

SCIENTIFIC LITERACY DEVELOPMENT IN ELEMENTARY SCHOOLS THROUGH BIODIVERSITY SUBTOPICS WITHIN THE MERDEKA CURRICULUM FRAMEWORK

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ABSTRACT

This study aims to analyze the development of scientific literacy among elementary school students through biodiversity subtopics in science (IPA) learning within the Merdeka Curriculum framework. In Indonesian elementary education, science is taught as an integrated subject without separating biology as a distinct discipline. Biological concepts are introduced through contextual subtopics such as characteristics of living organisms, life cycles, and biodiversity. This study employs a qualitative descriptive approach using classroom observations, learning document analysis, and literature review. The findings indicate that biodiversity-based science learning supports students' understanding of scientific concepts, enhances inquiry skills, and promotes the ability to relate scientific knowledge to everyday life. Contextual learning activities aligned with the Merdeka Curriculum encourage active student participation and meaningful learning experiences. This study contributes to elementary science education by providing insights into effective instructional practices for strengthening scientific literacy through integrated biological subtopics.

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1. INTRODUCTION

Scientific literacy has become a central objective of contemporary science education, particularly at the elementary school level where students begin to construct foundational understandings of natural phenomena. Scientific literacy equips learners with the ability to comprehend scientific concepts, interpret evidence, and apply scientific knowledge in everyday life. Developing scientific literacy from an early age is therefore essential to prepare students for lifelong learning and informed decision-making in a science- and technology-oriented society (Bybee, 2021).

Despite its importance, numerous studies and international assessments report that elementary school students' scientific literacy remains relatively low, especially in terms of scientific reasoning and contextual application of knowledge. Many students are able to recall factual information but experience difficulties when asked to explain natural phenomena or relate scientific concepts to real-life situations. This condition indicates that science learning at the elementary level often emphasizes content transmission rather than meaningful understanding and inquiry-based learning (OECD, 2022). The implementation of the Merdeka Curriculum in Indonesia aims to address these challenges by promoting student-centered, flexible, and contextual learning. At the elementary level, science is taught as an integrated subject (*Ilmu Pengetahuan Alam/IPA*), without separating biology, physics, and chemistry into distinct disciplines. Biological concepts are embedded within thematic subtopics, such as biodiversity, characteristics of living organisms, and interactions between organisms and their environments. This integrated approach allows teachers to design learning activities that are more relevant to students' developmental stages and local contexts (Kemdikbudristek, 2023).

Preliminary observations conducted at SDN 1 Bireuen, Aceh Province, reveal several challenges related to students' scientific literacy in science learning. First, science learning activities tend to rely heavily on textbooks and teacher explanations, with limited opportunities for students to engage in direct observation or inquiry. Second, students show limited ability to explain biodiversity-related concepts, such as differences among living organisms and their roles in the environment, using scientific reasoning. Third, learning activities have not optimally utilized the school's surrounding environment as a learning resource, even though biodiversity subtopics are highly contextual and observable in students' daily lives. These conditions indicate that scientific literacy development at SDN 1 Bireuen has not yet been fully supported through contextual and inquiry-based science learning. Several recent studies emphasize that biodiversity subtopics offer strong potential for strengthening scientific literacy because they allow students to learn science through direct interaction with real objects in their environment. Context-based science learning has been shown to increase student engagement, deepen conceptual understanding, and improve students' ability to connect scientific knowledge with everyday experiences (Putri & Nugraha, 2024). When students are actively involved in observing and classifying living organisms, they are more likely to develop essential scientific skills such as observing, questioning, and drawing simple conclusions.

Furthermore, inquiry-oriented learning approaches are increasingly recognized as effective strategies for improving scientific literacy in elementary education. Inquiry-based science learning encourages students to actively construct knowledge through exploration and reflection, rather than passively receiving information from teachers. This approach aligns with the pedagogical principles of the Merdeka Curriculum, which emphasize meaningful learning experiences, learner autonomy, and contextual relevance (Rahmawati et al., 2025).

