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Development of an Atlas of Mangrove Plant Morphology Based on the Local Potential of PPLH Puntondo Takalar as a Supplementary Teaching Material for the Plantae Topic in Grade 10 Senior High School

[1*]Nurul Akma, [2]Ummul Hasanah, [3]Misykat Malik Ibrahim
[1,2,3]Department of Biology Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Alauddin Makassar, Makassar, Indonesia.
*Corresponding Author e-mail: 20500118049@uin-alauddin.ac.id
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Abstract: This study aimed to develop a mangrove plant morphology atlas based on the local potential of the Puntondo Takalar Center for Environmental Education (PPLH Puntondo Takalar) as a supplementary teaching material for the Grade 10 high school Plantae topic that meets the criteria of validity, practicality, and effectiveness. The study employed a Research and Development (R&D) method using the ADDIE model, which consists of the analysis, design, development, implementation, and evaluation stages. The research subjects comprised 26 Grade 10 students and one biology teacher in a limited trial conducted at a senior high school in Takalar Regency. Data were collected through observation, interviews, needs analysis questionnaires, expert validation sheets, response questionnaires, and learning outcome tests. The results showed that the developed atlas included nine mangrove species identified through field observations, presented systematically based on morphological characteristics and distribution locations. The atlas was supplemented with field photographs, identification keys, distribution maps, and observation tasks that support environment-based learning and scientific literacy. Expert validation results yielded an average score of 3.6, categorized as highly valid. The practicality test indicated a positive response rate of 92% from both the teacher and students, categorized as highly practical. The effectiveness test showed that classical learning mastery reached 100%, with all students achieving scores above the minimum mastery criterion (KKM). Therefore, this mangrove plant morphology atlas based on local potential is feasible for use as a supplementary teaching material and has the potential to support contextual biology learning while enhancing students' biodiversity literacy.
Keywords: Teaching material development, biology education, contextual learning, local potential, mangrove

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INTRODUCTION

Biology learning at the secondary education level aims to develop students' conceptual understanding of life and its interrelationships with the surrounding environment. In practice, however, biology instruction continues to face challenges, particularly the limited availability of contextual teaching materials that integrate the local environmental potential of students' communities. This issue is especially significant in coastal areas, which possess distinctive biodiversity richness that has not yet been widely utilized as a learning resource. As one of the world's megadiverse countries, Indonesia has one of the highest levels of biodiversity globally, spanning both terrestrial and coastal ecosystems (Hadi et al., 2024). This richness is distributed across diverse regions and represents natural resources with ecological, economic, and educational value (Faizah, 2024). From the perspective of values and scientific reflection, natural phenomena are also regarded as objects of learning that encourage humans to observe and understand the signs of nature as part of the process of acquiring knowledge (Putri et al., 2024). Accordingly, modern scientific inquiry positions biodiversity as an empirical object that can be studied, documented, and responsibly utilized for educational and sustainability purposes (Sulistiyowati, 2024).

At the policy level, the integration of local potential into learning has become part of the direction of curriculum development in Indonesia. The National Education System Law emphasizes that the curriculum must be developed according to the principle of diversification, in line with regional characteristics, environmental potential, and students' needs (Indonesia, 2003). In the current operational implementation of the curriculum, including within the *Merdeka Curriculum*, science learning is directed toward enabling students to understand biodiversity and organismal characteristics through direct observation of their surrounding environment. At the secondary education level, the topics of Kingdom Plantae and plant diversity provide substantial opportunities to utilize local potential as a contextual learning resource. The integration of the local environment is expected to help students connect biological concepts with the ecological realities they encounter in everyday life.

Nevertheless, various studies indicate that the implementation of learning based on local potential remains suboptimal and tends to be limited to the normative level of the curriculum (Alatas et al., 2024). Empirical evidence shows that biology learning is still dominated by the use of general national textbooks that do not adequately represent the unique characteristics of students' local environments (Anzelina, 2023). In addition, the availability of teaching materials specifically addressing local potential in schools remains limited, leading teachers to rely primarily on generally available learning resources. As a result, students often learn biological concepts in an abstract manner, without a strong connection to their surrounding environment. This condition creates a gap between the concepts learned in the classroom and the ecological realities present in students' own communities.

