



# Journal of Educational Sciences

Journal homepage: <https://jes.ejournal.unri.ac.id/index.php/JES>



P-ISSN  
2581-1657

E-ISSN  
2581-2203

## The Effectiveness of Coastal Environment-Based PBL in Improving Students' Ecological Literacy and Learning Outcomes in Biodiversity Ecology

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### ARTICLE INFO

#### *Article history:*

Received: 10 June 2026

Accepted: 29 July 2026

Available Online: 05 Aug 2026

#### *Keywords:*

Biodiversity Ecology,  
Coastal Environment,  
Ecological Literacy,  
Learning Outcomes,  
Problem-Based Learning

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#### *Article Doi:*

<https://doi.org/10.31258/jes.10.8.p.117-136>

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### ABSTRACT

This study examined the effectiveness of coastal environment-based Problem-Based Learning (PBL) in improving students' ecological literacy and learning outcomes in biodiversity ecology. The research was motivated by the need to make ecology and biodiversity learning more contextual, meaningful, and connected to students' surrounding environmental realities. A quantitative pre-experimental method with a one-group pretest-posttest design was employed. The participants were 30 seventh-grade students at SMP Negeri 2 Bokan Kepulauan, Banggai Laut Regency, selected through saturated sampling. Data were collected using a 25-item multiple-choice learning outcomes test, an ecological literacy questionnaire, and a student activity observation sheet. The data were analyzed using the Shapiro-Wilk normality test, Wilcoxon Signed Rank Test, normalized gain, and descriptive percentage analysis. The results showed a significant improvement in students' learning outcomes and ecological literacy after the implementation of coastal environment-based PBL. The N-gain score for learning outcomes reached 0.713, while ecological literacy reached 0.74, both categorized as high. Student activity also remained consistently high during the learning sessions. These findings indicate that coastal environment-based PBL is effective in enhancing students' conceptual understanding, ecological awareness, and active participation in biodiversity ecology learning.

## 1. Introduction

The teaching of ecology and biodiversity is important in biology education because it supports students' understanding of the interdependence among living organisms, the environment, and the sustainability of life. Amid environmental crises such as pollution, habitat degradation, climate change, coastal ecosystem decline, and

biodiversity loss, biology learning should not focus only on conceptual mastery. It should foster ecological awareness, environmental concern, and responsible action. Ecoliteracy, first introduced by Capra in 1997, refers to understanding the ecological principles and patterns that sustain life on Earth (Hannah & Varuneshwaran, 2024). It includes five interconnected dimensions: ecological knowledge, awareness, ethics, emotion, and behavior (Ha & Dong, 2023). Therefore, ecoliteracy is not merely understanding environmental concepts, but also developing values, attitudes, and actions that support sustainability.

Developing ecoliteracy is urgent because environmental problems require citizens to understand ecological issues and participate in solutions. Ecoliteracy develops environmental biophysical knowledge, awareness, and participation in problem solving (Safitri et al., 2023). Without environmental awareness, science and technology may contribute to ecological imbalance (Sholihah et al., 2021). Ecoliteracy is aligned with environmental education in *The Belgrade Charter* by UNESCO-UNEP, which emphasizes knowledge, motivation, and action to solve problems and prevent new ones (Kopnina et al., 2024). In biology learning, ecological literacy can develop problem-solving skills, critical thinking, and concern for nature (Nawawi & Wardhani, 2023). It can also be strengthened through experiences connecting biological concepts with waste management, ecosystem observation, and field-based learning (Berman, 2021; Kim et al., 2017; Minsih et al., 2024).

However, ecology and biodiversity teaching faces challenges. Learning often remains textual, textbook-oriented, and weakly connected to students' environmental experiences. Instruction focused on the cognitive domain encourages memorization without developing environmental awareness and eco-friendly behavior (Paryanti et al., 2021). Low ecoliteracy is associated with limited opportunities to experience, observe, and solve environmental problems (Ayu Setyowati et al., 2024; Ramadhanti et al., 2023; Suharja et al., 2023). Ecology and biodiversity involve organisms, abiotic factors, energy flow, food chains, ecosystem balance, and human impacts. This complexity may create misconceptions when learning lacks contextual experience and authentic inquiry (Ha & Dong, 2023; Minsih et al., 2024; Nawawi & Wardhani, 2023). Other barriers include curriculum limitations, teacher readiness, inadequate laboratory and field facilities, and insufficient interdisciplinary integration (Hannah & Varuneshwaran, 2024; Safitri et al., 2023; Sholihah et al., 2021).

