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# Development of an Encyclopedia of Unique Biota Based on the Local Potential of Sabang Island to Improve Students' Conceptual Understanding

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**Abstract:** Learning about marine ecosystems is often hampered by students' difficulty in visualizing abstract concepts and a lack of contextual teaching materials relevant to their surroundings. This study aims to develop teaching materials in the form of an encyclopedia of unique biota based on Sabang Island's local potential and to evaluate its validity, practicality, and initial effectiveness in improving students' conceptual understanding. The research used a Research and Development method, applying the 4D model (Define, Design, Develop, and Disseminate). Seven material and media experts comprehensively assessed the product's feasibility and validity, while five education practitioners evaluated its practicality. Additionally, an initial evaluation of the shift in student learning outcomes was conducted using a one-group pretest–posttest design involving 46 high school students in a coastal area socio-ecologically equivalent to Sabang Island. The results showed that experts declared the developed encyclopedia highly valid, giving it a "Very Good" rating across all evaluated aspects (General Appearance, Word Usage & Language, Presentation, and Content Suitability). In terms of practicality, the product was also deemed highly practical for learning, earning a "Very Good" rating in three key aspects (Ease of Use, Usefulness, and Efficiency) and a "Good" rating in the Interest aspect. Furthermore, the analysis of learning outcomes showed an average N-Gain of 0.3844, which falls into the moderate category, indicating a positive trend in student conceptual understanding after product utilization. Based on these findings, the local potential-based encyclopedia "Umbak Gembara" is highly feasible and practical, showing strong initial indications as an independent learning resource that can meaningfully bridge abstract biological concepts with the reality of coastal ecosystems. However, since this initial effectiveness finding relies on a single trial group, future comparative experimental studies are needed.

**Keywords:** encyclopedia, unique biota, local potential, sabang island, conceptual understanding.

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## INTRODUCTION

Biology learning in the 21st century requires the integration of theoretical concepts with real phenomena in students' environments. The Contextual Teaching and Learning (CTL) approach is crucial because the concepts of biology, particularly on the topic of biodiversity and ecosystems, are often considered difficult for students due to the large number of Latin terminology and abstract concepts (Hallaby & Hamama, 2025; Umar et al., 2024; Zukswert et al., 2019). Furthermore, experts state that

biodiversity is a "complex concept, yet crucial" that requires students to recognize and interpret complex ecological patterns across multiple spatial scales (Oliveira et al., 2025; Styers et al., 2021). Biodiversity is a complex, multi-scale, and multidimensional subject; thus, effective education requires an approach that bridges abstract concepts with local realities (Baylon et al., 2026; Bermudez & Krell, 2025; Mercier et al., 2025; Ottogalli & Bermudez, 2024; Schlecht et al., 2026). One material that has high complexity is marine ecosystems. In contrast to terrestrial ecosystems, which are easy to observe directly, underwater ecosystems have limited visual accessibility (Bell et al., 2023; Eberbach et al., 2021; Hagen et al., 2024; Lopez-Vazquez et al., 2026), making it difficult for students to visualize the biological interactions that occur in them without the aid of special media. In contrast, learning resources available in schools, such as standard textbooks (BSE) and students' worksheets (LKS), tend to present material in a general manner. The examples of biota or ecosystems presented often refer to Western literature or distant locations, creating a "psychological distance" between students and the material they learn. This gap contributes to low marine literacy and limited students' appreciation of biodiversity in their own regions (Imtihana & Djukri, 2020; Santana et al., 2024).

Environmental and marine literacy in Indonesia's coastal regions, particularly among senior high school students, remains critically alarming. Nationally, the 2022 PISA study noted that Indonesia's literacy levels remain low, a challenge that is especially felt in coastal areas facing complex environmental issues (Husain et al., 2026). Across educational levels, from early childhood to university students, environmental literacy has been documented as low to moderate, reflecting a systemic deficit in the education system (Aulia & Hadiyanto, 2022; Hariyadi et al., 2021; Nasution, 2021). Furthermore, in coastal communities, some individuals still lack environmental awareness (Suselo et al., 2025), and legal awareness regarding maritime literacy remains low (Indrawati et al., 2025). Coastal settlements have minimal environmental sanitation infrastructure, reflecting a deficit in practical environmental literacy (Misdayanti & Suwanti, 2021). Moreover, limited exposure to environmental (maritime) literacy may contribute to their lack of awareness of marine issues (Indrawati et al., 2024). This lack of knowledge distances high school students from their local marine environment. Learning only broad ecological concepts prevents them from connecting with or even noticing the unique local species right outside their doors.

