JPPIPA 11(8) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

The Effect of Ethnoscience-Based Problem-Based Learning on Energy Literacy and Learning Outcomes in High School

Devia[1*], I Nyoman Tika[1], Putu Artawan[1]

[1]Departement of Natural Science Education, Ganesha University of Education, Singaraja, Indonesia.

Received: June 04, 2025
Revised: July 28, 2025
Accepted: August 25, 2025
Published: August 31, 2025

Corresponding Author:
Devia
devianbbn@gmail.com

DOI: 10.29303/jppipa.v11i8.12330

Abstract: This study aimed to examine the effect of a Problem-Based Learning (PBL) model integrated with ethnoscience on students' energy literacy and learning outcomes compared to conventional PBL. A quasi-experimental design was employed using a non-equivalent control group with pre-test and post-test. The population consisted of all 67 Grade X students at SMA Negeri Satu Atap Lembongan, who were divided into experimental and control classes based on their existing class groupings. The experimental group received instruction using the ethnoscience-integrated PBL model, while the control group was taught using standard PBL. Data were collected using validated instruments assessing energy literacy (knowledge, attitudes, and behavior) and cognitive learning outcomes. Results of analyzed using MANCOVA showed that the experimental group experienced significantly higher gains in both energy literacy ($p < 0.05$) and learning outcomes ($p < 0.05$) compared to the control group. The findings suggest that integrating ethnoscience into PBL provides contextual relevance and enhances the effectiveness of science instruction. This model can serve as a culturally responsive approach to improve students' scientific understanding and engagement.

Keywords: Energy Literacy; Learning Outcomes; Problem Based Learning Model Containing Ethnoscience

Introduction

Energy issues have become a global concern due to the increasingly evident negative environmental impacts of fossil fuels. This has heightened attention to climate change and the urgent need fatmior sustainable energy (DeWaters et al., 2013). In Indonesia, the increasing energy demand driven by industrial and transportation sectors reflects the need for sustainable solutions. However, the effectiveness of government energy-saving programs—such as the "10% Reduction Movement" and promotion of energy-efficient technologies—is strongly influenced by the public's level of energy literacy (Blasch et al., 2017).

Education plays a key role in developing energy-literate citizens who understand the concept of energy, make informed decisions, and adopt energy-saving behaviors (Holden & Barrow, 1984; Lin & Lu, 2018; Suratmi et al., 2025). Despite policy efforts, studies show that Indonesian high school students still exhibit low levels of energy literacy, particularly in understanding alternative energy sources, showing awareness of energy-related issues, and translating knowledge into responsible behavior (Chun & Hsuan, 2023; Supriatna et al., 2020). This problem is compounded by teacher-centered learning models that limit student engagement and motivation.

Globally, energy literacy challenges are also reported in countries such as Taiwan and the United

How to Cite:
Devia, Tika, I. N., & Artawan, P. (2025). The Effect of Ethnoscience-Based Problem-Based Learning on Energy Literacy and Learning Outcomes in High School. *Jurnal Penelitian Pendidikan IPA*, *11*(8), 353–361. https://doi.org/10.29303/jppipa.v11i8.12330

States, where research emphasizes that attitudes and values have a stronger influence on energy-related behavior than knowledge alone (K. L. Chen et al., 2015; S. J. Chen et al., 2015). In Indonesia, empirical studies exploring innovative and context-based instructional models to address energy literacy—especially at the senior high school level—remain limited. This highlights an urgent need to identify effective and culturally relevant pedagogical approaches.

One promising solution is the integration of Problem-Based Learning (PBL) with ethnoscience content. While PBL has been widely used to foster critical thinking, problem-solving, and higher-order thinking skills, its implementation often encounters challenges, such as students' unfamiliarity with real-world problems, insufficient teacher support, and limited access to resources. Integrating ethnoscience—local knowledge, wisdom, and practices—into the PBL framework offers contextual and cultural relevance, bridging abstract scientific concepts with students' lived experiences.

Ethnoscience-enriched PBL incorporates local traditions such as the Nyepi Day in Bali, which embodies principles of energy conservation and sustainability (Mega et al., 2020). This contextualization makes science learning more relatable and meaningful, enhancing students' conceptual understanding, motivation, and participation (Agustia et al., 2023; Amini et al., 2021; Aninnas et al., 2023; Sari et al., 2021). Moreover, the use of culturally rooted problems encourages student ownership and fosters collaborative learning dynamics, which are essential to effective PBL implementation.