Students' learning outcomes in ecology and biodiversity need improvement. Learning outcomes include academic scores and encompass students' ability to understand concepts, relate them to real phenomena, think critically, and make ecologically informed decisions. Weak ecological understanding is associated with limited appreciation of the environment and conservation (Hannah & Varuneshwaran, 2024). In megabiodiverse Indonesia, biodiversity knowledge should be mastered from school through higher education (Ha & Dong, 2023). Research highlights a gap between curriculum goals and classroom experiences (Sholihah et al., 2021). This gap strengthens the need for applicable, contextual, and

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meaningful learning connecting ecological knowledge with sustainable action (Kim et al., 2017; Minsih et al., 2024; Nawawi & Wardhani, 2023; Safitri et al., 2023).

The coastal environment can overcome textual instruction. Coastal environments contain biodiversity, human-environment interactions, ecosystem change, and conservation issues. Mangroves, seagrass beds, sandy beaches, estuaries, coral reefs, shallow waters, and intertidal ecosystems serve as natural laboratories for ecology learning (Ha & Dong, 2023; Hannah & Varuneshwaran, 2024). Coastal ecosystems illustrate relationships among species, habitats, and conservation (Ha & Dong, 2023). They provide shoreline protection, habitats, fisheries production, recreation, education, and carbon storage (Minsih et al., 2024; Nawawi & Wardhani, 2023; Verutes et al., 2024). Coastal areas also contextualize urbanization, erosion, habitat change, degradation, and environmental management (Kim et al., 2017; Sholihah et al., 2021; Verutes et al., 2024). Thus, coastal environment-based learning makes ecological concepts concrete and meaningful.

To prevent the coastal environment from becoming an object of observation, a model should guide students to identify problems, seek information, discuss findings, formulate solutions, and reflect. Problem-Based Learning (PBL) uses authentic problems to initiate active, collaborative, student-centered, contextual problem solving (Angraini et al., 2023; Carrió et al., 2020; Sugiharto et al., 2019). Its stages include problem identification, strategy planning, problem-solving activities, presentation, and reflection (Aryulina & Riyanto, 2016). PBL is characterized by authentic problems, investigation, collaboration, idea or artifact production, and the teacher as facilitator (Markula & Aksela, 2022; Sari & Aprilliandari, 2021; Shuster et al., 2020; Sirajudin et al., 2024). In ecology learning, it can engage students with coastal pollution, mangrove degradation, biodiversity decline, and community waste behavior.

PBL can effectively improve ecoliteracy and learning outcomes by connecting scientific concepts with real-world problems. In biodiversity learning, it relates to everyday life and trains students to analyze their environment (Waty Hiola et al., 2023). It supports systems reasoning (Gonczi et al., 2021) and strengthens critical thinking, collaboration, ecological awareness, and sustainability connections (Chen Jie & Abidin, 2024; Hernández-Ramos et al., 2021; Himes et al., 2023; Rasi, 2021). Research integrating PBL, coastal environments, ecoliteracy, and ecology and biodiversity learning outcomes remains limited. Existing studies call for contextual, empirically tested ecoliteracy models across educational settings (Hendratno et al., 2022; Okorie, 2023; S. S. Putri et al., 2019; Setyaningsih et al., 2024). The novelty of this study lies in the integration of coastal environment-based problems into the stages of PBL and in the simultaneous assessment of students' ecoliteracy and learning outcomes in ecology and biodiversity. This approach positions the coastal environment not merely as an object of observation, but as an authentic learning resource through which students investigate ecological problems, construct scientific understanding, and formulate sustainable solutions. Therefore, this study examines the effectiveness of coastal environment-based PBL in improving students' ecoliteracy and learning outcomes in ecology and biodiversity.

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## **2. Methodology**

Make sure that work can be repeated according to the details provided. It contains technical information of the study presented clearly. Therefore, readers can conduct research based on the techniques presented. Materials and equipment specifications are necessary. Approaches or procedures of study together with data analysis methods must be presented. Explain using Sub; Instrument, Data Collection, Data Analysis. This study employed a quantitative approach using a pre-experimental method with a one-group pretest-posttest design. This design was used to examine changes in students' ecoliteracy and learning outcomes before and after the implementation of coastal environment-based Problem-Based Learning (PBL). The study was conducted at SMP Negeri 2 Boka Kepulauan, Banggai Laut Regency. The research subjects consisted of 30 Grade VII students selected through saturated sampling because all members of the population in the selected class were involved as research participants.