However, utilizing local potential as a learning resource has been proven to improve motivation and learning outcomes by connecting students directly with the objects being studied (Dini & Rini, 2024; Fajeriadi et al., 2025; Kamila et al., 2024). Contextualizing abstract biological concepts in learning materials effectively bridges the theory-practice gap, with multiple studies demonstrating measurable improvements in student outcomes (Afnan & Puspitawati, 2024; Fitarahmawati & Suhartini, 2021; Honra & Monterola, 2024; Reynolds et al., 2022). Many studies strongly support the claim that direct proximity to nature can foster engagement and environmental awareness (Ilhami et al., 2025; Jaikrasen & Ketsing, 2025; Williamson et al., 2022). Numerous studies indicate that connecting textbook material with students' local environments enhances their understanding (Chang et al., 2024; Harrison, 2025; Lyesmaya et al., 2025). Consequently, using localized contexts transforms passive reading into an active learning experience, improving academic performance and retention.

Sabang Island in Aceh Province constitutes a strategic area with high marine biodiversity, including coral reef ecosystems, mangroves, and

seagrass beds. Despite this rich ecological potential, research indicates that local natural resources are frequently underutilized as contextual learning resources in coastal schools, leaving a significant gap between students' immediate environment and their classroom curriculum. Educators still rely on general textbooks that lack visuals and include few original images relevant to the local context. As a result, students struggle to identify local species and understand their ecological roles. The lack of media that brings Sabang's "underwater world" into the classroom is an urgent issue that must be addressed to foster meaningful environmental literacy.

Photo-based, contextual learning resources can enhance student engagement with marine ecosystems, although impacts on learning outcomes vary. Strategically selected photographs not only foster emotional engagement and post-learning pro-environmental behavior (Gehlbach et al., 2022; Hoongland et al., 2018), but also spark in-depth discussions regarding biodiversity concepts (Camandero & Abo, 2025; Hassan et al., 2024). Furthermore, photographic media have been shown to stimulate critical and creative thinking, encourage open communication, and strengthen emotional bonds through students' personal reflections and experiences (Coles-Ritchie et al., 2015; deNoyelles et al., 2024; Lindner et al., 2021), ultimately facilitating the teacher's management of the learning process (Nkomo, 2023; Wikanengsih et al., 2023).

To bridge the gap between local natural resources and the visual learning materials students need in the classroom, a supplementary module rich in visual elements and contextual information is required. One proposed solution is to develop an Encyclopedia of Typical Biota. The quality of such encyclopedias lies in presenting structured, in-depth information supported by realistic photographic imagery that effectively represents real objects (Aini et al., 2024; Etika et al., 2024; Nasution & Ulfa, 2025). The use of encyclopedias as a biology learning medium has proven effective in optimizing the academic process by improving student learning outcomes, interest, and critical thinking skills (Al Habib et al., 2022; Ayuni et al., 2024; Dewi & Firanti, 2024; Kumala & Setiawan, 2019; Salahli et al., 2019). Encyclopedias have also proven significant in improving scientific literacy skills (Agustiani et al., 2024; Vetter et al., 2019). In addition to benefiting students, encyclopedias support teacher efficiency by providing relevant, up-to-date learning materials (Zahro et al., 2024; Zhelezniak & Ishchenko, 2021). Therefore, developing a context-specific encyclopedia is a strategic step toward creating a meaningful learning experience.

To address these needs, this research aims to develop an encyclopedia titled "Umbak Gembara" (which means Happy Waves), focusing on Sabang's unique aquatic ecosystem through a joyful learning design approach. Beyond merely shifting the geographical focus to a new local context, the practical and educational novelty of this study lies in providing concrete visual scaffolding using native, rarely exposed specimens from Aceh waters to support students' conceptual understanding. Methodologically, this study contributes to the literature by demonstrating how structured, context-rich print media can improve students' conceptual mastery and knowledge retention in regions challenged by digital infrastructure gaps. Through the development of this encyclopedia, the resulting material is expected to meet strict criteria for validity and practicality while serving as an empirically supported model for contextual science education.

Consequently, the research questions guiding this study are (1) To what extent does the "*Umbak Gembara*" Encyclopedia meet the criteria of validity based on expert judgment and practicality as evaluated by practitioners? and (2)

How do student learning outcomes differ between the pretest and posttest measurements following the implementation of the encyclopedia?

## METHOD

Participants were selected based on the objectives of each research and development (R&D) phase, using distinct sampling approaches. A purposive sampling technique was used to select experts and practitioners, ensuring that evaluators had the required professional expertise.

1. Experts: Seven experts were recruited for the validation process, consisting of two biology education experts, two language specialists, two biological science specialists, and one curriculum design expert, each with a minimum of 10 years of professional experience.
2. Practitioners: Five high school biology teachers participated in testing the encyclopedia's practicality, selected based on their experience in teaching contextualized ecology/ecosystem.
3. Encyclopedia trial: 46 high school students, class XI, in a one-group pretest-posttest experiment. Given the constraints of the school environment, a non-probability convenience sampling (intact class selection) approach was used. The sample included 16 men and 30 women, with an average age of 15 years.