Based on these conditions, it is necessary to examine how biodiversity subtopics can be utilized effectively to support scientific literacy development in elementary schools, particularly within the context of the Merdeka Curriculum. Therefore, the purpose of this study is to analyze the development of scientific literacy among elementary school students

at SDN 1 Bireuen through biodiversity subtopics in integrated science (IPA) learning under the Merdeka Curriculum framework. This study is expected to provide empirical and practical insights for improving elementary science learning practices and strengthening scientific literacy development. Scientific literacy has become a central objective of contemporary science education, particularly at the elementary school level where students begin to construct foundational understandings of natural phenomena. Scientific literacy equips learners with the ability to comprehend scientific concepts, interpret evidence, and apply scientific knowledge in everyday life. Developing scientific literacy from an early age is therefore essential to prepare students for lifelong learning and informed decision-making in a science- and technology-oriented society (Bybee, 2021). Despite its importance, numerous studies and international assessments report that elementary school students' scientific literacy remains relatively low, especially in terms of scientific reasoning and contextual application of knowledge. Many students are able to recall factual information but experience difficulties when asked to explain natural phenomena or relate scientific concepts to real-life situations. This condition indicates that science learning at the elementary level often emphasizes content transmission rather than meaningful understanding and inquiry-based learning (OECD, 2022).

The implementation of the Merdeka Curriculum in Indonesia aims to address these challenges by promoting student-centered, flexible, and contextual learning. At the elementary level, science is taught as an integrated subject (*Ilmu Pengetahuan Alam/IPA*), without separating biology, physics, and chemistry into distinct disciplines. Biological concepts are embedded within thematic subtopics, such as biodiversity, characteristics of living organisms, and interactions between organisms and their environments. This integrated approach allows teachers to design learning activities that are more relevant to students' developmental stages and local contexts (Kemdikbudristek, 2023). Preliminary observations conducted at SDN 1 Bireuen, Aceh Province, reveal several challenges related to students' scientific literacy in science learning. First, science learning activities tend to rely heavily on textbooks and teacher explanations, with limited opportunities for students to engage in direct observation or inquiry. Second, students show limited ability to explain biodiversity-related concepts, such as differences among living organisms and their roles in the environment, using scientific reasoning. Third, learning activities have not optimally utilized the school's surrounding environment as a learning resource, even though biodiversity subtopics are highly contextual and observable in students' daily lives. These conditions indicate that scientific literacy development at SDN 1 Bireuen has not yet been fully supported through contextual and inquiry-based science learning. Several recent studies emphasize that biodiversity subtopics offer strong potential for strengthening scientific literacy because they allow students to learn science through direct interaction with real objects in their environment. Context-based science learning has been shown to increase student engagement, deepen conceptual understanding, and improve students' ability to connect scientific knowledge with everyday experiences (Putri & Nugraha, 2024). When students are actively involved in observing and classifying living organisms, they are more likely to develop essential scientific skills such as observing, questioning, and drawing simple conclusions. Furthermore, inquiry-oriented learning approaches are increasingly recognized as effective strategies for improving scientific literacy in elementary education. Inquiry-based science learning encourages students to actively construct knowledge through exploration and reflection, rather than passively receiving

information from teachers. This approach aligns with the pedagogical principles of the Merdeka Curriculum, which emphasize meaningful learning experiences, learner autonomy, and contextual relevance (Rahmawati et al., 2025).

Based on these conditions, it is necessary to examine how biodiversity subtopics can be utilized effectively to support scientific literacy development in elementary schools, particularly within the context of the Merdeka Curriculum. Therefore, the purpose of this study is to analyze the development of scientific literacy among elementary school students at SDN 1 Bireuen through biodiversity subtopics in integrated science (IPA) learning under the Merdeka Curriculum framework. This study is expected to provide empirical and practical insights for improving elementary science learning practices and strengthening scientific literacy development.

