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https://jurnal.unimed.ac.id/2012/index.php/geo/article/view/72342
https://doi.org/ 10.24114/jg.v18i2.68937- (Vol 18, No 2 – 2026)
available at http://jurnal.unimed.ac.id/2012/index.php/geo
e-issn (2549-7057) & p-issn (2085-8167)

Enhancing Students' Problem-Solving Skills through Ecological Awareness-Based Problem-Based Learning in Secondary Geography Education

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ARTICLE INFO
Article History:
Received: September 05, 2025
Revision: June 23, 2026
Accepted: June 24, 2026

Keywords:
Ecological Awareness;
Problem-Based Learning;
Problem-Solving Skills;
Geography Education;
Classroom Action Research

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ABSTRACT
This study investigates the effectiveness of Ecological Awareness-based Problem-Based Learning (PBL) in enhancing students' problem-solving skills in secondary geography education. The research was motivated by the limited integration of sustainability-oriented learning and ecological awareness within conventional geography classrooms, which remain predominantly teacher-centered. A Classroom Action Research (CAR) design consisting of three iterative cycles was implemented involving 35 eleventh-grade students at SMA Negeri 1 Kuala Kurun during the 2024/2025 academic year. Data were collected through classroom observations, problem-solving tests, questionnaires, reflective journals, and field notes. Quantitative data were analyzed using descriptive statistics, normalized gain (N-gain), and effect size, while qualitative data were examined using thematic analysis. The findings demonstrate a consistent improvement in students' problem-solving abilities and learning outcomes across the three cycles. Learning mastery increased from 68.6% in Cycle I to 91.4% in Cycle III, while the average written test score improved from 63.85 to 86.85. The N-gain score of 0.64 indicates a high level of improvement, and the effect size of 1.12 reflects a strong instructional impact. Furthermore, the integration of ecological awareness into each stage of PBL fostered students' critical thinking, sustainability-oriented reasoning, and engagement with real-world environmental issues. These findings suggest that Ecological Awareness-based PBL provides an effective pedagogical framework for promoting meaningful, contextual, and sustainability-oriented geography learning.

INTRODUCTION

Geography has its own advantages in developing a more holistic understanding of global environmental challenges because it encompasses all sciences, including the social, environmental, and humanities sciences (Meadows, 2020). With these many disciplines, geography education is a very important element in equipping students with the competence, anaysis, and expertise to understand and respond to various socio-ecological challenges in the 21st century (Pascu, 2026). In line with these challenges, Education for Sustainable Development (ESD) emerged as a global framework that emphasizes the integration of cognitive, affective, and behavioral dimensions to form learners who are able to make responsible decisions on environmental sustainability, economic sustainability, and social justice (Suwono et al., 2026; Nguyen et al., 2026).

The implementation of ESD in geography education requires a contextual, participatory and real-world problem-based approach to learning (Redman & Wiek, 2021; Supple et al., 2026). However, the practice of geography learning is still dominated by a teacher-centered approach that focuses on material transfer compared to inquiry, critical reflection, and contextual problem analysis (Bendl et al., 2023; Kriewaldt et al., 2024).

This condition limits students' involvement in understanding real environmental problems and reduces opportunities for the development of higher-order thinking skills.

One approach considered relevant to addressing these challenges is Problem-Based Learning (PBL). PBL is a constructivist learning model that encourages analytical reasoning, collaborative inquiry, and contextual problem-solving through direct engagement with real problems (Marini et al., 2026 Funa, 2026). In geography education, PBL allows students to analyze spatial patterns, understand cause-and-effect relationships, and formulate solutions to environmental problems. Various studies have shown that PBL is able to improve academic achievement and critical thinking skills; however, most studies still focus on cognitive aspects without systematically integrating sustainability constructs in learning design (Lovren & Jablanovic, 2023 Gonzalez, 2023).