The novelty of this research lies in the integration of ethnoscience into the PBL model to enhance not only students' cognitive outcomes but also their energy-related attitudes and behaviors. Unlike conventional PBL, this model embeds local values and community knowledge into the learning process, offering a more holistic and sustainable educational experience. By aligning with the Merdeka Curriculum's emphasis on contextual learning and the Pancasila student profile, this approach presents a culturally responsive innovation in science education.

Therefore, this study aims to investigate the effect of an ethnoscience-integrated Problem-Based Learning model on energy literacy and learning outcomes of senior high school students, and to determine its effectiveness compared to conventional PBL.

Method

This study employs a quantitative research approach using a quasi-experimental design aimed at examining the effect of the ethnoscience-integrated Problem-Based Learning (PBL) model on improving students' energy literacy and learning outcomes. The design used is a non-equivalent control group design, involving two naturally formed classes: an experimental group and a control group. Both groups received instruction using the PBL model; however, the key difference lies in the integration of ethnoscience content in the experimental group. This design ensures that the variable being tested is the ethnoscience integration itself, not the general use of PBL.

The population in this study includes all Grade 10 students at SMA Negeri Satu Atap Lembongan during the 2024/2025 academic year, totaling 67 students. The sampling technique applied is census sampling, meaning that every student in the population was involved in the study. The sample consisted of two existing classes: 35 students in the experimental group and 32 in the control group. These classes were chosen based on similar academic characteristics and learning environments to ensure balanced group comparisons.

Data were collected using two primary instruments. The energy literacy instrument was developed to assess students' knowledge, attitudes, and behaviors. Knowledge was evaluated using multiple-choice questions, while attitudes and behaviors were measured with a Likert-scale questionnaire. To measure cognitive learning outcomes, a separate multiple-choice test was used, aligned with the physics curriculum's competency indicators. The validation process for these instruments included expert judgment and statistical testing. For the energy literacy instrument, analyses covered content validity, reliability testing (Cronbach's alpha), item discrimination, and difficulty level to ensure the tool's robustness and scientific quality.

Data analysis involved both descriptive and inferential statistical methods. Descriptive analysis was used to summarize mean scores, standard deviations, and overall score distributions. To examine differences in learning outcomes and energy literacy between the two groups, inferential analysis was conducted using Multivariate Analysis of Covariance (MANCOVA), with pretest scores as covariates. Prior to applying MANCOVA, normality and homogeneity tests were performed to confirm that the assumptions required for this analysis were met. All statistical tests were conducted at a 5% significance level ($\alpha = 0.05$).

Result and Discussion

Distribution of Energy Literacy Research Data

The energy literacy data show the distribution of values including the mean, median, mode, standard deviation, minimum value, maximum value, and range.

This information helps identify patterns in students' understanding, awareness, and attitudes toward energy use. The energy literacy data are presented in Table 1.

Table 1. Data of Energy Literacy

Test	Class	N	Mean	Std. dev	Min	Max
Pretest-energy literacy	Experiment	35	52.57	11.10	32	80
	Control	32	50.62	9.40	32	68
Posttest- energy literacy	Experiment	35	84.80	7.24	72	96
	Control	32	78.25	8.31	60	92

The data in Table 1 show a pattern of improvement in energy literacy that aligns with the trend in learning outcomes. In the pretest, the average energy literacy score of students in the experimental class was 52.57 with a standard deviation of 11.10, a minimum score of 32, and a maximum score of 80. In the control class, the average was 50.62 with a standard deviation of 9.40, a minimum score of 32, and a maximum score of 68. This indicates that prior to the intervention, the energy literacy levels of both classes were relatively balanced.

Following the intervention, the posttest results showed a greater increase in the experimental class, with an average score of 84.80, a standard deviation of 7.24, a minimum score of 72, and a maximum score of 96. Meanwhile, the control class improved to an average of 78.25, with a standard deviation of 8.31, a minimum score of 60, and a maximum score of 92. These findings suggest that the implementation of the intervention in the experimental class was more effective in improving students' energy literacy compared to the control class.

Distribution of Learning Outcome Data

The learning outcome data reflect students' overall achievement after the learning process. These data include the mean, median, mode, standard deviation, highest and lowest scores, as well as score distribution. This information helps evaluate the effectiveness of the learning model, identify learning gaps, and develop strategies to enhance the quality of instruction and student performance. The learning outcome data are presented in Table 2.

