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Environmental literacy readiness of preservice biology teachers in the context of wetland ecosystems to support SDG 4

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ABSTRACT

Environmental literacy is an essential competency for supporting Sustainable Development Goal (SDG) 4, particularly in fostering quality education that promotes sustainability awareness and responsible environmental action. As future educators, pre-service biology teachers are expected to possess adequate environmental literacy to integrate sustainability principles into biology learning. This study aimed to examine the environmental literacy readiness of pre-service biology teachers as a foundation for integrating sustainability principles into future biology teaching, using wetland ecosystems as a contextual learning setting aligned with SDG 4. A quantitative descriptive survey design was employed involving 42 fourth-semester pre-service biology teachers. Participants were selected using purposive sampling. Data were collected using an Environmental Literacy Readiness Questionnaire consisting of four dimensions: environmental knowledge, cognitive skills, environmental attitudes, and pro-environmental behavior. The instrument met validity requirements ($r > 0.397$) and demonstrated very high reliability (Cronbach's Alpha = 0.987). The results indicated that all four dimensions of environmental literacy scored above 80%, indicating a very high level of environmental literacy readiness among pre-service biology teachers. The overall readiness index reached 82.38%, indicating a very high level of readiness. These findings suggest that pre-service biology teachers are well-positioned to support sustainability-oriented biology education and contribute to the achievement of SDG 4 through wetland-based learning.



INTRODUCTION

Preparing future biology teachers to address sustainability challenges has become an important priority in higher education. This priority is closely aligned with Sustainable Development Goal (SDG) 4, which extends beyond improving access to quality education by emphasizing the development of competencies that enable learners to contribute to sustainable development. Consequently, teacher education programs are increasingly expected to cultivate environmental literacy among pre-service teachers so that sustainability principles can be meaningfully integrated into future biology teaching (Rassanjani, 2018; Sánchez-Carracedo et al., 2021). The context of the SDGs states that education serves not only as a means of transferring knowledge but also as an instrument for shaping individuals who possess the awareness, skills, attitudes, and behaviors necessary to act responsibly toward the environment (Ruwaida et al., 2026; Sánchez-Carracedo et al., 2021).

Environmental education is one approach that can support the achievement of SDG 4 through the development of environmental literacy. Environmental literacy is understood as an individual's ability to understand environmental concepts, identify and analyze environmental issues, demonstrate concern for the environment, and take responsible actions toward environmental sustainability. Environmental literacy has been widely recognized as a multidimensional construct encompassing environmental knowledge, cognitive skills, environmental attitudes, and pro-environmental behavior (Mardiana et al., 2026). Previous studies have extensively assessed these dimensions among school students, university students, and pre-service teachers, generally reporting moderate to high levels of environmental literacy depending on participants' educational experiences and environmental exposure. Mastery of these four dimensions serves as a crucial foundation for shaping a society capable of actively participating in environmental conservation and sustainable development efforts (Ampofo et al., 2026; Ashurova et al., 2026; Maleknia & Zamani, 2025). While these studies have contributed to understanding environmental literacy as an educational outcome, most have focused primarily on describing literacy levels rather than examining how environmental literacy reflects the readiness of future biology teachers to integrate sustainability principles into their professional practice.

Efforts to strengthen environmental literacy must begin in educational institutions, particularly through the role of teachers as agents of change in society. Teachers have a responsibility to instill values of sustainability and foster environmental awareness in students through the learning process (King & Franzen, 2017). Therefore, pre-service teachers, especially those training to become biology teachers must possess adequate environmental literacy before entering the profession. This preparedness is crucial because biology education is closely linked to various environmental and sustainability issues. Pre-service biology teachers with strong environmental literacy are expected to be able to develop contextual, meaningful lessons that support the potential of the surrounding environment (Husamah et al., 2025; Maleknia & Pakravan-Charvadeh, 2025).