One of the main limitations of PBL research in geography education is the lack of attention to ecological awareness. Ecological awareness encompasses not only factual knowledge of the environment but also affective sensitivity, pro-environmental behavior, and the ability to understand the ecological consequences of human actions within interconnected systems. However, in learning practice, ecological awareness is often measured only as an attitude variable, rather than as an integral part of the learning process. Research in China and Ukraine shows that environmental awareness has an effect on pro-environmental behavior, but the integration of ecological competencies in formal learning models is still not optimally developed (Ma et al., 2023; Hnatyuk et al., 2024).

Based on these gaps, this study proposes a Problem-Based Learning model grounded in ecological awareness, in which ecological awareness is explicitly integrated at each stage of learning. In this model, ecological awareness is not positioned as the end result but rather as a primary orientation integrated into the stages of problem orientation, investigation, solution development, and evaluative reflection. The novelty of this research lies in three main aspects. First, ecological awareness is conceptualized as a multidimensional construct (cognitive, affective, and behavioral) that is integrated into the PBL cycle. Second, this study empirically links the sustainability-based learning approach to improvements in measurable problem-solving skills, as measured by normalized gain and effect size analyses. learning practices in the classroom, within the broad framework of ESD, resulting in a contextual and theoretical model of geography learning.

Thus, this study aims to: (1) examine the effectiveness of ecological awareness-based Problem-Based Learning in improving students' problem-solving skills; (2) analyze the process of ecological awareness development during the PBL cycle; and (3) evaluate the contribution of this learning model to sustainability-based geography education that is aligned with SDG target 4.7. To support this conceptual framework, this study also developed a research framework that describes the integration of ecological awareness at each stage of PBL, as shown in Figure 1. This framework shows the interaction between learning interventions, student engagement, ecological awareness development, and learning outcomes in the iterative classroom action research cycle.

RESEARCH METHODS

Research Design

This study employed Classroom Action Research (CAR) using the cyclical model of Kemmis et al. (2014), comprising planning, action, observation, and reflection. The design was selected because it enables systematic improvement of classroom learning practices through repeated cycles of intervention and evaluation. In this study, CAR was conducted using an awareness-based Problem-Based Learning (PBL) model. Each cycle was implemented by integrating ecological awareness into the main stages of PBL, namely problem orientation, inquiry and investigation, data analysis, solution development, and reflective evaluation. The reflection stage in each cycle was used to identify learning constraints, evaluate students’ progress, and formulate improvement strategies for the subsequent cycle. Thus, the intervention was not treated as a single instructional activity but as an iterative learning process aimed at strengthening students' ability to understand environmental problems and formulate sustainability-oriented solutions.