One form of local potential with high ecological and educational value in coastal areas is the mangrove ecosystem. Mangroves are known for their diversity of plant species, distinctive morphological characteristics, and important role in maintaining the balance of coastal ecosystems. The uniqueness of their root structures, leaves, and morphological adaptations makes mangrove plants highly relevant as learning objects in the study of Kingdom Plantae and plant morphology (Setiana, 2021). However, scientific documentation on mangrove plant morphology that has been systematically developed as teaching material remains relatively limited. Available teaching materials generally have not yet integrated plant morphological data with the local ecosystem context in a structured manner for formal learning purposes (Janna, 2020).

One form of teaching material with considerable potential to support the learning of plant morphology is the biology atlas. An atlas has the advantage of presenting information visually and systematically, thereby facilitating the identification process and enhancing understanding of organismal characteristics (Mariyanti et al., 2022; Sulistiyawati & Hafiz, 2025). In the context of biology learning, an atlas should ideally contain not only images and descriptions of organisms but also spatial information regarding the location and distribution of the objects being studied. The presentation of such spatial information should follow cartographic principles, including clear scale, geographic coordinates, legends, map orientation, and accurate location representation. However, several studies have shown that previously developed atlases still place greater emphasis on visual and descriptive aspects, without being complemented by distribution maps that meet these cartographic standards (Muwaffaqoh & Puspitawati, 2018; Wiono, 2024).

Various studies on the development of biology atlases have demonstrated that atlases are feasible and practical teaching materials for use in learning (Maisarah et al., 2022). Nonetheless, these studies still present several limitations. First, most of the atlases developed have not specifically integrated the local potential of coastal ecosystems, particularly mangrove plants. Second, existing atlases generally do not systematically connect plant morphological characteristics, the ecosystem context in which the plants live, and map-based spatial representation. Third, from a methodological perspective, several atlas development studies have remained at the product validation stage without conducting a more comprehensive evaluation of effectiveness in actual learning contexts (Mariyanti et al., 2022; Sulistiyawati & Hafiz, 2025). These conditions indicate a research gap both in terms of the teaching material products developed and the evaluation approaches employed.

Based on these gaps, the development of a Kingdom Plantae atlas based on the local potential of mangrove plants is important. The atlas developed in this study is designed to integrate information on mangrove plant morphology with the coastal ecosystem context and is complemented by species distribution maps compiled from field coordinate data and proper cartographic principles. In this way, the atlas functions not only as a visual medium but also as a scientific source of information that assists students in identifying plant characteristics and understanding their relationships with the environments in which they grow.

This study offers novelty in the development of biology teaching materials based on local potential. This novelty lies in the integration of a mangrove plant morphology atlas, the presentation of species distribution maps based on geographic coordinates, and the organization of the atlas structure to support organism identification in biology learning. In addition, this study seeks to address the limitations of previous research by developing an atlas that simultaneously fulfills scientific, pedagogical, and cartographic standards, while also testing its feasibility and effectiveness in learning. Therefore, the findings of this study are expected to contribute to the development of contextual biology teaching material models based on local potential and to be replicable in other regions with similar biodiversity characteristics.

METHOD

Research Type and Design

This study employed a Research and Development (R&D) approach aimed at producing an instructional material in the form of an atlas of mangrove plant morphology based on local potential to support biology learning on the topic of Kingdom Plantae. The development process adopted the ADDIE model as a systematic framework for designing, developing, and evaluating the instructional product. The ADDIE model consists of five main stages—analysis, design, development, implementation, and evaluation—which were carried out sequentially, with formative evaluation conducted at each stage to ensure the quality of the resulting product.

At the analysis stage, a learning needs assessment was conducted through classroom observations, interviews with teachers, and curriculum analysis to identify the alignment between the material and the intended learning competencies. The design stage involved planning the atlas structure, organizing the content on mangrove plant morphology, designing species distribution maps, and developing the research instruments. The development stage included the preparation of the atlas, expert validation, and product revision based on the validators' suggestions. The implementation stage involved testing the use of the atlas in biology learning with students. Finally, the evaluation stage was conducted to assess the validity, practicality, and effectiveness of the atlas as an instructional material.

The study was conducted at Madrasah Aliyah Muhammadiyah Salaka, Takalar Regency. The research subjects were 26 eleventh-grade science students (Grade XI IPA). The selection of the participants was based on the relevance of the Kingdom Plantae topic, particularly Angiosperms, to the learning outcomes in secondary-level biology education.