One environmental resource of strategic value in biology education is the wetland ecosystem. This ecosystem plays a vital role in maintaining ecological balance through its hydrological functions, carbon sequestration, flood control, and provision of habitat for various species of flora and fauna (Wajdi et al., 2022). Indonesia is one of the countries with a high diversity of wetland ecosystems, including in the Kalimantan region, which is known for its distinctive environmental features such as swamps, rivers, and peatlands. However, various human activities such as land-use conversion, pollution, and excessive exploitation of natural resources, have led to a decline in the quality of wetland ecosystems (Cahayani & Utami, 2025; Yikii et al., 2017). These conditions indicate that environmental conservation efforts require the support of human resources who possess an understanding of and concern for environmental sustainability, including through education (Liu et al., 2021).

Wetland ecosystems provide authentic and locally relevant learning contexts that enable students to connect biological concepts with environmental issues encountered in their daily lives. Empirical studies have reported that integrating wetland ecosystems into biology learning enhances students' environmental understanding, ecological awareness, and engagement with sustainability-related issues (Amin & Maritasari, 2023; Cahayani & Utami, 2025). Learning activities situated in local wetland environments also encourage contextual learning by allowing students to observe ecological processes directly and relate scientific concepts to real environmental challenges. These findings suggest that wetland ecosystems offer a meaningful educational context for examining environmental literacy among pre-service biology teachers (Cahayani & Utami, 2025). Using wetland ecosystems as a learning context provides opportunities for pre-service biology teachers to connect biological concepts with real-world phenomena occurring in their surrounding environment. A learning approach that leverages local resources can enhance the relevance of learning while strengthening students' ecological awareness. Furthermore, the wetland context can also serve as a means to develop 21st-century competencies aligned with the principles of Education for Sustainable Development (ESD), ensuring that education is not only focused on conceptual mastery but also on fostering character and behavior that demonstrate environmental responsibility (Kumar et al., 2024; Mochizuki & Fadeeva, 2010; Saragih et al., 2021).

Previous studies have investigated environmental literacy across various educational levels. A recent study by (Husamah et al., 2024; Ashurova et al., 2026) have examined environmental literacy among university students and generally reported high levels of environmental knowledge and environmental attitudes. However, these studies have primarily focused on assessing overall environmental literacy levels, while research examining environmental literacy readiness among pre-service biology teachers, particularly within the context of wetland ecosystems and its relevance to SDG 4, remains limited (Ashurova et al., 2026). In fact, information regarding the environmental literacy readiness of pre-service teachers is essential as a foundation for designing educational programs capable of producing educators who are environmentally aware and oriented toward sustainable development. Therefore, there is a need to conduct a more in-depth study on the environmental literacy readiness of pre-service biology teachers by utilizing the local context of wetland ecosystems (Cahayani & Utami, 2025). Although these studies have contributed to understanding environmental literacy among learners, they primarily focused on measuring environmental literacy levels as educational outcomes. Limited attention has been given to interpreting environmental literacy as an indicator of pre-service biology teachers' readiness to integrate sustainability into future teaching, particularly within locally relevant contexts such as wetland ecosystems.

In this study, *environmental literacy readiness* refers to the preparedness of pre-service biology teachers to integrate environmental literacy principles into future biology teaching that supports Education for Sustainable Development (ESD) and SDG 4. This readiness is reflected through four interconnected dimensions: environmental knowledge, cognitive skills, environmental attitudes, and pro-environmental behavior. Therefore, environmental literacy is conceptualized not merely as a set of competencies, but as an indicator of pre-service teachers' readiness to facilitate sustainability-oriented biology learning. Based on the above discussion, this study aims to analyze the level of environmental literacy among pre-service biology teachers in supporting the achievement of Sustainable Development Goal (SDG) 4 through the context of wetland ecosystems. This study contributes to the existing literature by conceptualizing environmental literacy as an indicator of pre-service biology teachers' readiness to integrate sustainability principles into future biology teaching, while interpreting this readiness within the local context of wetland ecosystems. Unlike previous studies that primarily reported environmental literacy levels among students, this study extends the discussion by examining environmental literacy readiness among pre-service biology teachers and interpreting the findings within the educational context of wetland ecosystems to inform sustainability-oriented teacher education.