Table 2. Data of Learning Outcome

Test	Class	N	Mean	Std. dev	Min	Max
Pretest-learning outcomes	Experiment	35	52.08	11.40	30	73
	Control	32	51.12	10.13	27	70
Posttest-learning outcomes	Experiment	35	84.34	8.24	70	97
	Control	32	75.62	11.02	50	93

The data in Table 2 reveal a notable difference between the experimental and control classes. In the pretest, the average learning outcome score in the experimental class was 52.08 with a standard deviation of 11.40, while the control class had an average of 51.12 with a standard deviation of 10.13. This suggests that the initial abilities of both classes were relatively balanced.

Following the intervention, the posttest scores increased in both classes; however, the improvement was more significant in the experimental class. The average posttest score in the experimental class reached 84.34, whereas the control class achieved an average of 75.62. These results indicate that the intervention applied in the experimental class was more effective in enhancing students' learning outcomes.

Hypothesis Prerequisite Test

Data Normality Test

The Shapiro-Wilk test is used to perform the normalcy test. A probability strategy can be utilized as the foundation for decision-making in the test; $\alpha = 0.05$ is the significance level. Examining the probability statistics with the following provisions serves as the foundation for decision-making. The normalcy assumption is satisfied if the Sig. value is greater than 0.05. The normalcy assumption is not satisfied if the Sig. value is less than 0.05.

Table 3. Normality Test of Energy Literacy Data and Learning Outcomes

Aspect	Class	Energy literacy		Learning outcomes	
		df	Sig.	df	Sig.
Pretest	Experiment	35	0.50	35	0.36
	Control	32	0.45	32	0.30
Posttest	Experiment	35	0.06	35	0.06
	Control	32	0.21	32	0.28

Based on the data in the table above, it shows that the significance value of the pretest and posttest is greater than 0.05 for both energy literacy data and learning outcome data, so the energy literacy data and learning outcomes in the experimental and control classes are normally distributed. In addition, the research data obtained is homogeneous data and there is a linear relationship between pretest and posttest data both in learning outcomes and energy literacy.

Correlation Test

To ascertain the degree of association between energy literacy characteristics and learning outcome variables, a correlation test is performed on dependent variables. Pearson's product moment test with a 5% significance level is used for testing. In making decisions based on statistical analysis, probability values play a crucial role. When the significance value (Sig.) exceeds 0.05, it suggests that there is no meaningful correlation between the variables being tested. Conversely, if the

Sig. value is below 0.05, it indicates a statistically significant correlation exists.

Table 4. Pearson's Product Moment Tests

	Enviromental concern attitude
Pearson correlation	0.22
Sig. (2-tailed)	0.07
N	67

The sig. value is 0.07, which is higher than the significance level of 0.05, according to the preceding table. This indicates that the energy literacy variable and the learning outcome variable are unrelated.

Hypothesis Test

The hypothesis test can be conducted once all requirements for the Mankova test have been satisfied. Finding the differences in outcomes for each dependent variable is the goal of the first and second hypothesis tests.

Table 5. Hypothesis Test

Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	Posttest.HB	1305.75[a]	3	435.25	4.538	0.00
	Posttest.LE	766.27[b]	3	255.42	4.149	0.01
Intercept	Posttest.HB	10181.68	1	10181.68	106.163	0.00
	Posttest.LE	8212.95	1	8212.95	133.406	0.00
Class	Posttest.HB	1286.44	1	1286.44	13.413	0.00
	Posttest.LE	674.79	1	674.79	10.961	0.00

The findings for the learning outcomes posttest variable (Posttest.HB) in the above table indicate a significance value of 0.00, which is less than 0.05. As a result, H0 is rejected, indicating that pupils using the ethnoscience-based Problem Based Learning model and those using the standard model have different learning results. In contrast, the significant value for the energy literacy posttest variable (Posttest.LE) is 0.01, which is likewise less than 0.05. As a result, H0 is likewise disproved, suggesting that the two learning models differ in how energy literacy increases.

The sig. value for Hotelling's Trace, Roy's Largest Root, Wilks' Lambda, and Pillai's Trace is less than 0.05, according to the table 6. As a result, either H0 is rejected or there is a difference between the learning outcomes and energy literacy gains of high school students that use the Problem Based Learning approach with ethnoscience content. All things considered, the test findings show that the Problem Based Learning model with ethnoscience material significantly improves learning outcomes and energy literacy when compared to the standard Problem Based Learning model. The research documentation is shown in Figure 1.