2. LITERATURE REVIEW

Scientific Literacy in Elementary Education

Scientific literacy in elementary education is defined as students' ability to understand basic scientific concepts, engage in scientific processes, and apply scientific knowledge to explain phenomena encountered in daily life. At the primary school level, scientific literacy development emphasizes observation, simple reasoning, and the ability to communicate scientific ideas using age-appropriate language. These competencies form the foundation for higher-level scientific thinking and lifelong learning (Fives et al., 2021). Recent international research highlights that scientific literacy at the elementary level should be nurtured through learning environments that promote active participation and exploration. Students who are exposed to inquiry-oriented learning activities tend to develop stronger conceptual understanding and more positive attitudes toward science. Such learning experiences help students move beyond rote memorization toward meaningful comprehension of scientific concepts (Areepattamannil & Kaur, 2022). National studies further indicate that elementary students' scientific literacy is influenced by the extent to which learning activities encourage questioning, observing, and reasoning. When science instruction focuses primarily on textbook-based explanations, students' ability to apply scientific knowledge to real-world contexts remains limited. Therefore, scientific literacy development requires instructional approaches that emphasize experience-based and student-centered learning (Handayani & Saputro, 2023).

Biodiversity Subtopics in Integrated Science (IPA) Learning

Biodiversity is a fundamental subtopic in integrated elementary science learning because it introduces essential biological concepts in a contextual and concrete manner. Through biodiversity-related content, students learn to recognize differences among living organisms, understand classification principles, and explore relationships between organisms and their environments. These concepts support the development of scientific thinking and environmental awareness from an early age (Widodo & Sudibyo, 2023). Several national studies report that biodiversity-based learning enhances students' engagement and comprehension because it utilizes familiar objects from students' surroundings. Learning activities such as observing plants around the school environment

or identifying animals in local ecosystems provide authentic experiences that support conceptual understanding. This relevance increases students' motivation and facilitates the development of scientific literacy (Sari & Lestari, 2024). International research also emphasizes that introducing biodiversity concepts at the elementary level contributes to students' awareness of environmental sustainability. When students understand biodiversity through direct observation and contextual learning, they are more likely to develop responsible attitudes toward nature. Such learning outcomes align with the broader goals of science education in fostering environmentally literate citizens (PalMBERG et al., 2025).

Contextual and Inquiry-Based Learning Approaches

Contextual learning in elementary science emphasizes connecting scientific concepts with students' everyday experiences. This approach allows students to construct meaning by relating new knowledge to familiar situations. Contextual science learning has been shown to improve students' comprehension and retention of scientific concepts, particularly at the primary school level where concrete experiences are essential (Setiawan & Wulandari, 2022). Inquiry-based learning complements contextual approaches by encouraging students to actively investigate scientific questions through observation, data collection, and simple experimentation. Inquiry-based science learning supports the development of scientific process skills, such as observing, classifying, and drawing conclusions based on evidence. These skills are central components of scientific literacy (Hmelo-Silver & Chinn, 2023). Recent studies indicate that inquiry-based learning is highly compatible with competency-based curricula, including the Merdeka Curriculum. By providing opportunities for exploration and reflection, inquiry-oriented instruction supports students' autonomy and deeper understanding of scientific concepts. Empirical evidence suggests that such approaches significantly enhance scientific literacy outcomes in elementary education (Yuliana & Prasetyo, 2025).

Synthesis of Previous Studies

Based on the reviewed literature, scientific literacy development in elementary schools is strongly influenced by instructional approaches, learning contexts, and content relevance. Biodiversity subtopics within integrated science learning offer valuable opportunities for contextual and inquiry-based instruction that supports scientific literacy development. However, previous studies have largely examined these aspects separately, with limited attention to their integration within the Merdeka Curriculum framework and specific school contexts. Therefore, this study addresses this gap by examining scientific literacy development through biodiversity subtopics in integrated science learning at the elementary level, particularly within the context of SDN 1 Bireuen. By focusing on both instructional practices and learning content, this study seeks to contribute to a more comprehensive understanding of effective strategies for strengthening scientific literacy in elementary education.