Research Instruments and Data Collection Techniques

The research data were collected through observation, interviews, validation questionnaires, response questionnaires, and learning outcome tests. The observation sheet was used to identify the initial conditions of biology learning at the school. The observed indicators included the use of instructional materials by teachers, the availability of learning resources based on local potential, the teaching methods applied, and students' engagement during the learning process.

The interview guide was used to obtain information from the biology teacher regarding the need for instructional materials, constraints in teaching the Plantae topic, and the potential use of the mangrove ecosystem as a learning resource. The expert validation sheet was used to assess the validity of the developed atlas. Validation was conducted by three validators with expertise in biology education, instructional material development, and cartography/mapping. The assessed aspects included content appropriateness, language, material presentation, graphical design, and cartographic aspects (map clarity, geographic coordinates, legend, and scale). Assessment was conducted using a 4-point Likert scale, as follows:

Table 1. Product assessment scale

Score	Description
1	Invalid
2	Less valid
3	Valid
4	Very valid

Teacher and student response questionnaires were used to determine the practicality of the atlas in the learning process. The questionnaires were arranged using a 4-point Likert scale, with assessment indicators covering ease of use, attractiveness of appearance, language readability, and usefulness in understanding the material.

The learning outcome test was used to measure the effectiveness of the atlas in instruction. The test consisted of 20 multiple-choice items developed based on indicators of plant morphology material in the topic of Kingdom Plantae. The test items were constructed to cover cognitive levels from C2 to C4. The content validity of the test was examined through expert judgment by a biology teacher, while test reliability was calculated using the Cronbach's Alpha coefficient.

Data Analysis Techniques

Validity analysis

Validation data were analyzed by calculating the mean score for each assessment aspect using the following formula:

$$\bar{X} = \frac{\sum X}{N}$$

Note:

$\bar{X}$= mean validation score

$\sum X$= total score obtained
N= number of raters
The mean scores were then categorized according to the following validity criteria:

Table 2. Score range and validity category

Rentang Skor	Kategori
3.26 – 4.00	Sangat valid
2.51 – 3.25	Valid
1.76 – 2.50	Kurang valid
1.00 – 1.75	Tidak valid

Practicality analysis

Practicality data were obtained from teacher and student response questionnaires and analyzed using the following percentage formula:

$$P = \frac{f}{N} \times 100\%$$

Note:
P = practicality percentage score

f = total score obtained
N = maximum score
The practicality categories were determined as follows:

Table 3. Percentage and practicality category of the product

Percentage	Category
81–100%	Very practical
61–80%	Practical
41–60%	Fairly practical
≤40%	Less practical

Effectiveness analysis

The effectiveness of the atlas was analyzed through students' learning outcome tests using a pretest–posttest design. The improvement in learning outcomes was calculated using the N-gain formula:

$$N\ gain = \frac{Postest - Pretest}{Maximum\ score - Pretest}$$

The categories for improvement in student learning outcomes were determined as follows:

Table 4. Categories of improvement in student learning outcomes

N-gain Value	Category
≥ 0.70	High
0.30–0.69	Moderate
< 0.30	Low

RESULTS AND DISCUSSION

Learning Needs Analysis

The analysis stage was conducted to identify the initial conditions of biology learning and the need for teaching materials on the topic of Plantae. Data were collected through classroom observations, interviews with the biology teacher, and a needs assessment questionnaire administered to 26 eleventh-grade science students at Madrasah Aliyah Muhammadiyah Salaka, Takalar Regency.

The results of the needs assessment indicated that 73% of the students did not own a personal biology textbook, while 27% relied solely on books available in the school library. In addition, 85% of the students stated that biology would be easier to understand if learning materials were related to their surrounding environment, and 81% reported that they had never used teaching materials specifically addressing the local potential of mangrove ecosystems.

Interviews with the biology teacher further revealed that instruction on the Kingdom Plantae topic, particularly plant morphology, was still dominated by the use of general national textbooks, which did not adequately represent the students' local environmental context. These findings formed the basis for designing a teaching resource in the form of an atlas of mangrove plant morphology based on local potential and relevant to the coastal ecosystem of the Takalar area.