METHODS

A descriptive quantitative survey design was employed to assess the environmental literacy readiness of pre-service biology teachers, with the findings interpreted within the context of wetland ecosystems. The study employed a purposive sample of 42 fourth-semester pre-service biology teachers from Universitas Lambung Mangkurat. Data were collected through an Environmental Literacy Readiness Questionnaire developed based on four dimensions of environmental literacy, namely environmental knowledge, cognitive skills, environmental attitudes, and pro-environmental behavior. Prior to implementation, the instrument was subjected to validity and reliability testing to ensure its appropriateness for data collection. The survey was administered online using Google Forms in June 2026. Subsequently, the collected data were analyzed using descriptive statistics by converting respondents' scores into percentage values, which were then interpreted according to predetermined criteria to determine the achievement level of each dimension and the overall Environmental Literacy Readiness Index.

Research Design

This study employs a descriptive quantitative approach to analyze the environmental literacy readiness of pre-service biology teachers in supporting Sustainable Development Goal (SDG) 4 within the context of wetland ecosystems. A survey design was chosen because it allows researchers to obtain an empirical picture of respondents' levels of environmental literacy based on data collected from the research instrument (John W & Creswell, 2018). This approach also facilitates the systematic and objective measurement of the level of achievement in each dimension of environmental literacy (Kobayashi et al., 2026; Kumar et al., 2024). This approach facilitates the measurement of the four main dimensions of environmental literacy: environmental knowledge, cognitive skills, environmentally conscious attitudes, and pro-environmental behavior. These main dimensions can provide a comprehensive understanding of the readiness of pre-service biology teachers as agents of sustainability-oriented education.

Population and Samples

The participants of this study consisted of 42 fourth-semester undergraduate students enrolled in the Biology Education Study Program, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Indonesia. The sample size of 42 participants was considered appropriate because this study employed a descriptive survey design aimed at providing a profile of environmental literacy readiness within a specific group of pre-service biology teachers rather than making statistical generalizations to a broader population. Participants were selected purposively based on predefined inclusion criteria, resulting in a relatively homogeneous sample consisting of fourth-semester biology education students who had completed ecology-related coursework. Assessing students at this stage enables the study to capture their baseline environmental literacy readiness before entering more advanced pedagogical and field-based training. Given the descriptive nature of the analysis, which relied on percentage scores and an Environmental Literacy Readiness Index rather than inferential statistical testing, the selected sample was considered sufficient to address the objectives of the study.

Instruments

Data were collected using a self-report Environmental Literacy Readiness Questionnaire, which was adapted from the environmental literacy framework developed by Rofiqi (2024a). The questionnaire consisted of four dimensions, namely environmental knowledge, cognitive skills, environmental attitudes, and pro-environmental behavior. Each dimension was measured using 10 questionnaire items distributed across the respective indicators, resulting in a total of 40 items. Environmental knowledge was measured through three indicators, cognitive skills through four

indicators, environmental attitudes through four indicators, and pro-environmental behavior through five indicators.

Responses were measured using a five-point Likert scale, ranging from strongly disagree (1), disagree (2), neutral (3), agree (4), to strongly agree (5). Positive statements were scored directly, whereas negative statements were scored reversely. Prior to data collection, the questionnaire underwent empirical validity testing using corrected item-total correlation analysis, while its internal consistency reliability was evaluated using Cronbach's alpha coefficient. The empirical validity of the questionnaire was evaluated using corrected item-total correlation analysis. The validity test results showed that all questionnaire items were valid, with an r -value greater than the critical value of 0.397 ($r > 0.30$). Furthermore, the reliability analysis yielded a Cronbach's alpha coefficient of 0.987, indicating a very high level of internal consistency. Therefore, the instrument was considered suitable for measuring the environmental literacy readiness of pre-service biology teachers.