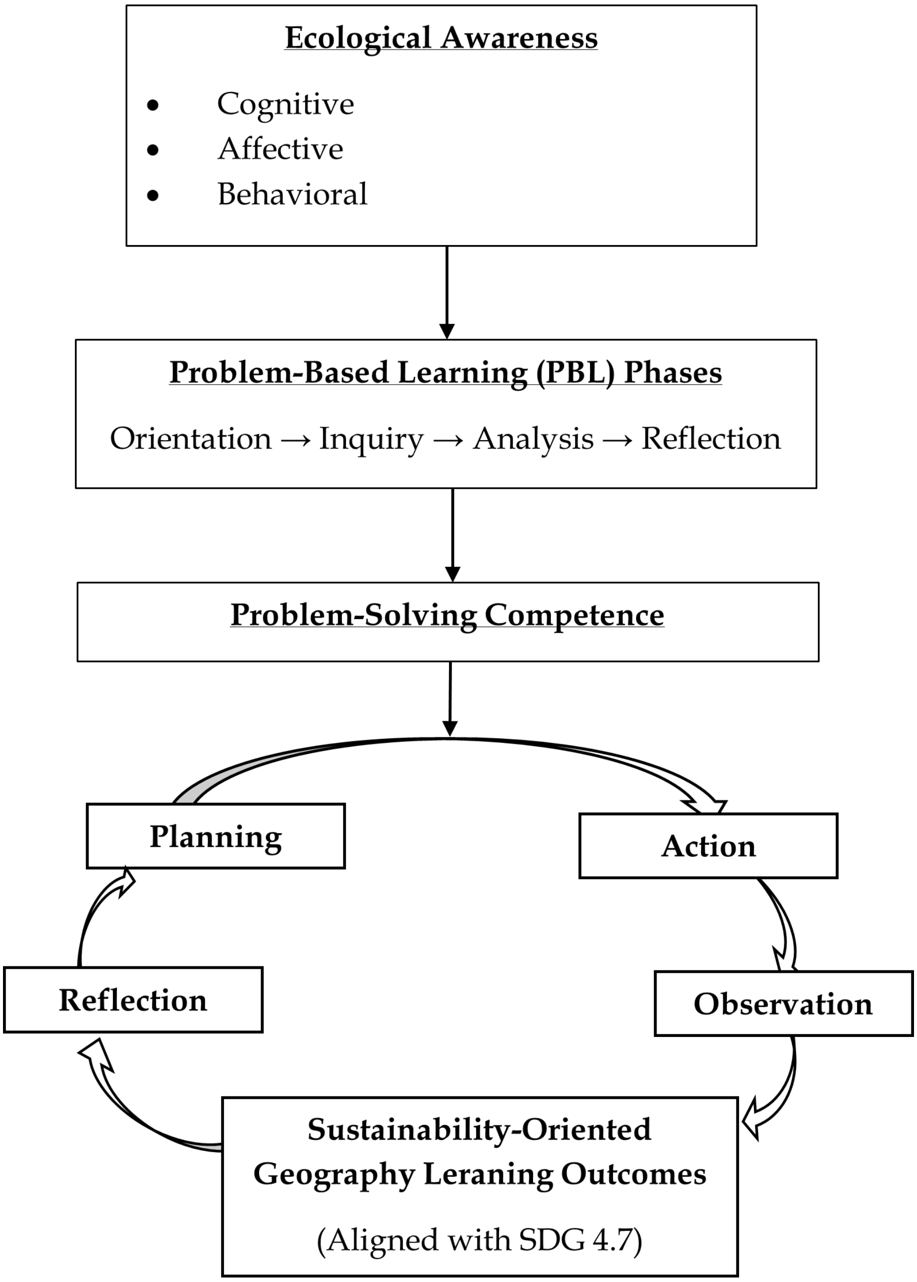

Figure 1. Research Framework of Ecological Awareness-Based Problem-Based Learning Model

Research Subjects and Settings

The research was conducted at SMA Negeri 1 Kuala Kurun, Central Kalimantan, during the second semester of the 2024/2025 academic year. The participants consisted of 35 Grade XI students enrolled in geography, comprising 18 males and 17 females. The class was selected purposively based on preliminary observations indicating that students' problem-solving performance and ecological awareness in geography learning still needed improvement. The study focused on implementing ecological awareness-based PBL in geography learning. The learning activities were designed to strengthen students' ability to identify environmental problems, analyze causal factors, evaluate alternative solutions, and formulate relevant solutions grounded in sustainability principles.

Ecological Awareness-Based PBL Intervention Procedures

The intervention was designed by embedding the cognitive, affective, and behavioral dimensions of ecological awareness into each stage of PBL. The learning problems were drawn from contextual environmental issues relevant to students' surroundings, so that students could connect geographical concepts with real socio-ecological conditions. The intervention procedures are presented in Table 1.

Table 1. Ecological Awareness-Based PBL Implementation Procedures

PBL Stages	Ecological Awareness Dimension	Student Activities
Problem Orientation	Cognitive-Affective	Identifying and formulating contextual environmental problems
Inquiry and Investigation	Cognitive	Collecting, processing, and interpreting environmental information or data
Data Analysis	Cognitive	Analysing the causes, impacts, and spatial relationships of environmental problems
Solution Development	Cognitive–Behavioral	Developing alternative solutions based on sustainability principles
Reflection and Evaluation	Affective–Behavioral	Reflecting on ecological consequences and considering responsible environmental actions

(Source: Modified from Merritt, J. D., & Kline, K, 2020)

In the planning stage, the researcher prepared lesson plans, learning materials, student worksheets, observation sheets, problem-solving tests, questionnaires, and field note formats. In the action stage, students worked collaboratively to examine environmental problems through the PBL stages. In the observation stage, the researcher and collaborator documented students' participation, discussion processes, problem-solving performance, and responses to the learning activities. In the reflection stage, the results of observations, tests, questionnaires, and field notes were analysed to identify necessary improvements for the next cycle.