### ***Instrument***

The instruments used in this study consisted of a learning achievement test, an ecoliteracy questionnaire, and a student activity observation sheet. The learning achievement test consisted of 25 multiple-choice items designed to measure students' understanding of ecology and biodiversity concepts. The ecoliteracy questionnaire was developed based on indicators of understanding environmental problems, understanding ecological principles, critical thinking ability, creative thinking ability, and the ability to evaluate the impacts of human activities on the environment (Putri & Rezania, 2024). The questionnaire was used to measure students' ecoliteracy before and after the learning intervention. The student activity observation sheet was used to monitor students' participation and engagement during the implementation of coastal environment-based PBL. The observed activities included students' involvement in identifying problems, discussing in groups, collecting information, proposing solutions, presenting results, and reflecting on learning activities. The learning materials and equipment used in the study included lesson plans, student worksheets, 25-item learning achievement test sheets, ecoliteracy questionnaires, observation sheets, and coastal environment-based learning resources related to ecology and biodiversity.

### ***Data Collection***

Data collection was carried out in three main stages. The first stage was the administration of the pretest to measure students' initial learning outcomes and ecoliteracy before the intervention. The second stage was the implementation of coastal environment-based PBL over four meetings. During the learning process, students were guided to identify ecological problems related to the coastal environment, discuss possible causes, collect relevant information, analyze the relationship between coastal environmental issues and ecology-biodiversity concepts, and formulate possible solutions. The PBL stages included problem orientation, group organization, investigation, presentation of findings, and reflection. The third stage was the administration of the posttest to measure

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students' learning outcomes and ecoliteracy after the intervention. Student activities during each meeting were observed using the observation sheet to obtain supporting data on student engagement during the learning process.

### **Data Analysis**

The data were analyzed quantitatively. The Shapiro-Wilk normality test was used to determine whether the pretest and posttest data were normally distributed. Because the number of participants was relatively small, the Shapiro-Wilk test was considered appropriate for testing data normality. The Wilcoxon Signed Ranks Test was then used to determine whether there was a significant difference between pretest and posttest scores. The level of significance was set at 0.05. In addition, the normalized gain or N-gain was calculated to determine the level of improvement in students' ecoliteracy and learning outcomes after the implementation of coastal environment-based PBL. The N-gain criteria were categorized as high if  $g > 0.7$ , moderate if  $0.3 \leq g \leq 0.7$ , and low if  $g < 0.3$  (Arifin et al., 2024). Student activity data were analyzed descriptively using percentages to describe the level of student engagement in each meeting.

## **3. Results and Discussion**

### **Result**

This section presents and discusses the findings related to the effectiveness of coastal environment-based Problem-Based Learning (PBL) in improving students' ecoliteracy and learning outcomes in ecology and biodiversity. The results are organized based on three main aspects: students' learning outcomes, students' ecoliteracy, and students' learning activities during the implementation of PBL. The analysis was conducted by comparing pretest and posttest scores, examining the significance of improvement using the Wilcoxon Signed Ranks Test, calculating the N-Gain score, and describing students' activity during the four learning meetings. Overall, the findings indicate that coastal environment-based PBL contributed positively to students' conceptual understanding, ecological awareness, and active participation in learning. The discussion does not merely report statistical results, but also explains why the improvement occurred and how the use of real coastal environmental problems supported more meaningful ecology and biodiversity learning. The percentages of student activity observed during the four learning sessions are presented in Table 1.

Table 1. Results of Student Activity Observations

| Session   | Percentage |
|-----------|------------|
| Session 1 | 79         |
| Session 2 | 89         |
| Session 3 | 85         |
| Session 4 | 86         |

Table 1 presents the results of student activity observations across four learning sessions, with each session assessed using the same seven aspects and corresponding behavioral indicators: active participation in learning through asking, answering, and responding to the teacher's explanations; participation in discussions through involvement in group discussions, expressing ideas, and responding to opinions; group cooperation through collaborative work, task sharing, and respect for group members; engagement in completing student worksheets (LKPD) through involvement in investigative tasks; thinking and analytical ability through processing information, integrating concepts, and drawing conclusions; communication ability through expressing opinions and presenting findings; and attitudes toward learning, including enthusiasm, attention, discipline, and responsibility. Student activity increased from 79% in Session 1 to 89% in Session 2, slightly decreased to 85% in Session 3, and rose again to 86% in Session 4, indicating consistently high levels of participation, cooperation, analytical engagement, communication, and positive learning attitudes throughout the learning process. Before testing the difference between the pretest and posttest scores, the normality of the academic achievement data was examined using the Shapiro-Wilk test, as presented in Table 2.