Table 6. Advanced Hypothesis Testing

Effect		Value	F	Hypo-thesis df	Error df	Sig.
Intercept	Pillai's trace	0.78	109.80[b]	2.00	62.00	0.00
	Wilks'lambda	0.22	109.80[b]	2.00	62.00	0.00
	Hotelling's	3.54	109.80[b]	2.00	62.00	0.00
	Roy's	3.54	109.80[b]	2.00	62.00	0.00
Class	Pillai's trace	0.26	11.17[b]	2.00	62.00	0.00
	Wilks'lambda	0.73	11.17[b]	2.00	62.00	0.00
	Hotelling's	0.36	11.17[b]	2.00	62.00	0.00
	Roy's	0.36	11.17[b]	2.00	62.00	0.00

Figure 1. Research documentation

Differences in the Improvement of Energy Literacy and Learning Outcomes Among Senior High School Students Taught Using Ethnoscience-Integrated Problem-Based Learning and Conventional Problem-Based Learning

The results of multivariate analysis (MANCOVA) indicated that the significance values for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root were all 0.000, which is below the 0.05 threshold. This confirms a significant difference in the improvement of energy literacy and learning outcomes between students taught using the ethnoscience-integrated Problem-Based Learning (PBL) model and those taught using the conventional PBL model. Students in the ethnoscience-integrated PBL group demonstrated higher gains in both energy literacy and overall learning outcomes.

Problem-Based Learning is an instructional model designed to develop contextual knowledge, critical thinking, independent learning, and teamwork through the systematic resolution of real-world problems (Kemendikbud, 2015). PBL employs real-life contextual problems as the starting point for students to build understanding and construct essential concepts. Through this process, students connect prior knowledge with new information, enabling the development of deeper and more meaningful understanding. PBL encourages critical thinking, communication skills, and conceptual comprehension (Sujanem & Suwindra, 2023). However, one potential limitation of PBL is the lack of emotional engagement if the problems presented are not relevant to the students' backgrounds.

In this context, the integration of ethnoscience plays a crucial role. Ethnoscience refers to the knowledge system of a particular cultural or ethnic group that evolves from tradition, experience, and inherited beliefs, and can be empirically validated. Ethnoscience bridges indigenous knowledge and scientific approaches, serving as a medium to convert traditional science into formal science in educational contexts. Incorporating local cultural values into instruction—such as Balinese cultural practices like the Ogoh-Ogoh parade and Nyepi Day, both rich in energy conservation values—provides authentic, familiar contexts for students. When PBL is combined with ethnoscience, the problems become more meaningful and contextual, fostering cognitive and emotional engagement (Pandiangan et al., 2025).

In the domain of energy literacy, this approach not only enhances students' conceptual understanding but also develops their skills in linking energy concepts to sustainable applications in daily life. This is crucial, as energy literacy involves understanding basic energy concepts, awareness of global energy issues, and the ability to make responsible energy-related decisions (DeWaters et al., 2013). Thus, students are not only conceptually knowledgeable but are also able to act reflectively and responsibly regarding energy issues.

The significant improvement in learning outcomes among students taught using ethnoscience-integrated instruction aligns with the characteristics of PBL, which promotes active student participation in constructing their own knowledge. When learning is connected to cultural values and the local environment, students become more motivated as they perceive the content to be directly relevant to their lives. This is supported by prior research showing that ethnoscience-integrated learning effectively enhances cognitive learning outcomes (Wulandari et al., 2018). Other studies also reveal that ethnoscience-based PBL fosters active student engagement during instruction (Ramandanti & Supardi, 2020). Other study similarly found that ethnoscience approaches make science learning more enjoyable and appealing than conventional methods(Atmojo, 2018).

Additional studies have found that ethnoscience-integrated PBL significantly improves critical thinking skills (Christiana & Rohaeti, 2024; Fitri & Asrizal, 2023; Sarkingobir & Bello, 2024), supporting the potential of embedding local cultural values into PBL to deepen learning. Another research also demonstrated that PBL is more effective in improving students' cognitive learning outcomes compared to conventional PBL (Handayani, 2023). Other study found that ethnoscience-based PBL strengthens critical thinking in science education (Amini et al., 2021).