Data Collection and Research Instruments

Data were collected through observation, problem-solving tests, questionnaires, field notes, and documentation. The use of multiple data sources was intended to obtain a more comprehensive understanding of students' learning processes and outcomes during the implementation of ecological awareness-based PBL.

Observation was conducted during the learning process to examine students' problem-solving performance and participation in PBL activities. The observation sheet used a four-point rating scale, ranging from very low to very high performance. The observed indicators included problem identification, problem formulation, issue analysis, conclusion drawing, solution evaluation, and solution formulation.

Problem-solving tests were administered at the end of each cycle. The tests were designed in essay form to measure students' ability to analyze environmental problems, evaluate possible solutions, and formulate sustainability-oriented recommendations. The test items were aligned with the indicators of problem-solving skills used in the observation instrument.

Questionnaires were used to examine students' responses to the implementation of ecological awareness-based PBL. The questionnaire covered students' perceptions of the learning process, learning resources, collaborative activities, assessment practices, and the contribution of learning to environmental decision-making.

Field notes were used to record important events during the learning process, including student interaction, group discussion dynamics, learning obstacles, and changes in student engagement. Documentation was used to support the research data through photographs of learning activities, teaching modules, students' worksheets, and classroom records. The indicators of students' problem-solving skills are presented in Table 2.

Table 2. Indicators of students problem-solving ability

No	Indicator	Description
1	Identify the problem	Identifying relevant environmental phenomena and issues
2	Summarizing the problem	Formulating problem statements or questions systematically
3	Analyze issues	Analysing the causes, impacts, and relationships among factors
4	Drawing conclusions	Drawing conclusions based on information, evidence, or data
5	Solution evaluation	Evaluating alternative solutions critically and contextually
6	Formulating a solution	Formulating relevant, feasible, and sustainability-oriented solutions

(Source: Modified from Merritt, J. D., & Kline, K., 2020)

Trustworthiness and Instrument Validity

The validity of the CAR process was established by referring to the criteria proposed by Gall et al. (2003), namely democratic validity, dialogic validity, catalytic validity, process validity, and outcome validity. Democratic validity was addressed by involving students actively in the learning process and by considering their responses to the intervention. Dialogic validity was strengthened through discussion with collaborators during observation and reflection. Catalytic validity was reflected in the continuous improvement of learning practices across cycles. Process validity was maintained by implementing the research procedures systematically and consistently. Outcome validity was examined through the improvements in students' problem-solving skills and learning participation across each cycle. To strengthen the instrument's validity, the observation sheet, test items, and questionnaire were reviewed to ensure alignment with the research objectives, PBL stages, ecological awareness dimensions, and problem-solving indicators. Data credibility was also supported through triangulation of techniques, namely by comparing the results of observations, tests, questionnaires, field notes, and documentation.

Data Analysis

The data were analysed using qualitative and quantitative approaches. Qualitative data obtained from observation notes, field notes, and documentation were analysed using the interactive model of Miles et al. (2014), which consists of data condensation, data display, and conclusion drawing. The analysis was conducted continuously throughout the research cycles to identify changes in students' participation, ecological awareness, group interaction, and problem-solving processes. Quantitative data obtained from problem-solving tests, observation scores, and questionnaires were analysed using descriptive statistics. The analysis included the mean score, the percentage of learning mastery, the percentage of student participation, and a comparison of students' progress across cycles. Students were considered to have achieved mastery if they scored at least 75. The improvement in students' problem-solving skills was assessed by comparing results from the preliminary condition and each cycle.

Research Success Indicators

The research was considered successful if the implementation of ecological awareness-based PBL resulted in measurable improvement in students' problem-solving skills, cognitive learning outcomes, and learning participation. The success indicators are presented in Table 3.