Data Collection and Analysis

Data collection was conducted in June 2026 using an online questionnaire administered through Google Forms. Before completing the questionnaire, participants were informed about the objectives of the study and were assured that their responses would remain confidential and be used exclusively for research purposes. Participation in the study was voluntary, and all respondents provided informed consent prior to completing the questionnaire (Rokhmah et al., 2021). The collected data were analyzed using descriptive statistics. The overall environmental literacy readiness score showed a mean of 4.10, a median of 4.00, modes of 4 and 5, and a standard deviation of 0.59, indicating that respondents generally demonstrated high levels of environmental literacy readiness with relatively low variability in their responses. The scores obtained for each indicator were averaged to obtain the mean score for each environmental literacy dimension. The mean scores were subsequently converted into percentage indices by dividing them by the maximum possible score and multiplying by 100. The Environmental Literacy Readiness Index was calculated based on the combined performance across four dimensions: environmental knowledge, cognitive skills, environmental attitudes, and pro-environmental behavior (Maleknia & Zamani, 2025; Safitri et al., 2025).

$$\text{Environmental Literacy Index (\%)} = \frac{\Sigma \text{Total score obtained}}{\Sigma \text{Maximum score}} \times 100\%$$

This approach enabled comparison of readiness levels across the four dimensions. The resulting percentage values were interpreted using the criteria adapted from (Santoso et al., 2021), as presented in Table 1.

Table 1

Criteria for environmental literacy readiness.

Percentage (%)	Category
81–100	Very High
61–80	High
41–60	Moderate
21–40	Low
0–20	Very Low

RESULTS AND DISCUSSION

The descriptive analysis was conducted to examine the environmental literacy readiness of pre-service biology teachers in supporting SDG 4 through the context of wetland ecosystems. Environmental literacy readiness was assessed across four dimensions, namely environmental knowledge, cognitive skills, environmental attitudes, and pro-environmental behavior. Given that environmental literacy readiness was assessed using a self-report questionnaire, the findings should be interpreted as reflecting participants' perceived levels of environmental literacy readiness, rather than objectively measured competencies or actual environmental performance. The achievement level of each dimension and the overall Environmental Literacy Readiness Index are presented in Table 2.

Table 2

Level of achievement for each dimension of the environmental literacy indicator.

No	Indicators	Sub-indicators	Sub-indicator Results (%)	Indicator Results (%)
1	Environmental knowledge	Knowledge of the environment (ecological) and the surrounding environment	85.36	84.75
		Knowledge of environmental pollution (causes, impacts, and environmental changes)	85.40	
		Knowledge of problem-solving related to environmental issues	83.49	
2.	Cognitive Skills	Identifying environmental issues or problems in wetland ecosystems	82.86	83.02
		Analyzing environmental issues or problems in wetland ecosystems	85.71	
		Ability to plan investigative actions regarding environmental issues in wetland ecosystems	80.95	
		Ability to conduct investigations into environmental issues in wetland ecosystems	82.54	
3.	Environmental Awareness	An attitude of appreciation for the environment	80.48	80.54
		Environmental awareness	80	
		Sensitivity to the environment	80.95	
		Motivation and the intention to take action to solve environmental problems	80.71	
4.	Environmentally Friendly Behavior	Eco-friendly transportation	80.95	81.19
		Green consumerism	82.86	
		Natural resource conservation	80.95	
		Recycling and waste reduction	79.05	
		Social Behavior Toward the Environment	82.54	

The results of the study indicate that pre-service biology teachers demonstrate a good level of environmental literacy across all measured dimensions. This achievement is reflected in high scores on indicators of environmental knowledge, cognitive skills, environmental concern, and pro-environmental behavior. The high scores obtained across the four dimensions should therefore be interpreted as reflecting a high level of perceived readiness rather than evidence of actual teaching competence. These findings indicate that the students already possess a sufficient foundation to understand various environmental issues and implement sustainability principles in their daily lives as well as in their future teaching practices (Law et al., 2023; Rozana et al., 2026). This readiness serves as a crucial asset for pre-service biology teachers in supporting the achievement of Sustainable Development Goal (SDG) 4, particularly Target 4.7, which emphasizes the importance of education for sustainable development. These dimensions were also considered indicators of pre-service teachers' preparedness to support sustainability-oriented biology education within wetland contexts.