Table 2. Results of the Normality Test for Academic Achievement Data

| Class |           | Shapiro-Wilk |    |       |
|-------|-----------|--------------|----|-------|
|       |           | Statistic    | df | Sig.  |
| Value | Pre Test  | 0,844        | 30 | 0,000 |
|       | Post Test | 0,952        | 30 | 0,196 |

Table 2 presents the results of the normality test for students' academic achievement data using the Shapiro-Wilk test. The pretest data obtained a Shapiro-Wilk statistic value of 0.844 with a significance value of 0.000. Since the significance value was lower than 0.05, the pretest data were not normally distributed. Meanwhile, the posttest data obtained a Shapiro-Wilk statistic value of 0.952 with a significance value of 0.196. This significance value was higher than 0.05, indicating that the posttest data were normally distributed. Therefore, the academic achievement data did not fully meet the assumption of normality because one of the datasets, namely the pretest data, was not normally distributed. Based on this result, the analysis of the difference between pretest and posttest scores was continued using a non-parametric statistical test, namely the Wilcoxon Signed Ranks Test, as shown in Table 3.

Table 3. Results of the Wilcoxon Signed Rank Test for Academic Achievement Data

|          |                | N               | Mean Rank | Sum of Ranks | Z                   | Asymptotic Sig.(2-sided test) |
|----------|----------------|-----------------|-----------|--------------|---------------------|-------------------------------|
| Posttest | Negative Ranks | 0 <sup>a</sup>  | .00       | .00          | -4.790 <sup>b</sup> | <.001                         |
| Pretest  | Positive Ranks | 30 <sup>b</sup> | 15.50     | 465.00       |                     |                               |
|          | Ties           | 0 <sup>c</sup>  |           |              |                     |                               |
|          | Total          | 30              |           |              |                     |                               |

Table 3 presents the results of the Wilcoxon Signed Rank Test for students' academic achievement before and after the implementation of coastal environment-based Problem-Based Learning. The results show that there were no negative ranks, indicating that no student experienced a decrease in posttest scores compared to pretest scores. All 30 students were categorized under positive ranks, with a mean rank of 15.50 and a sum of ranks of 465.00, showing that all students achieved higher scores after the learning intervention. The Wilcoxon test produced a Z value of -4.790 with an Asymptotic Sig. (2-sided) value of  $< .001$ . Since this significance value was lower than 0.05, it can be concluded that there was a statistically significant difference between students' pretest and posttest scores. These findings indicate that coastal environment-based Problem-Based Learning significantly improved students' academic achievement in ecology and biodiversity learning. To determine the magnitude of improvement in students' academic achievement, the N-gain score was calculated, as presented in Table 4.

Table 4. N-gain Scores for Learning Outcomes

| N-Gain Score | Category |
|--------------|----------|
| 0,713        | High     |

Table 4 presents the N-gain score for students' learning outcomes after the implementation of coastal environment-based Problem-Based Learning. The analysis showed an N-gain score of 0.713, which falls into the high category. This result indicates that the improvement in students' learning outcomes from pretest to posttest was not only statistically significant but also educationally meaningful. The high N-gain score suggests that the learning intervention effectively supported students in understanding ecology and biodiversity concepts. Therefore, coastal environment-based Problem-Based Learning can be considered an effective instructional approach for improving students' academic achievement in ecology and biodiversity learning. The normality of the students' ecoliteracy pretest and posttest scores was also examined using the Shapiro-Wilk test, as presented in Table 5.

Table 5. Results of the Normality Test for Ecoliteracy Data

| Class       |           | Shapiro-Wilk |    |       |
|-------------|-----------|--------------|----|-------|
|             |           | Statistic    | df | Sig.  |
| Ecoliteracy | Pre Test  | 0,784        | 30 | 0,000 |
|             | Post Test | 0,973        | 30 | 0,622 |

Table 5 presents the results of the normality test for students' ecoliteracy data using the Shapiro-Wilk test. The pretest ecoliteracy data obtained a Shapiro-Wilk statistic value of 0.784 with a significance value of 0.000. Since the significance value was lower than 0.05, the pretest data were not normally distributed. Meanwhile, the posttest ecoliteracy data obtained a Shapiro-Wilk statistic value of 0.973 with a significance value of 0.622. Since this significance value was higher than 0.05, the posttest data were normally distributed. Therefore, the ecoliteracy data did not fully meet the assumption of normality because the pretest data were not normally distributed. Based on this result, the analysis was continued using a non-parametric test, namely the Wilcoxon Signed Rank Test, to determine whether there was a

significant difference between students' ecoliteracy scores before and after the implementation of coastal environment-based Problem-Based Learning. Since the ecoliteracy pretest data were not normally distributed, the difference between the pretest and posttest scores was analyzed using the Wilcoxon Signed-Rank Test, as shown in Table 6.