Table 3. Research Success Indicators

Measured Aspects	Success Targets	Instruments
Problem-solving capabilities	At least 75% of students achieved the good category in problem-solving performance	Observation sheet and problem-solving rubric
Cognitive learning outcomes	At least 75% of students obtained a score of ≥75	Essay test
Learning participation	At least 75% of students were actively involved in discussion and learning activities	Observations sheet and field notes
Ecological awareness	Students showed improvement in cognitive, affective, and behavioural responses toward environmental problems	Questionnaire, observation, and field notes

(Source: Djamarah, 2006)

RESULT AND DISCUSSION

Improving Problem-Solving Skills through Ecological Awareness-Based PBL

The results showed that implementing Problem-Based Learning (PBL) grounded in ecological awareness was associated with a gradual increase in students' problem-solving skills from cycle I to cycle III. In the first cycle, problem-solving skills remained in the medium category, with an average score of 66.4 and a completeness rate of 68.6%. This condition suggests that most students still have difficulty in identifying important information, analyzing data, and drawing conclusions based on the available evidence.

However, after learning improvements were made through the use of more contextual environmental case studies, structured group discussions, and more intensive mentoring, problem-solving skills increased to 73.5 in cycle II and reached 77 in cycle III. Although the percentage of completeness of problem-solving ability has reached 91.4% in cycle II and remains relatively stable in cycle III, improvements are still evident in the average score and the quality of students' responses when solving environmental problems. Therefore, the improvement is reflected not only in the completeness of learning but also in the depth of the thinking process and the quality of the argumentation shown by students during learning. This improvement shows that ecological awareness-based PBL is able to create improved critical thinking skills and environmental decision-making (Yusuf, 2022).

In this learning approach, students not only receive information passively but are also directly involved in identifying environmental problems, gathering information, analyzing causes, and formulating relevant solutions. This process aligns with the theory of constructivism, which places students at the center of learning and views knowledge as the result of constructing learning experiences. These findings are in line with research by Kardoyo et al. (2020), which states that PBL is effective in improving critical thinking and problem-solving skills because it provides opportunities for students to learn through real-life experiences and social collaboration.

Observation data and field notes also show changes in student learning behavior during the study. In the first cycle, most students still rely on the teacher's guidance to identify problems and determine the steps to solve them. However, in cycle III, students were able to ask investigative questions, connect data to geographical concepts, and justify their chosen solution. These qualitative findings reinforce the quantitative results, showing that improvements in problem-solving skills occur not only in outcomes but also in students' thinking processes during learning.

The gradual improvement that occurs in each cycle indicates that mastering problem-solving skills requires a continuous learning process. In the first cycle, students are still adapting to problem-based learning because they were previously more accustomed to teacher-centered learning. As the frequency of involvement in PBL activities increases in cycles II and III, students begin to demonstrate a better ability to identify cause-and-effect relationships, evaluate alternative solutions, and make more rational decisions. This shows that students are still in the early stages of knowledge development, so they need repeated mentoring to develop analytical thinking skills (Guo et al., 2024).

The Development of Each Indicator of Problem-Solving Ability

Analysis of each indicator shows that the development of problem-solving skills does not occur evenly in all aspects. In cycle I (Figure 2), the highest achievement was found in the indicators of formulating problems, determining alternative solutions, and choosing appropriate solutions. This shows that students are generally able to recognize environmental problems and develop solutions based on their experience or prior knowledge. In contrast, the indicators received for data collection and conclusion drawing obtained the lowest scores, indicating that students still had difficulty processing information and engaging in evidence-based reasoning.