These consistent findings affirm the advantages of ethnoscience-integrated PBL in improving students' energy literacy and learning outcomes. This advantage can be attributed to two main factors. First, integrating local culture into problem contexts makes learning more relevant and contextualized, enhancing students' motivation and linking content to their social environment. Second, PBL's structure, which requires students to think critically, collaborate, reflect, and solve problems, becomes more effective when enriched with ethnoscience. Local cultural content offers students a meaningful and familiar cognitive framework, promoting deeper and more targeted learning processes.

Therefore, the ethnoscience-integrated PBL model has been proven to produce positive and significant effects in developing energy literacy and improving student learning outcomes. The integration of scientific and local cultural approaches makes learning more relevant and meaningful, while also fostering learning grounded in students' social and ecological contexts. Hence, the implementation of ethnoscience-integrated PBL is highly recommended as an innovative strategy to enhance the quality of education at the secondary school level—especially in efforts to cultivate energy-literate, critically thinking, and environmentally conscious learners.

Differences in the Improvement of Energy Literacy Among High School Students Taught Using Ethnoscience-Integrated Problem-Based Learning and Conventional Problem-Based Learning

The results of multivariate data analysis to test the first hypothesis showed that the significance value for the posttest energy literacy variable was 0.010, which is lower than the threshold of 0.05. This indicates a statistically significant difference in the improvement of energy literacy between the two groups studied: the experimental group that received instruction through ethnoscience-integrated Problem-Based Learning (PBL), and the control group that received instruction using the

PBL model without ethnoscience content. The experimental group demonstrated higher achievements in various aspects of energy literacy, including knowledge, attitudes, and behavior. These findings support the effectiveness of the ethnoscience-based PBL model in fostering a deeper understanding of energy concepts and raising awareness of responsible energy use.

The PBL model is a constructivist learning approach that places students in authentic and challenging problem situations, encouraging active involvement in constructing knowledge through inquiry and discussion (Khatimah, 2022). However, in practice, PBL often faces challenges in engaging students emotionally when the problem context lacks relevance. In this regard, the integration of ethnoscience emerges as a solution to enhance the contextual relevance of learning. Ethnoscience brings local knowledge into the learning process as a legitimate scientific resource, thus offering a more contextual, meaningful, and relatable learning experience for students (Ningrum, 2018; Yuliana, 2017). In this study, the integration of local wisdom—such as the celebration of Nyepi Day and the Ogoh-Ogoh parade—served as concrete examples of how energy concepts can be related to familiar socio-cultural practices, such as energy conservation, sustainability values, and environmental awareness.

This approach enables students to understand energy concepts in a contextual manner, integrating scientific knowledge with their socio-cultural realities. Learning becomes more authentic, fostering emotional engagement and intrinsic motivation. Students feel that what they are learning is not foreign, but rather part of their everyday lived experiences. Such involvement significantly contributes to improving energy literacy by enhancing conceptual understanding, awareness of the impacts of energy use, and responsible behavior regarding energy resources (DeWaters & Powers, 2011).

This study aligns with findings from other relevant research, which shows that integrating local values into PBL makes the learning process more reflective and contextual, allowing students to connect scientific knowledge with real-life actions (Amini et al., 2021). Other studies have shown that energy learning embedded with ethnoscience and local practices significantly enhances students' scientific literacy (Sari et al., 2021). Similarly, ethnoscience-based PBL has been proven effective in improving students' cognitive learning outcomes (Handayani, 2023). Moreover, other researchers found that the application of PBL with an ethnoscience approach significantly develops critical thinking skills and scientific awareness among high school students, particularly in topics related to environment and energy (Nur et al., 2023).

Ethnoscience-integrated PBL also allows teachers to act more as facilitators who bridge modern scientific knowledge with students' local cultures. Teachers are not merely providers of information but play a key role in helping students construct new meanings from their own experiences. This aligns with 21st-century learning demands, where teachers are expected to create relevant, collaborative, and high-order thinking-oriented learning environments. In this context, teachers who can leverage local cultural potential as part of the learning process not only enhance students' learning outcomes but also foster applicable science and energy literacy skills.