Table 6. Results of the Wilcoxon Signed-Rank Test for Ekoliterasi Data

|          |                | N               | Mean Rank | Sum of Ranks | Z                   | Asymptotic Sig.(2-sided test) |
|----------|----------------|-----------------|-----------|--------------|---------------------|-------------------------------|
| Posttest | Negative Ranks | 0 <sup>a</sup>  | .00       | .00          | -4.785 <sup>b</sup> | <.001                         |
| Pretest  | Positive Ranks | 30 <sup>b</sup> | 15.50     | 465.00       |                     |                               |
|          | Ties           | 0 <sup>c</sup>  |           |              |                     |                               |
|          | Total          | 30              |           |              |                     |                               |

Table 6 shows the results of the Wilcoxon Signed-Rank Test for students' ecoliteracy scores. All 30 students obtained higher posttest scores than pretest scores, as indicated by 30 positive ranks, with no negative ranks or ties. The test produced a Z value of -4.785 and a significance value of  $p < .001$ , indicating a statistically significant improvement in students' ecoliteracy after the implementation of coastal environment-based Problem-Based Learning. To determine the magnitude of improvement in students' ecoliteracy, the average N-gain score was calculated, as presented in Table 7.

Table 7. Average N-Gain Scores for Ekoliterasi

| N-Gain Score | Category |
|--------------|----------|
| 0,74         | High     |

Table 7 presents the average N-gain score for students' ecoliteracy after the implementation of coastal environment-based Problem-Based Learning. The analysis showed an N-gain score of 0.74, which is categorized as high. This finding indicates that students' ecoliteracy improved substantially after participating in the learning intervention. The high N-gain score suggests that coastal environment-based Problem-Based Learning effectively supported students in understanding environmental problems, ecological principles, critical and creative thinking, and the impacts of human activities on ecosystems. Therefore, this learning approach can be considered effective in enhancing students' ecoliteracy in ecology and biodiversity learning. To provide a more detailed comparison of improvement across the five ecoliteracy indicators, the N-gain scores for each indicator are illustrated in Figure 1.

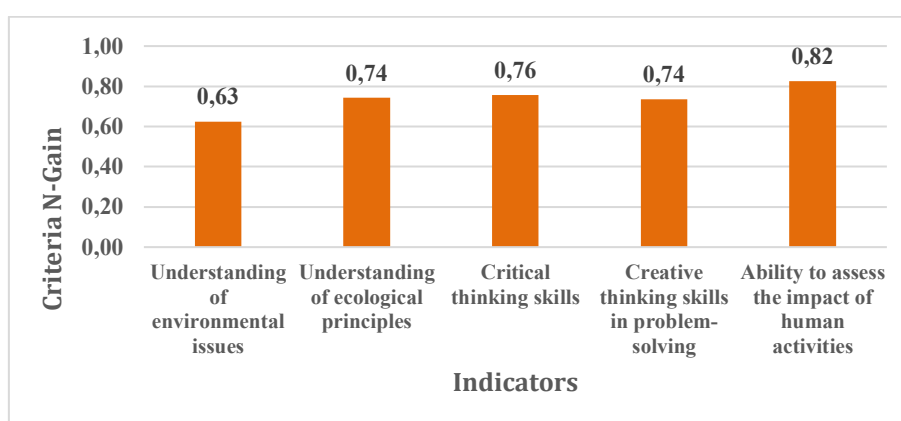


Figure 1. Ecoliteracy N-Gain Scores by Indicator

Figure 1 presents the N-gain scores of students' ecoliteracy based on five indicators. The highest improvement was found in the indicator of the ability to evaluate the impacts of human activities, with an N-gain score of 0.82, which falls into the high category. This was followed by critical thinking ability with an N-gain score of 0.76, understanding ecological principles and creative thinking in solving problems, each with an N-gain score of 0.74, all of which were categorized as high. Meanwhile, the indicator of understanding environmental problems obtained the lowest N-gain score of 0.63, which was categorized as moderate. Overall, these results indicate that coastal environment-based Problem-Based Learning was effective in improving most aspects of students' ecoliteracy, particularly in helping students analyze human impacts on ecosystems, understand ecological principles, and develop critical and creative thinking in solving environmental problems. The pattern of student activity across the four learning sessions is further illustrated in Figure 2.