Inventory of Mangrove Species

The development of the atlas was based on a reinventory of mangrove species in the PPLH (Center for Environmental Education) Puntondo area, Takalar Regency. Data collection was carried out using the exploration method, with the geographic coordinates of each species recorded using a Global Positioning System (GPS) device.

Species identification referred to several mangrove taxonomy references, including *Flora Malesiana*, *Field Guide to Mangrove Trees*, and other relevant botanical literature. Morphological identification was conducted based on major diagnostic characteristics, such as leaf shape, root type, flower structure, and fruit characteristics. The identification results were then verified through consultation with a botany lecturer and a biology teacher to ensure the accuracy of species classification.

The inventory results showed that the PPLH Puntondo area contained nine mangrove species belonging to three families and five genera, as presented in Table 5.

Table 5. Inventory of mangrove species in PPLH Puntondo, Takalar

No	Species Name	Common Name	Coordinate Point
1	*Avicennia alba*	Black mangrove	5°35′07.7"S 119°29'12.6"E
2	*Avicennia marina*	White mangrove	5°35′07.9"S 119°29'11.4"E
3	*Bruguiera gymnorrhiza*	Putut	5°35′07.9"S 119°29'11.7"E
4	*Ceriops decandra*	Tenggadai	5°35′06.6"S 119°29'11.9"E
5	*Ceriops tagal*	Tengar	5°35′06.8"S 119°29'11.9"E
6	*Lumnitzera racemosa*	White teruntum	5°35′08.5"S 119°29'13.3"E
7	*Rhizophora apiculata*	Mangrove	5°35′07.2"S 119°29'10.9"E
8	*Rhizophora mucronata*	Kurap mangrove	5°35′06.9"S 119°29'11.7"E
9	*Rhizophora stylosa*	Small mangrove	5°35′07.4"S 119°29'11.1"E

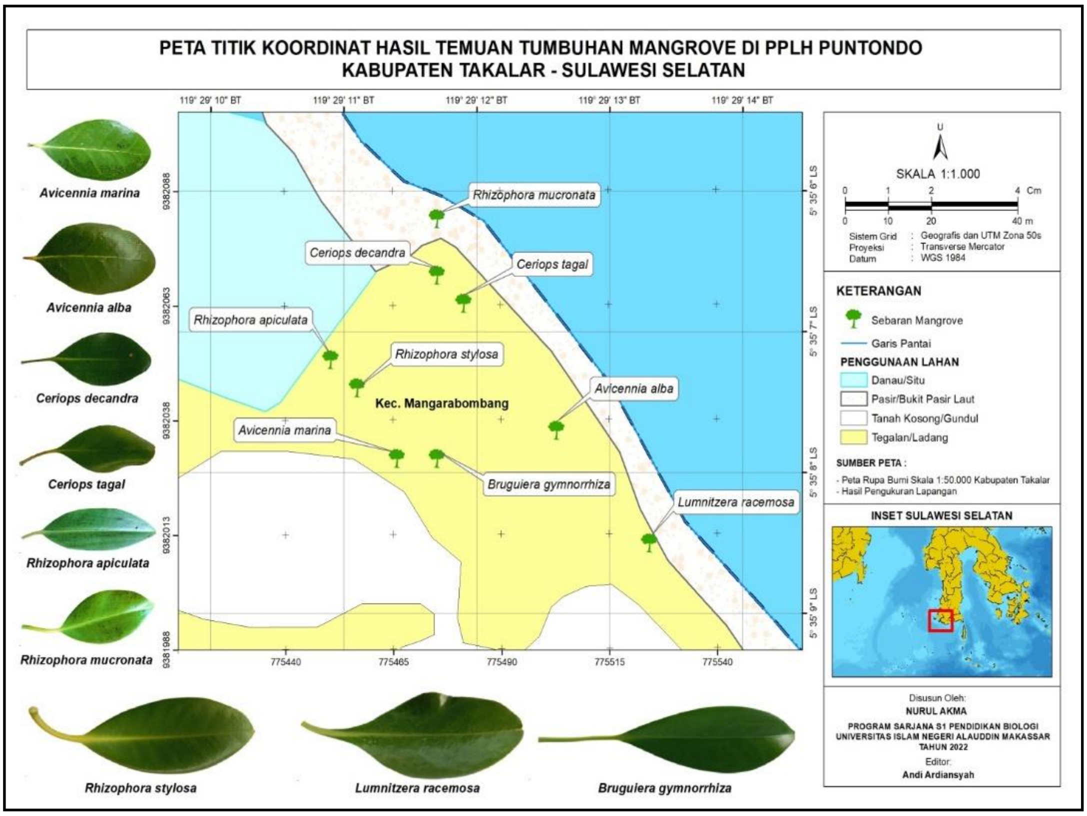

Figure 1. Map of coordinate points of mangrove species found in PPLH Puntondo, Takalar