Based on the above explanation, it can be concluded that ethnoscience-integrated PBL significantly enhances students' energy literacy. This model enriches both the content and the delivery of learning. From a content perspective, the integration of scientific concepts with local cultural values renders the subject matter more contextual and aligned with students' real-life experiences. This facilitates deeper understanding and more effective internalization of concepts. From a pedagogical standpoint, the PBL model encourages active student engagement in critical and collaborative thinking processes. Additionally, students are trained to solve real-world problems that are relevant to their lives and environments. This approach also nurtures cultural awareness, as students are guided to recognize, appreciate, and relate scientific knowledge to cultural practices they are already familiar with. Moreover, ecological values embedded in local wisdom—such as principles of energy conservation and sustainability—help shape students' awareness of the importance of environmental stewardship.

Therefore, learning is not only oriented toward academic achievement but also toward character development that emphasizes cultural and environmental care. Ethnoscience-integrated PBL is effective not only in developing conceptual understanding but also in shaping students who think critically, contextually, and responsibly about energy and environmental issues in real life.

Differences in Learning Outcomes Among High School Students Taught Using Ethnoscience-Integrated Problem-Based Learning and Conventional Problem-Based Learning

The results of multivariate statistical analysis to test the first hypothesis revealed that the significance value for the posttest learning outcomes variable (Posttest.HB) was 0.006, which is lower than the threshold of 0.05. This indicates a significant difference in the improvement of learning outcomes between high school students who were taught using the ethnoscience-integrated Problem-Based Learning (PBL) model and those who received instruction through conventional PBL. This difference suggests that the integration of ethnoscience into problem-based learning has a positive impact on students' understanding, critical thinking skills, and overall academic performance.

Students who participated in learning through the ethnoscience-integrated PBL model not only found it easier to understand learning concepts—due to the contextual connection with familiar local settings—but also demonstrated higher enthusiasm in engaging with learning activities. This increased engagement, in turn, contributed to better learning outcomes.

The PBL model inherently encourages students to engage actively in solving problems through collaboration, exploration, and decision-making based on data and experience. When this model is combined with ethnoscience—knowledge rooted in local wisdom—the learning experience becomes more relevant to students' everyday lives. Students are able to relate learning topics to traditions, customs, and practices that are long embedded within their social and cultural environments (Sari et al., 2021). This makes learning more contextual and meaningful, while also enhancing both cognitive and affective engagement. Conceptual understanding is more easily achieved because students construct their knowledge through authentic experiences they are familiar with.

The effectiveness of this approach is further supported by findings from previous studies. One relevant study confirmed that integrating ethnoscience into science education is beneficial in various dimensions (Handayani, 2023). These benefits include increased learning interest, stronger conceptual understanding, and enhanced critical thinking skills among students(Hidayanti & Wulandari, 2023). These findings are consistent with the present study, which confirms that the ethnoscience-integrated PBL model provides a more comprehensive and holistic learning experience for students.

Based on these findings, it is evident that implementing ethnoscience-integrated PBL results in more effective and meaningful learning, and positively influences the improvement of high school students' learning outcomes. This integration serves as a powerful instructional model that bridges scientific knowledge with students' real-life experiences, enabling them to develop a deep and applicable understanding of the content being taught.

Conclusion

This study concludes that the ethnoscience-integrated Problem-Based Learning (PBL) model has a significant effect on improving students' energy literacy and learning outcomes. The multivariate analysis results (MANCOVA) showed that students in the experimental group achieved higher average scores in both energy literacy and learning outcomes ($p < 0.05$) compared to students taught using the conventional PBL model without ethnoscience integration. These findings suggest that the integration of ethnoscience into PBL offers a more contextual and meaningful learning experience, leading to enhanced conceptual understanding and responsible behavior related to energy use. Therefore, the ethnoscience-integrated PBL model is recommended as an effective instructional strategy for increasing energy literacy and learning outcomes at the senior high school level.

Acknowledgments

The researcher would like to express sincere gratitude to Universitas Pendidikan Ganesha, SMA Negeri Satu Atap Lembongan, the participating physics teachers, and the students who served as research participants. Their support and involvement made it possible to conduct this study smoothly and to produce meaningful and reliable findings for science education.

Author Contributions

Conceptualization, D., IYT. and PA.; methodology, IYT.; validation, IYT. and PA.; formal analysis, D..; investigation, D..; resources, D.; data curation, D.; writing—original draft preparation, D.; writing—review and editing, D.; visualization, D.; supervision, D.; project administration, D. All authors have read and agreed to the published version of the manuscript.

Funding

This research was conducted independently without any financial support from external parties.

Conflicts of Interest

The authors declare no conflict of interest.

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