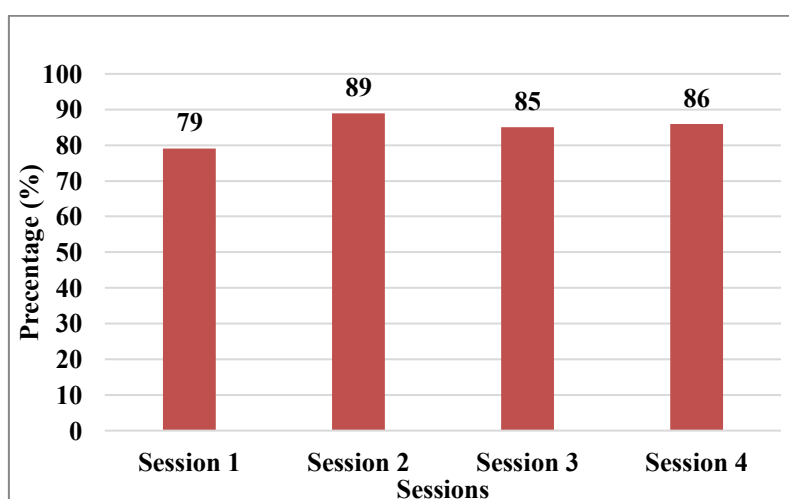


Figure 2. Percentage of Student Activity per Session

Figure 2 presents the percentage of student activity during the four learning sessions using coastal environment-based Problem-Based Learning. The results show that student activity was consistently high across all sessions. In the first session, student

activity reached 79%, indicating that students were already actively involved at the beginning of the learning process. The percentage increased to 89% in the second session, showing the highest level of participation during the intervention. In the third and fourth sessions, student activity remained stable at 85%, suggesting that students maintained active engagement throughout the learning process. Overall, these findings indicate that coastal environment-based Problem-Based Learning encouraged students to participate actively in problem identification, group discussion, investigation, presentation, and reflection. This high level of student activity supports the effectiveness of the learning model in creating an interactive and meaningful ecology and biodiversity learning environment.

### ***Discussions***

The findings indicate that coastal environment-based Problem-Based Learning (PBL) provides a meaningful pedagogical pathway for improving both students' ecological literacy and learning outcomes in biodiversity ecology. The benefit of this result lies not only in the increase of students' post-intervention performance, but also in the way the learning model transformed ecology and biodiversity learning from abstract classroom knowledge into contextual, problem-oriented, and action-based learning. This is important because biology education often faces the challenge of conventional, teacher-centered instruction that limits students' active participation and conceptual understanding (Elkhidir, 2020; Kurnianti & Arif, 2025; Usman et al., 2024). Through coastal environment-based PBL, students were positioned as active problem-solvers who examined real ecological issues, discussed possible causes, and constructed solutions collaboratively. This learning situation is consistent with studies showing that PBL improves academic achievement, content retention, critical thinking, motivation, and student engagement in science and biology education (Tonda et al., 2024; Yamin et al., 2024)

The improvement in learning outcomes can be explained by the contextual nature of the coastal environment as a learning resource. Coastal ecosystems, such as mangroves, seagrass beds, coral reefs, estuaries, and intertidal areas, provide authentic examples of biodiversity, ecological interactions, habitat zonation, ecosystem services, and human impacts. When students learn biodiversity ecology through familiar coastal phenomena, concepts such as species diversity, food chains, ecosystem balance, habitat degradation, and conservation become easier to understand because they are connected to observable realities. Previous studies emphasize that coastal environments function as living laboratories that support experiential, place-based, and multidimensional learning (Elkhidir, 2020; Kurnianti & Arif, 2025; Usman et al., 2024). This explains why the learning intervention was beneficial: students did not merely receive biological information, but interpreted ecological concepts through real environmental conditions that were close to their daily lives.

The findings also show that coastal environment-based PBL strengthened students' ecological literacy. Ecological literacy requires more than knowing environmental facts; it involves ecological knowledge, awareness, values, attitudes, skills, and

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responsible behavior. This multidimensional nature of ecoliteracy requires learning approaches that engage students cognitively, emotionally, socially, and practically. PBL is relevant because it begins with authentic environmental problems and requires students to analyze, investigate, collaborate, and formulate solutions. This aligns with the view that ecoliteracy should develop students' understanding of ecological systems, systems thinking, empathy for living things, and the ability to act sustainably (Kadarisman & Pursitasari, 2023; Kopnina et al., 2024; Okorie, 2023). The result is also supported by studies explaining ecoliteracy through the "head, heart, hands, and spirit" domains, as well as through ecological, social, emotional, economic, and green consumer dimensions (Majumdar & Chatterjee, 2022; Sholeh, 2017). Therefore, the benefit of this study is that it demonstrates how PBL can become a practical model for developing ecoliteracy in an ecology and biodiversity classroom.