This study employs a Research and Development (R&D) approach, following the Four-D framework (Define, Design, Develop, and Disseminate) proposed by Thiagarajan (Aswita et al., 2026; Firdausi et al., 2023; Hasnunidah et al., 2025; Maulina et al., 2025; Rachman et al., 2024). To comprehensively evaluate the encyclopedia's development and effectiveness, a balanced mixed-methods data collection was embedded directly within the R&D stages. Qualitative data collection was prioritized during the initial phase to capture the baseline environmental context, while quantitative measures were subsequently deployed to evaluate product quality and shifting student outcomes.

The step-by-step procedures of this study were executed through four systematic stages corresponding to the design framework (Figure 1):

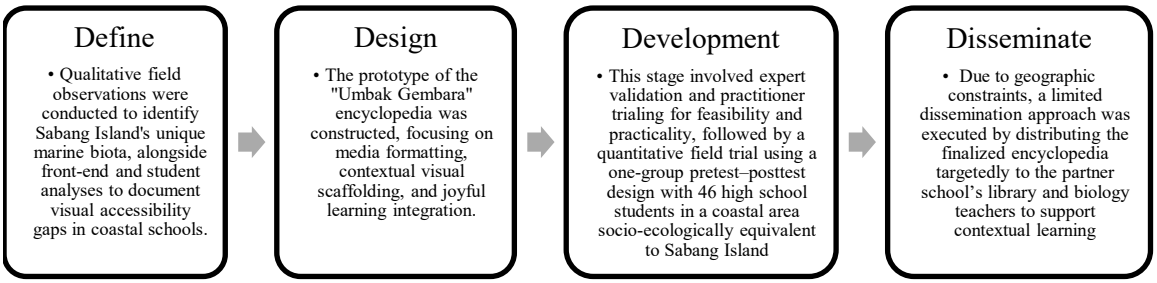



**Figure 1.** Research procedure with four-d framework

To ensure a coherent design logic, the instruments were categorized as follows:

*Qualitative instruments: observation field notes used to identify local resource potential*
*Quantitative instruments:*

a. Validation Sheets: Using a 5-point Likert scale to assess the encyclopedia's feasibility across general appearance, word-language usage, presentation, and content suitability.
b. Practicality Questionnaires: Distributed to practitioners to measure the ease of implementation in the field.
c. Pre-posttest instruments: Distributed to high school students to measure the effectiveness of using the encyclopedia in supporting biology learning. To evaluate the product's

effectiveness, students' conceptual understanding of marine biology was measured using a cognitive test consisting of 25 multiple-choice questions with 4 options (A–D). The instrument was developed based on the Indonesian National Curriculum (Kurikulum Merdeka) indicators for Biodiversity and Marine Ecosystems, adapting cognitive framework parameters from Anderson & Krathwohl (2001).

All data collection instruments, including expert validation sheets, teacher practicality questionnaires, and the 25-item conceptual understanding test, underwent rigorous content and construct validation by expert reviewers. The cognitive test items were developed from a detailed table of specifications aligned with high school biology learning objectives. Experts iteratively addressed qualitative suggestions to ensure face validity, conceptual clarity, and item precision before field deployment. The study utilized a triangulation analysis method to ensure reproducibility:

1. Qualitative data obtained from field observations were analyzed using the interactive model of Huberman & Saldaña (Miles et al., 2014).

a. Data Reduction: Raw qualitative data collected from field observation notes on Sabang Island's marine biodiversity were rigorously selected, focused, and simplified. Overly general environmental descriptions were filtered out, while specific data on unique local marine species were systematically coded and categorized into potential encyclopedia content groups.

b. Data Display: The summarized qualitative data were organized and structured into clear formats to enable conclusions to be drawn. These displays used matrix tables that mapped the classification of unique marine biota on Sabang Island, their symbiotic relationships, and their levels of ecological vulnerability.

c. Conclusion Drawing and Verification: From the beginning of data collection, initial meanings, patterns, and explanations for how to integrate these local potentials into biology teaching materials were recorded. These initial conclusions were continuously verified for validity through various literature sources and relevant studies.

2. Quantitative Analysis: The quantitative data, derived from expert validation sheets and practitioner questionnaires, were analyzed using descriptive statistics. Meanwhile, the pre-post test data were tested using SPSS. Data were analyzed using criterion-referenced evaluation on a 5-point scale to determine the feasibility and quality of the developed encyclopedia, as proposed by Mardapi (Mardapi, 2012). Validity criteria are interpreted based on the scores presented in Table 1.