Environmental Knowledge Indicators

The environmental knowledge indicator showed a high achievement rate (84.75%), indicating that the participants possessed a very high level of environmental knowledge. This finding is consistent with previous studies reporting that environmental knowledge is generally the strongest component of environmental literacy among pre-service teachers and university students (Alkaher & Goldman, 2018a; Hikmah et al., 2024; Husamah et al., 2024). Mastery of this knowledge is a fundamental component of environmental literacy because it enables individuals to understand the relationship between human activities and environmental conditions (Liu & Tobias, 2024). This finding is consistent with explains that environmental knowledge serves as the primary foundation for shaping ecological awareness and encouraging individuals to make environmentally responsible decisions. Based on this, mastery of environmental concepts is an important prerequisite for developing sustainability competencies in pre-service biology teachers (Hafsaridewi et al., 2018; Si et al., 2022).

The high level of environmental knowledge possessed by pre-service biology teachers indicates that the respondents already have sufficient academic capital to integrate environmental issues into the learning process. Mastery of environmental concepts by pre-service biology educators is not only necessary for understanding ecological phenomena but also for developing learning experiences that foster environmental awareness and responsibility among students. Environmental knowledge in sustainable education serves as the foundation for building critical thinking, decision-making, and problem-solving skills related to sustainability issues. Pre-service teachers with a high level of environmental knowledge tend to be better prepared to integrate sustainability principles into their teaching practices (Harris et al., 2025). Furthermore, emphasize that mastery of knowledge related to the environment and sustainability is one of the key competencies required to support the implementation of Education for Sustainable Development (ESD) (Maleknia & Zamani, 2025).

The high environmental knowledge score (84.75%) may also be explained by the learning context experienced by the participants. As fourth-semester biology education students at Universitas Lambung Mangkurat, they had completed foundational biology and ecology courses while studying in a region characterized by extensive wetland ecosystems. This educational context likely enhanced their understanding of environmental concepts, environmental pollution, and environmental problem-solving, particularly those related to local wetland ecosystems. Rather than functioning as the object of investigation in this study, wetlands provided an authentic environmental context through which students developed and interpreted environmental knowledge. This contextual exposure may explain why environmental knowledge emerged as the highest-scoring dimension of environmental literacy readiness (Sihombing et al., 2024).

Cognitive Skills Indicators

The cognitive skills dimension achieved a very high score (83.02%), indicating that the participants perceived themselves as capable of identifying, analyzing, and planning investigations related to environmental issues in wetland ecosystems. Within the context of South Kalimantan, these issues may include peatland degradation, river and swamp pollution, land conversion, biodiversity loss, and other environmental challenges affecting wetland sustainability. Rather than referring to environmental problems in general, the wetland context in this study represents authentic local issues that prospective biology teachers are likely to encounter and discuss during their academic learning.

Among the assessed sub-indicators, the ability to analyze environmental issues obtained the highest score, whereas planning investigative actions showed the lowest achievement. This pattern suggests that students were more confident in interpreting environmental problems than in designing systematic investigative procedures, highlighting the need to strengthen inquiry-oriented learning experiences within biology education (Tosun et al., 2025). Students' cognitive skills serve as a crucial foundation for developing biology education grounded in scientific inquiry. Students' ability to connect biological concepts with environmental phenomena occurring around them—particularly within wetland ecosystems—reflects the higher-order thinking skills required for 21st-century learning (Jones et al., 2020). A solid understanding of environmental concepts strengthens the critical thinking and problem-solving skills needed to comprehend the complexity of environmental issues (Ampofo et al., 2026).