The use of real coastal environmental problems also helps explain the improvement in students' ecological awareness and responsibility. Real environmental issues, such as coastal waste, mangrove degradation, habitat disturbance, erosion, and biodiversity decline, allow students to see the direct relationship between ecological principles and human activities. This is important because environmental knowledge alone does not always produce responsible behavior. Students need learning experiences that connect knowledge with emotional engagement, social participation, and action competence (Ninsiana et al., 2024; Safitri et al., 2023; Yudistira et al., 2025). The coastal context allowed students to understand that ecological problems are not distant or theoretical, but part of their own environment. Such learning can bridge the knowledge-action gap by encouraging students to evaluate human impacts, identify possible solutions, and develop a sense of responsibility toward ecosystem sustainability (Campbell et al., 2021; Marouli, 2021).

The variation in N-gain scores across the ecoliteracy indicators demonstrates that coastal environment-based PBL did not influence all dimensions of ecoliteracy equally. The ability to evaluate the impacts of human activities obtained the highest N-gain score of 0.82 because this indicator was closely aligned with the authentic problems and investigative activities presented during the learning process. Coastal problems such as waste accumulation, mangrove degradation, habitat disturbance, erosion, and biodiversity decline provided observable evidence of the relationship between human actions and ecological consequences. Through problem orientation, group discussion, investigation, presentation, and reflection, students repeatedly identified human activities, analyzed their environmental impacts, compared possible consequences, and formulated solutions. These processes required evaluative reasoning rather than the simple recall of ecological information (Hartati et al., 2023). Therefore, the coastal environment functioned not merely as a learning location but as an authentic source of evidence that strengthened students' ability to analyze cause-and-effect relationships between human behavior and ecosystem change. This interpretation is consistent with studies showing that authentic environmental and socio-scientific problems in PBL can promote critical thinking, evidence-based reasoning, environmental problem-solving, and biodiversity

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literacy (Hernández-Ramos et al., 2021; Qing Gao & Rebecca L. Hite, 2018; Waty Hiola et al., 2023).

In contrast, understanding environmental problems obtained the lowest N-gain score of 0.63 and remained in the moderate category. This finding may be related to the multidimensional nature of environmental problems, which requires students to integrate ecological, social, economic, and behavioral factors. Students may have been able to identify visible symptoms, such as coastal waste, habitat degradation, or biodiversity decline, but may still have experienced difficulty distinguishing immediate causes, underlying drivers, long-term consequences, and interactions among environmental system components. Understanding environmental problems therefore requires a broader conceptual framework than evaluating directly observable human impacts. In addition, the four-session intervention may have provided sufficient opportunities to examine concrete ecological consequences but may not have been long enough to develop comprehensive systems-level understanding. Differences in students' prior knowledge and familiarity with ecological concepts may also have influenced the moderate improvement. Previous studies indicate that students' ecoliteracy varies across knowledge, awareness, attitudes, and behavioral dimensions, while complex environmental understanding requires contextual teaching materials, conceptual scaffolding, and sustained learning experiences (Paryanti et al., 2021; Ramadhanti et al., 2023; Zidan et al., 2023).

Student activity during the learning sessions also provides an important explanation for the effectiveness of the intervention. High and sustained student engagement indicates that the learning process encouraged students to participate actively in identifying problems, discussing in groups, conducting investigations, presenting findings, and reflecting on learning experiences (Mustika et al., 2024). Engagement is a key mechanism through which PBL improves learning outcomes and ecoliteracy because it activates cognitive, behavioral, emotional, and social participation. When students are engaged in meaningful environmental problems, they process information more deeply, maintain motivation, build shared understanding, and develop stronger connections with ecological issues (Mercan & Varol Selçuk, 2024; Paraskeva-Hadjichambi et al., 2020; Zidan et al., 2023). In this sense, student activity was not merely a supporting observation; it was a learning condition that helped transform coastal environmental issues into meaningful ecological understanding. This is consistent with the idea that effective learning ecosystems require social engagement, motivation, and self-directed participation (Redmond & Macfadyen, 2020).

The high N-Gain category obtained in both learning outcomes and ecoliteracy indicates that the intervention produced substantial and educationally meaningful improvement. In science education research, N-Gain is commonly used to measure how much of the possible learning improvement has been achieved after an intervention. A high N-Gain suggests that students captured a large proportion of the possible gain from their initial level toward the expected level of mastery (Elkhidir, 2020; Kurnianti & Arif, 2025). This strengthens the interpretation that coastal environment-based PBL was not only statistically effective, but also

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pedagogically valuable (Ardiana et al., 2025). However, this interpretation should still be made carefully because N-Gain should be understood together with the research design, statistical significance, learning context, and possible student-related factors (Kopnina et al., 2024). Therefore, the benefit of the result is not simply that scores increased, but that the learning intervention created a measurable and meaningful improvement in students' ecological understanding.