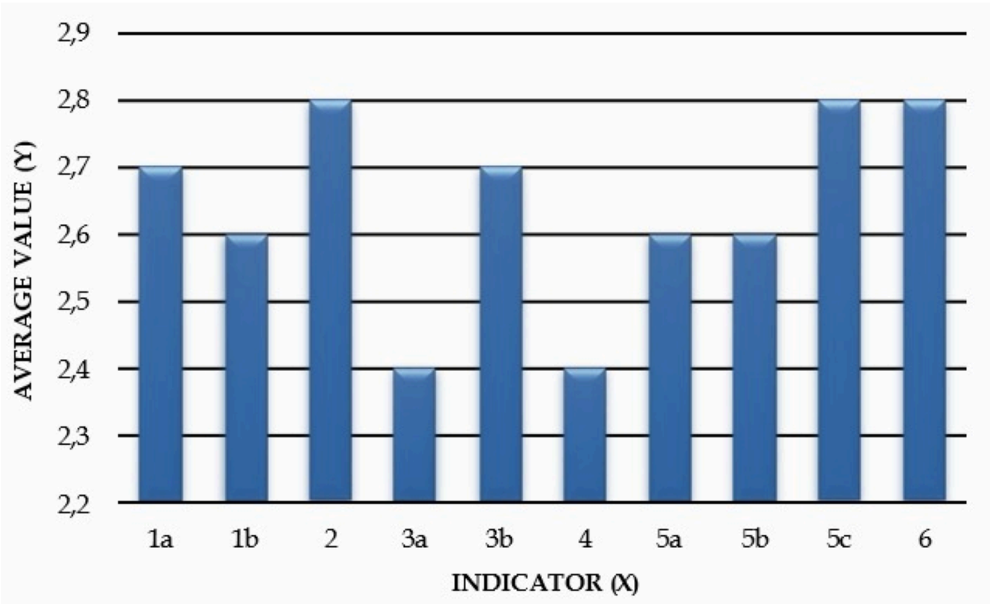

Figure 2. Score each indicator of Cycle I problem-solving ability
(Source: Research Result, 2025)

Furthermore, learning improvements in cycles II and III showed significant improvements, especially in data analysis indicators, evaluation of alternative solutions, and drawing conclusions. This increase occurred because students gained repeated learning experiences through conducting investigations, participating in group discussions, and reflecting on the results of the analysis. The experience helps students build a more systematic mindset in solving problems. These findings are in line with those of (Matsuda et al., 2024), who stated that experiences through increased team collaboration and active involvement in problem-solving can provide significant improvements in students' communication skills, developmental mindsets, and metacognitive abilities.

However, data collection indicators remain among the areas with relatively lower achievement than other indicators. These findings suggest that investigative skills require more time and practice than the ability to identify problems or propose solutions. This is confirmed by the findings of (Pozuelo-muñoz et al., 2025), which state that in the early stages of PBL, students generally still experience obstacles in data analysis, information interpretation, and reasoning skills because they are not used to inquiry-based learning.

The development of problem-solving skills needs to be carried out on an ongoing basis through structured and contextual investigative activities. Studies from China show that learning that includes three dimensions consisting of the student's foundation, subject resources, and social environment, which together support the development of learning, can develop students' problem-solving skills (Zhang et al., 2025)

The Effect of Ecological Awareness-Based PBL on Learning Outcomes

In addition to improving problem-solving skills, implementing ecological awareness-based PBL positively impacts student learning outcomes. The results showed that the average score of the written test increased from 63.85 in cycle I to 73.5 in cycle II and reached 86.85 in cycle III. The increase was followed by a rise in learning completeness, which ultimately reached 91.45% in cycle III.

Improved learning outcomes show that problem-based learning gives students the opportunity to understand concepts more deeply than memorization-oriented learning. Through problem-identification activities, case analysis, information gathering, and group discussions, students gain a more meaningful learning experience, enabling them to understand the concepts more comprehensively. This is supported by the theme (Uliyandari et al., 2021), which explains that the PBL model can improve students' conceptual understanding and critical thinking skills.

In geography, understanding of environmental issues becomes stronger as students connect theoretical concepts to the phenomena around them. These findings are in line with (Marini et al., 2026), which emphasizes that sustainability-based learning using PBL has a positive effect on student engagement, critical thinking skills, and educational sustainability in students. Thus, ecological awareness-based PBL can be an effective alternative learning strategy for improving the quality of geography learning across various levels of education.