The relatively lower score for planning investigative actions suggests that participants reported lower confidence in designing environmental investigations than in identifying or analyzing environmental issues. As the cognitive skills dimension was measured using a self-report questionnaire, these findings should be interpreted as participants' perceptions of their inquiry-related competencies rather than evidence of their actual performance in conducting environmental investigations. This finding indicates that opportunities to strengthen inquiry-oriented learning experiences may further enhance students' confidence in planning investigations within the context of wetland ecosystems. These findings suggest that a high level of knowledge mastery has not yet been fully accompanied by optimal inquiry skills (Maleknia & Zamani, 2025). The development of environmental literacy requires learning experiences that enable students to actively engage in the process of investigating and solving environmental problems (Çolak & Karakaya, 2026). Therefore, project-based learning and the use of the surrounding environment as a natural laboratory are essential for enhancing the cognitive skills of pre-service biology teachers (Clarisa et al., 2020; Liu et al., 2026).

Indicators of environmental awareness

Environmental awareness obtained the lowest score among the four measured dimensions (80.54%), although it remained within the very high category. Similar findings have been reported in previous studies, where pre-service teachers generally demonstrated strong environmental awareness, but affective dimensions tended to develop more gradually than cognitive dimensions because they are influenced not only by academic knowledge but also by personal experiences and environmental engagement (Alkaher & Goldman, 2018a; Fatimah et al., 2024). One possible explanation is that environmental awareness develops gradually through continuous personal experiences and emotional engagement with environmental issues, in addition to formal academic learning. Although participants had been exposed to environmental concepts through biology and ecology courses, developing deep environmental concern may require more sustained interaction with authentic environmental challenges (King & Franzen, 2017). Within the context of South Kalimantan, students are frequently exposed to environmental issues affecting wetland ecosystems, such as river pollution, peatland degradation, seasonal flooding, and land-use conversion. These local environmental conditions may contribute to students' awareness of environmental problems, while also highlighting the need for educational experiences that

strengthen emotional engagement and personal responsibility toward wetland conservation (Sobirova et al., 2026).

Environmental knowledge and strong cognitive skills further contribute to the development of an environmentally conscious attitude among pre-service biology teachers. This attitude is reflected in their attention, sensitivity, appreciation, and motivation to participate in environmental conservation (Ainin & Asafri, 2023). These findings indicate that an understanding of various environmental issues not only fosters critical thinking skills but also cultivates awareness and concern for environmental sustainability (Alkaher & Goldman, 2018a). Individuals who feel connected to the environment and have a good understanding of environmental issues tend to exhibit more positive attitudes toward environmental conservation efforts (Abdellatif, 2022). Thus, the affective aspect is a crucial component in shaping the character of pre-service teachers with an environmental perspective.

The high level of environmental concern demonstrated by pre-service biology teachers indicates their readiness to serve as agents of change in supporting sustainability-oriented education (Dharma et al., 2024). This attitude is reflected not only in their concern for various environmental issues but also in their motivation to engage in environmental conservation efforts and encourage others to take similar actions (Dharma et al., 2024; Syarifudin et al., 2026). As pre-service educators, an environmentally conscious attitude is a crucial asset in fostering a learning culture that instills sustainability values in students. A positive attitude toward the environment also influences pre-service teachers' readiness to integrate environmental issues into their teaching (Fatimah et al., 2024; Rahmat et al., 2025). Furthermore, the affective dimension plays a crucial role in shaping sustainability competencies because it encourages individuals to translate environmental knowledge and understanding into tangible commitments to environmental conservation (Aurora et al., 2026). Although environmental awareness scored the lowest among all dimensions of environmental literacy, it still remained at a high level. This pattern suggests that learning experiences that go beyond conceptual understanding may be necessary to strengthen environmental concern, thereby enabling students to form stronger emotional connections with the environmental issues they encounter in local wetland ecosystems. The high level of environmental awareness observed in this study may indicate that pre-service biology teachers have strong potential to develop instruction that focuses not only on conceptual mastery but also on character development and fostering students' environmental responsibility (Hamidah & Dewi, 2025; Law et al., 2023; Pangsuma et al., 2024).