3. RESEARCH METHODOLOGY

Research Design and Approach

This study employed a qualitative descriptive research design to examine the development of scientific literacy among elementary school students through biodiversity subtopics in integrated science (IPA) learning. A qualitative approach was chosen because the study focused on exploring learning processes, classroom practices, and students' responses in a natural instructional setting rather than measuring causal relationships or statistical effects. The descriptive design allowed the researcher to capture in-depth information related to how biodiversity-based learning was implemented and how it contributed to students' scientific literacy development within the Merdeka Curriculum framework. This approach is appropriate for educational research that seeks to understand instructional phenomena and contextual learning experiences in real classroom settings.

Research Setting and Participants

The study was conducted at SDN 1 Bireuen, located in Aceh Province, Indonesia. This school was selected purposively because it has implemented the Merdeka Curriculum at the elementary level and provides relevant contexts for studying integrated science learning. The research participants consisted of elementary school students and a science teacher involved in IPA learning that included biodiversity subtopics. The focus was placed on classroom activities related to the introduction of living organism diversity, classification of organisms, and interactions between living organisms and their environment. Participant selection was based on their direct involvement in the learning process under investigation.

Data Sources

The data in this study were derived from multiple qualitative data sources to ensure comprehensive analysis. The primary data sources included classroom observations of science learning activities related to biodiversity subtopics. Secondary data sources included lesson plans, teaching modules, student worksheets, and assessment documents aligned with the Merdeka Curriculum.

Data Collection Techniques

Data collection was carried out using the following techniques:

1. Classroom Observation

Non participant classroom observations were conducted to document learning activities, teacher instructional strategies, and student engagement during biodiversity-based science lessons. Observations focused on indicators of scientific literacy, such as students' ability to observe, ask questions, explain phenomena, and relate learning to everyday contexts.

2. Document Analysis

Document analysis was performed on lesson plans, teaching modules, and student learning materials to identify how biodiversity subtopics were integrated into IPA learning. This analysis also examined the alignment of instructional materials with the principles of the Merdeka Curriculum and scientific literacy objectives.

3. Field Notes

Field notes were used to record contextual information, classroom interactions, and reflective observations that were not captured through structured observation instruments.

Data Analysis Techniques

The collected data were analyzed using thematic analysis. The analysis process involved several stages: data reduction, data categorization, theme identification, and interpretation. Observation notes and documents were coded to identify recurring patterns related to scientific literacy components, including conceptual understanding, inquiry skills, and application of scientific knowledge.

The analysis emphasized how biodiversity subtopics supported scientific literacy development through contextual and inquiry-based learning activities. The findings were then synthesized to provide a comprehensive description of instructional practices and learning outcomes within the Merdeka Curriculum framework.

Trustworthiness of the Study

To ensure the trustworthiness of the research findings, several strategies were employed. Data triangulation was conducted by comparing information obtained from observations, document analysis, and literature sources. This process helped validate the consistency of findings across different data sources.

4. RESULTS AND DISCUSSION

Implementation of Biodiversity Subtopics in Science Learning

The results of classroom observations at SDN 1 Bireuen indicate that biodiversity subtopics were implemented through integrated science (IPA) learning activities aligned with the Merdeka Curriculum. Learning activities focused on introducing the diversity of living organisms, recognizing characteristics of plants and animals, and understanding simple interactions between living organisms and their environment. Teachers implemented learning activities using contextual approaches, such as observing plants in the schoolyard, discussing differences among living organisms, and guiding students to classify organisms based on observable characteristics. These activities allowed students to engage directly with real objects, making abstract scientific concepts more concrete and accessible. In addition, learning activities were generally organized in small group discussions to encourage student interaction and collaboration. Students were encouraged

to share their observations with peers and respond to guiding questions posed by the teacher. This learning structure supported active participation and reduced students' dependence on direct explanations from the teacher. However, the effectiveness of implementation varied depending on time allocation and students' readiness to engage in exploratory learning activities.

Students' Scientific Literacy Based on Observation Indicators

Students' scientific literacy development was analyzed based on three main indicators: conceptual understanding, scientific inquiry skills, and application of scientific knowledge. The results of classroom observations are summarized in Table 1.

