Table 5. Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Scientific Literacy	Based on Mean	0.453	1	58	0.504
	Based on Median	1.077	1	58	0.304
	Based on trimmed mean	1.049	1	58	0.310

The independent-samples t-test (Table 6) showed no significant difference between the pre-test scores of the two classes, t(58) = -0.61, p = 0.546, indicating that both groups started with comparable levels of scientific literacy. However, for the post-test scores, there was a highly significant difference between the experimental and control classes, t(58) = -8.71, p < 0.001, 95% CI [-23.6, -14.7]. This demonstrates that the STEM-based PjBL model had a strong positive effect on improving scientific literacy.

Table 6. Result of t-Test

	t-value	p-value (Sig.)
Pre-Test	-0.61	0.546
Post-Test	-8.71	<0.001

An independent-samples t-test further indicated a significant difference in post-test scores between the experimental group (M = 84.83, SD = 7.93) and the control group (M = 65.67, SD = 9.07), t(58) = -8.71, p < 0.001. The calculated effect size (Cohen's d = 2.25) indicates a very large practical significance of the intervention. This confirms that the treatment not only achieved statistical significance but also had a strong practical impact on students' scientific literacy.

Table 7. Result of Cohen's d

Comparison	t	p	Cohen's d
Post-test Exp vs Ctrl	-8.71	<0.001	2.25

The results demonstrate that integrating the PjBL-STEM model with the Engineering Design Process (EDP) significantly improves students' scientific literacy in physics, as shown by higher mean post-test scores (84.83 vs. 65.67), high N-Gain values (0.83 vs. 0.49), and a large effect size (Cohen's d = 2.25). These findings support the hypothesis that contextual, project-based learning combined with systematic design processes can effectively foster conceptual understanding and scientific literacy.

The significant improvement in the experimental group aligns with prior research emphasizing the benefits of project-based learning for engaging students in active knowledge construction and problem-solving (Chang et al., 2022; Song et al., 2025; Sukackė et al., 2022; Yu, 2024). However, unlike Sumarni et al. (2023), who applied PjBL-STEM without explicitly mapping instructional phases to scientific literacy outcomes, this study uniquely aligned PjBL syntax, EDP stages, and OECD indicators. This systematic alignment may explain the higher gains observed, particularly in evaluating and designing scientific investigations (N-Gain=0.88).

Moreover, the local-context waterwheel project appears to have deepened students' understanding by connecting abstract physics concepts to tangible community-relevant problems, reflecting principles of deep conceptual learning (Zhou & Zhang, 2025). This supports findings by Lin et al. (2021), who noted that engineering design tasks foster critical thinking and creativity. Unlike Anwar et al. (2022), who reported moderate improvements, our study's higher gains suggest that explicit integration of local context and design processes can enhance engagement and learning outcomes.

Theoretically, this study contributes to science education by operationalizing the alignment of PjBL, EDP, and OECD literacy indicators within the Merdeka Curriculum framework. Practically, it demonstrates that contextualizing projects using local resources—such as the Samalanga River—can increase students' scientific reasoning, problem-solving, and reflection skills.

Nevertheless, several limitations should be acknowledged. The sample was limited to two purposively selected classes from one school, which may affect generalizability. Teacher facilitation, group collaboration dynamics, and student motivation could also have influenced results. Additionally, although effect size analysis confirmed practical significance, further studies with larger and more diverse samples are needed to validate these findings across contexts.

In summary, the integration of PjBL, STEM, and EDP in a local-context project shows promise for enhancing scientific literacy and aligns with the Merdeka Curriculum's emphasis on creativity, critical thinking, and sustainability. Future research should explore adaptation in different subjects and socio-geographical settings.

N-Gain Analysis by Scientific Literacy Indicators

To assess the effectiveness of the STEM-based Project-Based Learning (PjBL) model more deeply, an analysis was conducted on three scientific literacy indicators. The average N-Gain calculation showed that the experimental class experienced a higher increase (0.83, high category) compared to the control class (0.49, medium category). The results indicate that the average N-Gain in the experimental class was significantly higher than in the control class, demonstrating a real impact from the project-based learning with the Engineering Design Process (EDP) approach. The details are presented in the following table:

Table 8. Average N-Gain by Scientific Literacy Indicator

No	Scientific Literacy Indicator	N-Gain Control	N-Gain Experiment
1	Explaining scientific phenomena	0.53 (medium)	0.82 (high)
2	Evaluating and designing scientific investigations	0.50 (medium)	0.88 (high)
3	Interpreting data and scientific evidence	0.46 (medium)	0.79 (high)
Total N-Gain		0.49 (medium)	0.83 (high)

Discussion

Explaining Scientific Phenomena

The increase in this indicator from 0.53 to 0.82 shows that the local context—namely the potential of the Samalanga River to generate electricity—has a strong influence on students' understanding of real physics phenomena. The "Define the Problem" and "Research and Imagine" phases in EDP guide students to start from concrete realities and relate them to the concepts of work and energy.