The Role of Ecological Awareness in Building Environmental Literacy

Ecological awareness is an important component that strengthens the effectiveness of PBL implementation in this study. The results of the students' reflections indicate that they are beginning to realize that environmental problems are caused not only by natural factors but also by human behavior and resource-use patterns. Some students stated that environmental case analysis activities help them understand the ecological consequences of human activities they had previously rarely considered in their daily lives.

Learning oriented towards real environmental issues helps students develop environmental literacy, including knowledge, skills, and attitudes towards environmental conservation. Through the process of investigation and problem-solving, students learn to identify the causes of environmental damage, how to analyze their impacts, and formulate solutions that take sustainability principles into account. These activities contribute to awareness that every human decision has consequences for environmental conditions.

These findings are in line with recent research showing that contextual problem-based learning is effective in improving students' critical thinking, problem-solving, and environmental awareness skills (Llach & Bastida, 2026 Bewersdorff et al., 2025). Thus, learning geography not only serves as a means of mastering concepts but also as a medium for building citizens who care about the environment and can contribute to solving environmental problems in the future.

Increased Student Engagement in Learning

The results of the study show that improvements in problem-solving skills and learning outcomes go hand in hand with increased student involvement in learning. In cycle I, student involvement was still limited to answering the teacher's questions and following group instructions. However, in cycles II and III, students began to actively express their opinions, ask critical questions, present data-based arguments, and engage in group decision-making. Field records show that group discussions become more dynamic with each cycle. Students no longer just exchange information, but begin to negotiate ideas, defend arguments, and evaluate various alternative solutions proposed by other group members.

This increase in engagement shows that ecologically awareness-based PBL can create a more participatory and student-centered learning environment. Aytaç & Kula, (2020) State critical thinking skills, problem-solving skills, and learning outcomes through collaborative and student-centered learning. This is emphasized by Pimdee et al., (2024) the fact that the PBL model is effective in improving critical thinking skills, problem-solving and learning outcomes through contextual and student-centered learning. Contextual environmental problems make students feel that the material they learn is relevant to their lives, thereby increasing motivation to engage in the learning process.

These findings are in line with the theory of social constructivism that emphasizes the importance of social interaction in the process of knowledge formation. This is supported by findings (Duan et al., 2021) that affirm that social interactive environments can support knowledge construction and enhance learning. On the other hand, student involvement is one of the main factors explaining the improvement in problem-solving skills and learning outcomes observed in this study.

Learning Satisfaction as an Indicator of Successful PBL Implementation

This study shows that the implementation of PBL based on ecological awareness received a positive response from students. The results of the questionnaire showed that most students were in the category of satisfied and very satisfied with the learning process carried out. Even in cycle III (Figure 3), the proportion of students who stated that they were satisfied and very satisfied reached more than 80%.

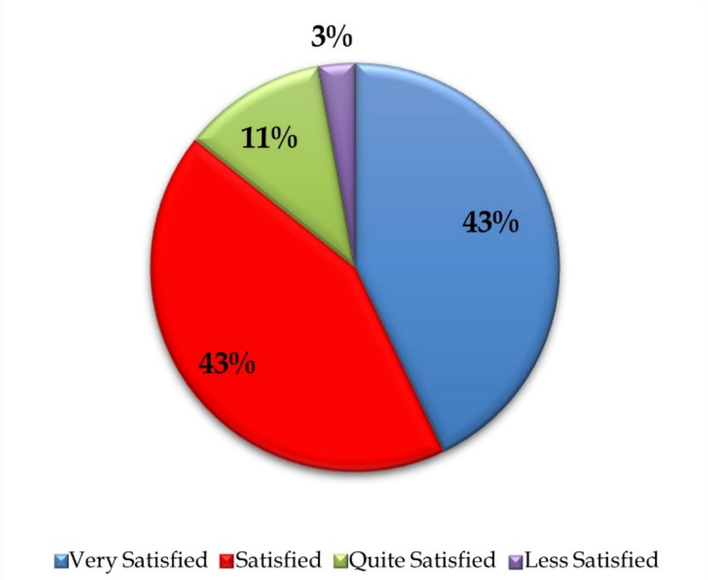

Figure 3. Distribution of Student Satisfaction Questionnaire
(Source: Research Result, 2025)

A high level of satisfaction indicates that students benefit from learning that provides opportunities to actively participate in solving real problems. The use of environmental case studies, group discussions, field investigations, and reflections makes the learning process more interesting and less monotonous. A study Kumas, (2022) states that learning should be encouraged in an environment that develops context-based activities related to experiments, analogies, and theoretical applications, as well as developing quality practices where students will be more active.