Table 1. Students' Scientific Literacy Indicators in Biodiversity-Based Science Learning

Scientific Literacy Indicator	Observation Description	Result Category
Conceptual understanding	Students recognize differences among living organisms and identify basic characteristics	Moderate High
Inquiry skills	Students observe objects, ask simple questions, and participate in guided discussions	Moderate
Application of knowledge	Students relate biodiversity concepts to daily life (e.g., plants at home or school)	Moderate

The data indicate that students showed the strongest performance in conceptual understanding, particularly when learning activities involved direct observation. Inquiry skills and application of knowledge were present but less consistently demonstrated across all students. Further observation revealed that students' scientific literacy indicators tended to improve when learning activities were supported by visual and real-life examples. When students interacted directly with objects, such as leaves or small plants, their engagement and understanding increased. In contrast, activities relying mainly on verbal explanations resulted in lower levels of student participation, suggesting that hands-on experiences play a critical role in supporting scientific literacy development.

Development of Conceptual Understanding

In terms of conceptual understanding, students showed positive responses to biodiversity based learning activities. Most students were able to describe observable characteristics of living organisms, such as shape, color, size, and habitat. When guided by the teacher, students could also group organisms into simple categories based on similarities and differences. Additional observations showed that students were able to recall concepts more accurately when they were linked to familiar objects from their environment. For example, students more easily identified plant characteristics when examples were taken from plants commonly found in the schoolyard or home gardens. This indicates that contextual learning supports memory retention and comprehension of scientific concepts. However, some students still experienced difficulties in explaining causal relationships, such as why certain organisms belong to the same group. Their explanations tended to focus on surface features rather than underlying characteristics. This suggests that

conceptual understanding at this stage was still primarily descriptive and requires continued instructional support to develop deeper scientific reasoning.

Development of Scientific Inquiry Skills

Observation results indicate that students' inquiry skills developed moderately during biodiversity-based learning. Students actively participated in observing living organisms and responding to teacher questions. Several students demonstrated curiosity by asking simple questions related to growth, function, or habitat. Further analysis revealed that inquiry activities were mostly structured and guided by the teacher. Students followed observation instructions and answered guiding questions but rarely initiated investigations independently. This condition reflects the early stage of inquiry skill development typical of elementary school learners. Although inquiry skills were still emerging, repeated exposure to observation-based activities appeared to increase students' confidence in expressing ideas and asking questions. Students who initially remained passive gradually became more involved in discussions. This suggests that continuous implementation of inquiry oriented learning may gradually strengthen students' inquiry competencies.

Application of Scientific Knowledge in Daily Contexts

Regarding the application of scientific knowledge, students demonstrated the ability to connect biodiversity concepts with familiar contexts. Many students referred to plants and animals found around their homes or school environment when discussing learning topics. In addition, some students were able to relate biodiversity concepts to simple environmental practices, such as caring for plants or avoiding harm to animals. These responses indicate that students were beginning to internalize scientific concepts as part of their daily experiences. However, the application of scientific knowledge remained limited in depth. Most students provided brief and concrete explanations without elaboration. This finding suggests that while contextual understanding is present, students require further opportunities to practice applying scientific concepts through varied and repeated learning experiences.

Summary of Results

Overall, the results indicate that biodiversity subtopics within integrated science learning at SDN 1 Bireuen contribute positively to students' scientific literacy development. Conceptual understanding emerged as the strongest indicator, followed by inquiry skills and application of scientific knowledge. The findings also show that contextual and observation-based learning activities play a significant role in supporting scientific literacy. However, inquiry and application skills require sustained instructional support and consistent practice. These results provide a strong empirical basis for further discussion on how biodiversity-based science learning can be optimized to strengthen scientific literacy in elementary education under the Merdeka Curriculum.

5. DISCUSSION

The findings of this study indicate that biodiversity subtopics can be effectively integrated into elementary science (IPA) learning to support the development of scientific literacy.

The use of real objects and direct observation activities enables students to engage actively with scientific content and construct understanding based on concrete experiences. This result supports previous research suggesting that life science concepts introduced through experiential learning enhance students' comprehension and motivation at the primary level (Minner, 2021). By interacting directly with living organisms in their surroundings, students are able to perceive science as relevant and meaningful rather than abstract.