The Wilcoxon Signed-Rank Test showed that all 30 students achieved higher posttest scores than pretest scores, with no negative ranks or tied scores. This uniform direction of improvement is noteworthy because it indicates that the learning gains occurred across the entire participating class rather than only among a small number of high-performing students. Several characteristics of the intervention may have contributed to this pattern. The use of coastal environmental problems that were familiar and relevant to students may have reduced the distance between abstract ecological concepts and observable phenomena in their surroundings. Furthermore, group investigation, peer discussion, worksheet completion, presentation, and reflection provided multiple opportunities for students to construct knowledge, exchange information, and receive support from their peers and teacher. Previous studies suggest that active, collaborative, and problem-oriented learning can increase students' engagement, scientific literacy, inquiry competence, critical thinking, and readiness to solve contextual problems (Angraini et al., 2023; Aryulina & Riyanto, 2016; Carrió et al., 2020; Rasi, 2021). The relatively homogeneous characteristics of one intact Grade VII class may also have created similar instructional conditions for all participants. However, the absence of negative and tied ranks may additionally have been influenced by the alignment between instructional activities and assessment instruments, repeated exposure to ecological concepts, increased motivation, and students' familiarity with the assessment format after completing the pretest.

The findings have important implications for science learning in coastal schools. Coastal schools are located near ecosystems that can serve as authentic learning resources, yet these environments are often underused in classroom instruction. Previous studies show that coastal environment-based learning can strengthen environmental literacy, conservation character, local ecological knowledge, and students' connection with community-based environmental issues (Fenny et al., 2019; Sukri, 2023; Yuliani et al., 2024). In this study, the use of coastal environmental problems enabled students to learn biodiversity ecology through issues that were relevant to their own surroundings. This supports the argument that coastal PBL can make science learning more culturally and ecologically responsive, especially in schools located in island, marine, or coastal areas. It can also help teachers design lessons that connect curriculum content with local environmental realities.

Beyond classroom achievement, the results also suggest broader educational benefits. Coastal environment-based PBL can contribute to environmental citizenship by preparing students to understand, value, and protect their local ecosystems. When science learning is connected to coastal problems, students may develop conservation awareness, problem-solving competence, and responsibility

toward sustainable resource management. This is consistent with studies emphasizing the importance of local wisdom, coastal biodiversity, land-sea interface education, global ocean awareness, and community empowerment in coastal education (Bryhn & Belgrano, 2023; Katili et al., 2018; Qing Gao & Rebecca L. Hite, 2018; Sugito et al., 2019). Thus, the implication of this study extends beyond improving test scores; it supports the development of students as young ecological actors who can participate in protecting coastal environments.

Nevertheless, the findings should be interpreted within the limitations of the research design. This study used a one-group pretest-posttest design, so the observed improvements cannot be attributed exclusively to coastal environment-based PBL. The absence of a comparison group makes it difficult to separate the effects of the intervention from testing, maturation, and other time-related influences (Knapp, 2016). Therefore, future research should involve control groups, larger samples, and longer intervention periods to strengthen causal interpretation. Further studies may also examine whether improvements in ecoliteracy are sustained over time and whether they influence students' actual environmental behavior outside the classroom. Despite these limitations, the present study offers practical evidence that coastal environment-based PBL is a beneficial learning model for biodiversity ecology because it integrates conceptual learning, active participation, ecological awareness, critical and creative thinking, and environmental responsibility in one coherent learning process.

#### **4. Conclusion**

This study concludes that coastal environment-based Problem-Based Learning was effective in improving students' ecological literacy and learning outcomes in biodiversity ecology. The learning model successfully connected scientific concepts with real coastal environmental issues, allowing students to understand ecology and biodiversity in a more contextual, meaningful, and problem-oriented way. Through the stages of problem identification, group discussion, investigation, presentation, and reflection, students were encouraged to participate actively, think critically, propose creative solutions, and evaluate the relationship between human activities and ecosystem sustainability. The findings show that this approach did not only support conceptual understanding, but also strengthened students' ecological awareness and responsibility toward their surrounding environment.

The success of this research indicates that coastal environments can be used as authentic learning resources, especially for schools located in coastal or island areas. Teachers can adapt this model to make science learning more relevant to students' daily lives and local environmental conditions. Future research should involve broader samples, comparison groups, longer implementation periods, and follow-up studies to examine whether improvements in ecological literacy are sustained and reflected in students' real environmental behavior.

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<https://doi.org/10.17509/aijbe.v6i2.59777>

How to cite this article:

Sriastuti, N., Odja, A. H., Pikoli, M., Yusuf, F. M., & Ali, R. (2026). The Effectiveness of Coastal Environment-Based PBL in Improving Students' Ecological Literacy and Learning Outcomes in Biodiversity Ecology. *Journal of Educational Sciences*, 10(8), 117-136.

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