In addition, students gain a more meaningful learning experience because they can relate learning materials to the environmental conditions around them. These findings support research (King & Henderson, 2018) indicating that local context-based environmental learning is more effective when supported by visual media, collaborative activities, and case studies. The high level of learning satisfaction also indicates that ecological awareness-based PBL has the potential to increase students' intrinsic motivation to learn geography and environmental issues. It should be noted that learning satisfaction in this study reflects students' perceptions of the learning process and is not used as a direct indicator of academic success. Therefore, learning satisfaction data is interpreted as supporting findings regarding student engagement and acceptance of the applied learning model.

Practical Implications for 21st Century Geography Learning

The results of the study provide important implications for the development of geography learning in the 21st century. These findings suggest that geography learning needs to shift from an information transfer-oriented approach to one that emphasizes investigation, problem-solving, collaboration, and evidence-based decision-making. Ecological awareness-based PBL has been proven to be able to support the development of 21st-century skills that include critical thinking, communication, collaboration, and creativity.

The use of local environmental issues as a learning context can help students understand the relationship between geographical concepts and real problems faced by society. This approach also supports the implementation of Education for Sustainable Development (ESD) by encouraging students to consider sustainability in every decision-making process. Thus, geography learning is oriented not only to academic achievement but also to the development of citizen competencies that are responsible for the environment.

In practice, geography teachers can integrate environmental case studies, field investigation activities, collaborative discussions, and critical reflection into the learning process. In addition, educational institutions need to provide support through contextual learning resources, teacher training, and strengthened integration of sustainability issues into the curriculum. These efforts are important to ensure that social studies learning produces individuals with environmental literacy and high-level thinking skills.

CONCLUSION

This classroom action research shows that the application of ecological awareness-based Problem-Based Learning (PBL) is associated with gradual improvements in problem-solving skills, learning outcomes, student involvement, and environmental literacy in geography learning. The improvement was evident in the average problem-solving score, which rose from 66.40 in cycle I to 77.00 in cycle III, as well as in the written test score, which increased from 63.85 to 86.85. In addition, observational data, student reflections, and field notes show that students are increasingly active in identifying environmental problems, analyzing causes, evaluating alternative solutions, and making decisions that consider sustainability.

The research findings indicate that the use of contextual environmental issues, collaborative investigation, group discussions, and critical reflection can support more meaningful and 21st-century skills-development-oriented geography learning. The integration of ecological awareness into the learning process also helps strengthen environmental literacy and students' ability to connect geographical concepts to real problems in the surrounding environment. However, the results of the study need to be interpreted with caution because it uses a Classroom Action Research design involving only one class without a comparison group. Therefore, the findings are more appropriately understood as evidence of improvement within the context of the class being studied than as evidence of effectiveness that can be generalized broadly. Further research is suggested using quasi-experimental designs or mixed methods with a larger sample size, including control groups, and measuring the development of ecological awareness and problem-solving skills with more comprehensive instruments to obtain stronger empirical evidence.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

BNS contributes to the conceptualization of studies, research design, classroom interventions, data collection and analysis, and the drafting of original manuscripts. **RN** contributes to the development of theoretical frameworks, the refinement of methodologies, the supervision of research processes, and the critical revision of manuscripts. **CM** contributes to the validation of research instruments, the interpretation of findings, and the review of manuscripts related to geography education and sustainability learning. **SS** contributes to the refinement of research methodology, data interpretation, and academic supervision during studies. **SP** contributes to manuscript review and editing, validation of learning models, and enhancement of the discussion and conclusion sections. All authors have read and approved the final version of the manuscript.

FUNDING

This research does not receive external funding.

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