This aligns with the principle of deep conceptual learning, which emphasizes the interconnection of concepts and their application in real life, rather than mere memorization (Levin et al., 2025; Zhou & Zhang, 2025). In the context of the Merdeka Curriculum, this approach supports the development of deep competencies through contextual, project-based learning (Pancasila Student Profile Strengthening Projects) (Sobirin et al., 2023).

The study by Sumarni (Sumarni et al., 2023) supports these findings, showing that learning beginning from contextual phenomena can strengthen the meaningful construction of science concepts. The implication is that teachers are expected to design learning that connects with the surrounding environment, enabling students to build connections between scientific knowledge and real phenomena, as mandated by the Merdeka Curriculum (Akhbar et al., 2023).

Evaluating and Designing Scientific Investigations

This indicator showed the highest increase, with an N-Gain value of 0.88 in the experimental class. In this learning, students not only understood theory but were directly involved in designing and building waterwheel prototypes through the "Plan" and "Create" phases in EDP. Students learned how to structure investigative steps, identify variables, and conduct testing based on their own designs.

This approach is highly relevant to deep learning because it hones critical thinking and problem-solving skills actively, rather than merely replicating provided procedures (Hikmawati et al., 2021; Kilag et al., 2023). Within the Merdeka Curriculum, this also aligns with the emphasis on student-centered activity-based learning, as well as strengthening scientific reasoning in independent experiments (Lin et al., 2021).

These findings are reinforced by the study of Saricam et al. (Saricam & Yildirim, 2021), which affirms that STEM activities integrating engineering processes enhance students' scientific thinking abilities and independence in learning. The implication is that physics teachers need to design open project-based experimental activities so that students gain direct experience as designers and executors of scientific processes, not just followers of steps (Lely et al., 2020; Rubashkin et al., 2023).

Interpreting Data and Scientific Evidence

The third indicator increased from 0.46 to 0.79. In this project, students dealt with data from testing the mini waterwheel, including electricity calculations, water flow rate, and efficiency. They then evaluated the experiment results and revised the design according to the "Test and Evaluate" and "Redesign" phases in EDP.

This process not only teaches data analysis skills but also fosters scientific literacy and reflective ability (Fortus et al., 2022; Hacioğlu & Gülhan, 2021; Kumar et al., 2024). This is at the core of deep learning: building knowledge through evidence evaluation and logical argumentation. In the context of the Merdeka Curriculum, this indicator reinforces the dimension of critical thinking and data-based decision-making (Mohseni et al., 2020).

Research by Anwar et al. (2022) shows that integrating projects and evaluative cycles in STEM improves data interpretation skills and evidence-based reasoning. The implication is that educators can utilize the EDP approach to systematically teach scientific thinking, which is a vital foundation for developing students as 21st-century problem solvers and critical thinkers (Putra et al., 2023; Romero Ariza et al., 2024).

CONCLUSION

This study demonstrated that integrating the STEM-based Project-Based Learning (PjBL) model with the Engineering Design Process (EDP) and local-context projects significantly enhances students' scientific literacy on the topic of Work and Energy. The experimental group achieved a higher mean post-test score (84.83) and N-Gain (0.83, high category) compared to the control group (65.67; N-Gain=0.49, medium category), supported by a large effect size (Cohen's d=2.25). These findings suggest that aligning PjBL syntax with EDP stages and OECD scientific literacy indicators, while contextualizing learning in local environments, effectively fosters deep conceptual learning, creativity, and scientific reasoning. The study contributes to curriculum innovation by operationalizing a structured pedagogical model that supports the Merdeka Curriculum's goals and Education for Sustainable Development (ESD). Nonetheless, the study's scope was limited to two purposively selected classes in a single school, which may limit the generalizability of findings. Other factors, such as teacher facilitation, student motivation, and group dynamics, could also influence outcomes. Future research is needed to validate these results in diverse contexts and with larger samples.

RECOMMENDATION

Based on the study's findings and identified limitations, several recommendations are proposed to enhance scientific literacy in physics learning. First, educators are encouraged to integrate STEM-based Project-Based Learning (PjBL) models that explicitly align each instructional phase with the Engineering Design Process (EDP) stages and OECD scientific literacy indicators, as this alignment has been shown to produce higher learning gains and deeper conceptual understanding. Second, curriculum developers and policymakers should design teacher training modules and instructional resources that emphasize the use of local environmental contexts—such as water resources, agriculture, or other community-relevant themes—to increase students' engagement and sense of relevance. Third, future research is recommended to implement similar models across different science topics and diverse socio-geographical contexts to validate generalizability, and to explore strategies that specifically strengthen weaker literacy indicators like interpreting data and scientific evidence. Additionally, integrating digital tools such as data analysis software or simulations can further support students in collecting, analyzing, and presenting scientific data, thereby enriching the PjBL experience and promoting higher-order thinking skills. Together, these recommendations aim to support broader adoption of contextualized, interdisciplinary learning approaches aligned with the Merdeka Curriculum and the principles of Education for Sustainable Development (ESD).

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Author Contributions

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E. Evendi				✓			✓						✓	
M. Mentari						✓				✓	✓			

Conflict of interests
The authors declare that there is no conflict of interest.

Data Availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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