The development of scientific literacy observed in this study was most evident in students' conceptual understanding. Students demonstrated an improved ability to recognize and describe characteristics of living organisms when biodiversity learning activities were contextualized. This finding is consistent with the view that experiential and context-based learning strengthens foundational scientific literacy by allowing students to connect new concepts with prior knowledge and everyday experiences (Osborne, 2021). However, the results also show that students' explanations tended to remain descriptive, indicating that conceptual understanding at the elementary level is still developing and requires continuous instructional support.

Inquiry skills and the application of scientific knowledge developed at a moderate level, reflecting the developmental characteristics of elementary school learners. Students were able to observe, respond to guiding questions, and relate biodiversity concepts to familiar situations, but they showed limited ability to initiate independent investigations. This pattern aligns with research indicating that inquiry-based learning in primary education typically begins with structured and guided inquiry before progressing toward more autonomous inquiry practices (Bell et al., 2021). Gradual exposure to inquiry-oriented learning environments is therefore essential to foster students' questioning and reasoning abilities. The contextual nature of biodiversity-based learning also played an important role in supporting students' ability to apply scientific knowledge in daily life. When students related science concepts to plants and animals around their homes or school environment, scientific knowledge became more meaningful and functional. Contextual learning has been shown to facilitate knowledge transfer by linking classroom learning with real-life situations, which is a key component of scientific literacy (Holbrook, 2022). Nevertheless, the limited depth of students' explanations suggests that application skills require repeated practice and varied learning experiences to develop more fully. In addition, the findings of this study highlight the importance of teacher scaffolding in supporting scientific literacy development. Teachers play a critical role in guiding students' observations, prompting reflective thinking, and encouraging scientific communication. Effective scaffolding helps students move from simple observation toward explanation and reasoning, which are essential elements of scientific literacy. Previous studies emphasize that appropriate teacher guidance in elementary science learning significantly influences the quality of students' inquiry processes and conceptual growth (van de Pol, Volman, & Beishuizen, 2022).

Furthermore, biodiversity-based learning contributes not only to cognitive aspects of scientific literacy but also to students' attitudes toward science and the environment. Exposure to local biodiversity encourages curiosity, care for living organisms, and awareness of environmental issues from an early age. Research in elementary science education indicates that learning experiences involving direct contact with nature can

foster positive attitudes toward science and strengthen students' sense of responsibility toward environmental sustainability (Jose, Patrick, & Moseley, 2023). These affective outcomes are important components of scientific literacy that support long-term engagement with science.

The integration of biodiversity subtopics within the Merdeka Curriculum framework also reflects the curriculum's emphasis on holistic competence development. Scientific literacy in the Merdeka Curriculum is not limited to content mastery but includes the development of skills, values, and attitudes through meaningful learning experiences. Biodiversity-based learning aligns with this orientation by integrating knowledge acquisition, inquiry skills, and contextual application within a single learning experience. Similar findings have been reported in studies emphasizing that competency-based curricula require learning activities that connect scientific concepts with real-world contexts (Priestley & Biesta, 2024).

Overall, the discussion suggests that biodiversity subtopics provide a pedagogically sound and contextually relevant foundation for strengthening scientific literacy in elementary schools. However, to optimize learning outcomes, instructional practices should be continuously refined to promote deeper inquiry and more explicit opportunities for students to articulate and apply scientific reasoning. Sustained implementation of contextual and inquiry-oriented learning, supported by effective teacher scaffolding, is essential for fostering comprehensive scientific literacy development among elementary school students (Furtak, 2024).

6. CONCLUSIONS

This study concludes that biodiversity subtopics integrated into elementary science (IPA) learning effectively strengthen students' scientific literacy within the Merdeka Curriculum framework. Learning activities based on direct observation and contextual experiences support students' understanding of biodiversity and basic scientific concepts. The results show that scientific literacy development is most evident in conceptual understanding, while inquiry skills and the application of scientific knowledge develop at a moderate level through guided learning. Overall, biodiversity-based science learning provides a meaningful foundation for scientific literacy development in elementary schools and supports the implementation of contextual and student-centered learning promoted by the Merdeka Curriculum.

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