These coordinate data were subsequently visualized in the form of a species distribution map, which became an important component of the atlas structure. The map was equipped with basic cartographic elements, including a title, legend, location point symbols, and a scale bar, thereby fulfilling the basic principles of spatial information presentation in scientific teaching materials.

Expert Validation of the Atlas

The developed atlas was then validated by three expert validators, consisting of a biology education lecturer, a learning media expert, and a biology education practitioner. The assessment used a four-point Likert scale covering the aspects of content feasibility, presentation, language, and graphics.

Table 6. Results of atlas validation

Assessment Aspect	Mean Score	Category
Content feasibility	3.8	Very valid
Presentation	3.7	Very valid
Language	3.5	Valid
Graphics	3.5	Valid
Average	3.6	Very valid

In addition to providing numerical ratings, the validators also offered several suggestions for product improvement, including:

1) clarifying several scientific terms in the plant morphology descriptions,
2) adding labels to several parts of the morphology illustrations,
3) improving the color contrast of the distribution map to enhance readability, and
4) completing the atlas with a glossary and an index of biological terms to facilitate term retrieval.

The product was revised based on these suggestions, resulting in a more systematic atlas that was easier to use in learning activities.

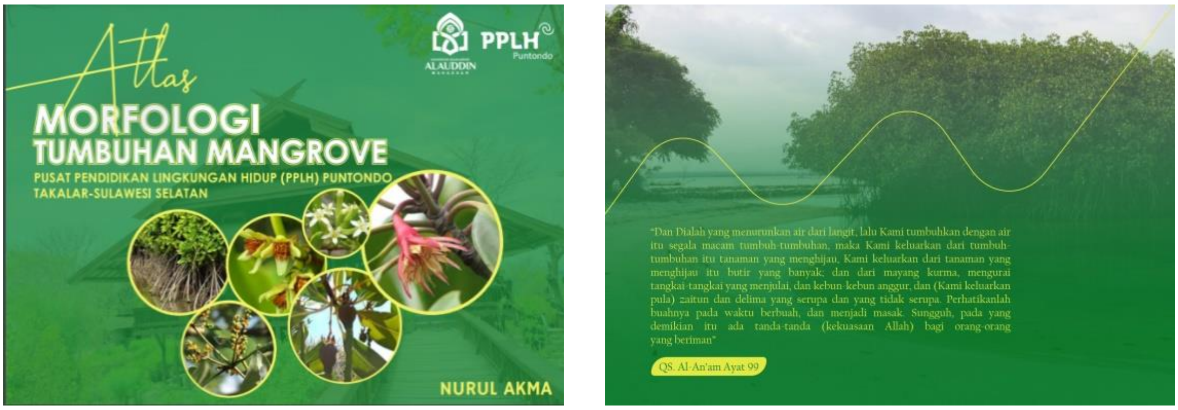

Figure 2. Front and back covers of the atlas

Practicality of the Atlas

The practicality of the atlas was assessed through response questionnaires completed by both teachers and students after the product had been used in learning activities. The results of the practicality analysis are presented in Table 7.

Table 7. Results of the atlas practicality analysis

Indicator	Percentage
Ease of use	90%
Visual attractiveness	93%
Language readability	91%
Usefulness in understanding the material	94%
Average	**92%**

These results indicate that the atlas falls into the **very practical** category, meaning that it is easy to use, visually appealing, and helpful in supporting students' understanding of plant morphology.

Effectiveness of the atlas on learning outcomes

The effectiveness of the atlas was analyzed based on students' learning test results after the teaching material had been used in the learning process. The Minimum Mastery Criterion (MMC = 75) was used as the benchmark for determining learning mastery. These results show that all students achieved scores above the MMC, with a classical mastery level of 100%.