Indicators of pro-environmental behavior

Pro-environmental behavior achieved a very high score (81.19%), indicating that participants perceived themselves as frequently engaging in environmentally responsible practices. Although this dimension was classified as very high, its score remained lower than environmental knowledge and cognitive skills, suggesting that adopting consistent pro-environmental behavior may require more than conceptual understanding alone. This pattern is consistent with previous studies reporting that environmentally responsible behavior tends to develop gradually because it is influenced not only by environmental knowledge but also by personal habits, social norms, and opportunities to engage in environmental activities (Alkaher & Goldman, 2018b; Barclay & Barker, 2020; Kurniawan et al., 2024).

In the context of South Kalimantan, where wetland ecosystems are closely associated with environmental challenges such as river pollution, peatland degradation, and land-use change, these local issues may also reinforce students' awareness of the importance of environmentally responsible behavior. However, because this study employed a self-report questionnaire, the findings should be interpreted as participants' perceived pro-environmental behavior rather than objectively observed environmental practices. The students' environmental awareness is reflected in their pro-environmental behavior, which is demonstrated through habits such as conserving resources, reducing waste, supporting conservation efforts, and participating in various activities

that promote environmental sustainability (Aurora et al., 2026). Such behavior indicates that students not only understand the importance of protecting the environment but have also put these values into practice (Barclay & Barker, 2020). Sound environmental knowledge and attitudes foster the development of environmentally responsible behavior. Thus, pro-environmental behavior can be viewed as a manifestation of the successful development of the knowledge, skills, and attitudes dimensions of environmental literacy (Alkahrer & Goldman, 2018a).

As ecosystems of high ecological value, wetlands offer a variety of phenomena that can be utilized as contextual learning resources in biology education. Utilizing local contexts allows students to connect biological concepts with real-world issues occurring in their surrounding environment, thereby making learning more meaningful and relevant (Nugroho et al., 2019). This approach aligns with the principles of Education for Sustainable Development (ESD), which emphasizes the interconnection between knowledge, values, and actions in support of sustainability. Therefore, wetland ecosystems have great potential to be utilized as a vehicle for developing environmental literacy among pre-service biology teachers (Cahayani & Utami, 2025; Norliani et al., 2026).

Environmental Literacy Index

The results of the study show that the Environmental Literacy Index of pre-service biology teachers reached 82.38%, falling into the “very high” category. This achievement indicates that the respondents are well-prepared in terms of environmental knowledge, cognitive skills, environmental concern, and pro-environmental behavior—the key components of environmental literacy (Kobayashi et al., 2026; Mardiana et al., 2026). The high index score indicates that the students not only possess a conceptual understanding of environmental issues but also demonstrate the ability to analyze environmental problems, show concern for sustainability, and engage in behaviors that support environmental conservation (Liu et al., 2021; Wajdi et al., 2022). These findings reinforce the theory that the level of environmental literacy among pre-service biology teachers has developed holistically through the integration of cognitive, affective, and behavioral aspects. A high level of environmental literacy among pre-service teachers also reflects their readiness to serve as agents of change in instilling sustainability values in future generations (Hunter & Jordan, 2023). Furthermore, that individuals with strong environmental literacy tend to demonstrate greater capacity to understand environmental issues, make responsible decisions, and participate in actions that support sustainability (Liu & Tobias, 2024). The very high environmental literacy index scores in this study also confirm that pre-service biology teachers have great potential to support the implementation of sustainable education and the achievement of SDG 4 through contextual biology learning based on wetland ecosystems (Mochizuki & Fadeeva, 2010; Sihombing et al., 2024; Suwanto et al., 2021).

Overall, the findings indicate that the participants reported very high levels across the four assessed dimensions of environmental literacy readiness, namely environmental knowledge, cognitive skills, environmental awareness, and pro-environmental behavior. Together, these findings provide a descriptive profile of participants’ perceived environmental literacy readiness within the context of wetland ecosystems. The interrelationships among these dimensions indicate that environmental literacy is a holistic concept that cannot be understood in isolation (Kumar et al., 2024; Ashurova et al., 2026). The environmental literacy readiness possessed by students serves as a crucial foundation for producing pre-service teachers capable of developing wetland-based and sustainability-oriented biology instruction (Law et al., 2023). Thus, this study confirms that strengthening environmental literacy among pre-service biology teachers is one strategy that can support the achievement of SDG 4 through the provision of high-quality, contextual, and sustainable education (Bezabih et al., 2026; Çolak & Karakaya, 2026).

In the present study, wetland ecosystems should be understood as the local environmental context within which participants’ environmental literacy readiness was assessed and interpreted, rather than as an instructional intervention or a determinant of environmental literacy. As one of

South Kalimantan's distinctive ecosystems with high ecological value, wetlands provide a contextual and relevant learning resource for linking biological concepts to real-world environmental phenomena (Cahayani & Utami, 2025; Diaz-Pinzón et al., 2024). The high achievements in the dimensions of environmental knowledge and cognitive skills indicate that students are able to understand and analyze various environmental issues related to the sustainability of wetland ecosystems (Bezabih et al., 2026; Liu et al., 2021). Furthermore, high achievement in the dimensions of environmental concern and pro-environmental behavior indicates a readiness to translate this understanding into concrete actions that support environmental conservation (Aurora et al., 2026; Norliani et al., 2026; Ruwaida et al., 2026). Wetland-based biology education not only has the potential to improve students' environmental literacy but can also serve as an effective means of preparing future educators capable of promoting environmental conservation and sustainable development through the educational process (Mardiana et al., 2026; Rofiqi, 2024b).

The findings of this study indicate that strengthening environmental literacy among pre-service biology teachers should be viewed as a long-term investment in building a sustainability-oriented educational culture. The high levels of achievement in the dimensions of environmental knowledge, cognitive skills, environmentally conscious attitudes, and pro-environmental behavior indicate that these future educators already possess sufficient capacity to transform environmental issues into meaningful learning experiences (Tosun et al., 2025). This situation presents an opportunity for higher education institutions to develop curricula and learning strategies that are more integrated with sustainability issues and local environmental characteristics. In the context of South Kalimantan, utilizing wetland ecosystems as a learning resource can strengthen the connection between scientific knowledge and the environmental realities faced by the community. Therefore, the results of this study not only provide an overview of the environmental literacy readiness of pre-service biology teachers but also offer an empirical foundation for the development of biology education capable of producing environmentally conscious educators, supporting wetland ecosystem conservation, and contributing to the achievement of sustainable development goals through contextual, adaptive, and future-oriented education.

CONCLUSION

This study concludes that pre-service biology teachers demonstrate a very high level of environmental literacy readiness, as indicated by an overall Environmental Literacy Readiness Index of 82.38%. This study provides a descriptive profile of the environmental literacy readiness of pre-service biology teachers based on four assessed dimensions: environmental knowledge, cognitive skills, environmental awareness, and pro-environmental behavior. Rather than examining causal relationships among these dimensions, the findings contribute empirical evidence that environmental literacy readiness can be comprehensively described through multiple cognitive, affective, and behavioral dimensions within the local context of wetland ecosystems. This study also extends the limited body of research on environmental literacy among pre-service biology teachers by providing evidence from South Kalimantan, where wetland ecosystems represent a distinctive environmental setting for interpreting environmental literacy readiness. The findings provide a useful baseline for biology teacher education programs to evaluate students' environmental literacy readiness and to design learning experiences that integrate local environmental issues into sustainability-oriented education. Future studies are encouraged to examine the relationships among environmental literacy dimensions and to explore how contextual learning experiences influence environmental literacy readiness using broader samples and analytical approaches beyond descriptive surveys.

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