Table 8. Percentage of learning outcome mastery

Category	Frequency	Percentage
Not mastered	0	0%
Mastered	26	100%

The findings demonstrate that the development of a mangrove plant morphology atlas based on local potential can produce teaching materials that are valid, practical, and effective in supporting biology learning. This finding is consistent with the contextual teaching and learning (CTL) paradigm, which emphasizes the importance of linking instructional content with students' real-life contexts (Johnson, 2002). When biology content is connected to objects found in the surrounding environment, learning becomes more meaningful because students are able to relate concepts to direct experience.

The atlas developed in this study contains several instructional features that support knowledge construction. Authentic photographs of mangrove plants, combined with morphological descriptions, enable students to understand species characteristics through simultaneous visual and verbal representations. This approach aligns with dual coding theory, which states that information presented through a combination of text and images can enhance comprehension and reduce cognitive load during learning (Mayer, 2013).

In addition, the glossary and index of biological terms help students access the scientific terminology used in plant morphology materials more easily. This feature contributes to the strengthening of scientific literacy, as students can understand biological terminology in a more systematic manner. Meanwhile, the map of mangrove species distribution adds a spatial dimension to learning, enabling students not only to understand plant morphological characteristics but also to recognize the ecological context in which the species are found.

The activities for identifying morphological traits included in the atlas also encourage students to engage in observation, classification, and comparison of plant characteristics, which are fundamental skills in biology learning. Therefore, the atlas functions not only as a source of information but also as a medium that supports simple scientific activities in the learning process.

This study revealed a high level of learning mastery, with 100% of students achieving scores above the MMC. Nevertheless, this result should be interpreted with caution because several other factors may also have contributed to this outcome. These factors include the relatively homogeneous characteristics of the class, the teacher's role in facilitating learning, the level of difficulty of the test items, and the available instructional time. Therefore, although the findings indicate high effectiveness, the generalization of the results should remain limited.

Compared with previous studies, the present findings are consistent with those of Pralisaputri et al. (2016) and Meiningsih et al. (2019), who reported that environment-based biology teaching materials can improve students' learning interest and achievement. The main similarity lies in the use of local objects and authentic visuals as learning resources. However, this study differs in the characteristics of the developed product, namely a morphology atlas containing field research data, including species inventories, morphological descriptions, and a distribution map based on geographic coordinates. Thus, the atlas serves not only as a teaching material but also as scientific documentation of local mangrove diversity.

From the perspective of teaching material development, this study contributes to the development of a local-potential-based biology atlas content model that can be replicated in other regions with different ecosystem characteristics. This is in line with the view that the utilization of local potential in learning can strengthen the relevance of the curriculum to students' environments (Maisarah et al., 2022; Wiono, 2024).

However, this study has several limitations. The research subjects were limited to a single class with a relatively small number of students, and the study was conducted within a specific coastal ecosystem context. Therefore, future studies are recommended to conduct broader-scale trials across different schools and to combine the atlas with active learning models such as project-based learning or inquiry learning in order to examine its effects on higher-order thinking skills and environmental conservation attitudes (Basri & Ibrahim, 2025; Zebua et al., 2025).

Overall, this study demonstrates that a mangrove plant morphology atlas based on local potential can serve as a relevant and contextual teaching material in biology learning. The integration of field data, visual representations, and spatial information within the atlas provides a more meaningful learning experience and supports the strengthening of students' biodiversity literacy.

CONCLUSION

This study produced a teaching material in the form of a mangrove plant morphology atlas based on the local potential of PPLH Puntondo, Takalar, developed through the ADDIE model. The evaluation results showed that the developed atlas had an average validity score of 3.6, categorized as very valid; an average practicality level of 92%, categorized as very practical; and student learning mastery reaching 100% above the Minimum Mastery Criterion (MMC). These findings indicate that the local-potential-based mangrove plant morphology atlas can be used as a supplementary teaching material to support contextual biology learning, help students understand plant morphology concepts through real objects in the coastal environment, and strengthen scientific literacy and awareness of local biodiversity. Nevertheless, the application of these findings remains limited to a single class and one research site, so broader testing in different school and regional contexts is still needed.

RECOMMENDATION

Based on the findings, biology teachers are encouraged to use the mangrove morphology atlas as a supplementary material to support contextual and environment-based learning. Future research should involve larger and more diverse samples to test the generalizability of the product, as well as develop digital or interactive versions to enhance its effectiveness.

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