**Table 1.** Interpretation of scores for the encyclopedia validation test

| Aspect | Score Range | Criteria |
|---|---|---|
| • General Appearance<br>• Word Usage & Language<br>• Presentation | $X > 21$ | Very Good |
| | $17 < X \leq 21$ | Good |
| | $13 < X \leq 17$ | Sufficient |
| | $9 < X \leq 13$ | Insufficient |
| | $X \leq 9$ | Very Poor |
| • Content Suitability | $X > 16.8$ | Very Good |
| | $13.6 < X \leq 16.8$ | Good |
| | $10.4 < X \leq 13.6$ | Sufficient |
| | $7.2 < X \leq 10.4$ | Insufficient |
| | $X \leq 7.2$ | Very Poor |

This interpretation is based on the average value for each sub-indicator; the encyclopedia is declared valid if each aspect falls within the "very good" and "good" categories. Furthermore, the practicality criteria refer to the score interpretation presented in Table 2.

**Table 2.** Score interpretation for the encyclopedia practicality test

| Aspect | Score Range | Criteria |
|---|---|---|
| • Ease to Use | X > 21 | Very Good |
| | 17 < X ≤ 21 | Good |
| | 13 < X ≤ 17 | Sufficient |
| | 9 < X ≤ 13 | Insufficient |
| | X ≤ 9 | Very Poor |
| • Interest<br>• Usefulness<br>• Efficiency | X > 16.8 | Very Good |
| | 13.6 < X ≤ 16.8 | Good |
| | 10.4 < X ≤ 13.6 | Sufficient |
| | 7.2 < X ≤ 10.4 | Insufficient |
| | X ≤ 7.2 | Very Poor |

The interpretation score for this product practicality test is determined based on the average score for each sub-indicator, where an encyclopedia is declared practical if each aspect falls within the "very good" and "good" categories.

To evaluate shifts in students' conceptual understanding, pretest and posttest scores were analyzed using the normalized gain ($g$) formula proposed by Hake (Hake & Reece, 1999). The resulting N-Gain scores were categorized based on Hake's criteria: High ($g > 0.70$), Medium (0.30 d" $g$ d" 0.70), and Low ($g < 0.30$).

This research was conducted in accordance with ethical principles for human subject research. All participants were informed of the study's objectives and provided voluntary informed consent before participating. Anonymity and data confidentiality were strictly maintained. Formal institutional ethics committee approval was not required for this educational development study in the local context, and the research adhered to the ethical standards of the Declaration of Helsinki regarding participant autonomy and privacy.

## ■ RESULT AND DISCUSSION

This research used a Research and Development (R&D) approach to develop supplementary biology teaching materials in the form of an encyclopedia of unique biota. The material development focused on the local potential of marine biodiversity on Sabang Island, encompassing organism types, habitats and distribution, habits and behaviors, and the ecological interactions of that biota.

The encyclopedia developed was titled "*Umbak Gembara*". The nomenclature "*Umbak Gembara*" represents the product's design philosophy, which upholds the principle of joyful learning and aims to increase students' affective engagement with environmental conservation materials. The stages of this encyclopedia's development are outlined as follows:

### Define

This stage began with a literature review and field observations to identify problems and delimit the research area. Data collection on potential flora and fauna focused on Sabang Island's ecotourism sites, which were divided into three ecosystem zones: (1) coral reef ecosystems, (2) mangrove ecosystems, and (3) the Iboih coastal area.

Concurrent with the field survey, the team developed a framework and constructed

research instruments for validity, practicality, and readability testing. Based on the research team's analysis of data sufficiency, the encyclopedia's development at this stage prioritized coral reef ecosystems. This prioritization was based not only on high biodiversity but also on Sabang's status as a vibrant marine tourism destination. Because coral reef ecosystems are among the most frequently accessed and exploited tourism sites, the encyclopedia is crucial as a preventive conservation tool to mitigate the risk of environmental damage through education. Furthermore, underwater ecosystems cannot be observed directly (with the naked eye) without special equipment. Therefore, encyclopedias are essential for visualizing objects that are difficult to reach, making them easier for students to understand.

Various studies have pursued similar goals, demonstrating that textbook development has offered significant educational benefits, particularly in improving learning effectiveness and meeting specific pedagogical needs (Kurnisar et al., 2025; Sadikin et al., 2018; Siburian & Sadikin, 2024). The primary benefits include supporting systematic, contextual learning; providing primary reference sources; enhancing student understanding; and facilitating more innovative teaching approaches.

The local potential analysis at the Define stage inventoried significant marine biodiversity, including 11 coral species across 9 families and 32 reef fish species from 20 families (Noviyanti et al., 2025), along with other associated marine invertebrates. These species include biota with unique biological characteristics that are rarely covered in conventional textbooks, such as fire coral (*Millepora* sp.), a colony of Hydrozoa, and the piso-piso fish (*Aeoliscus strigatus*), which has adapted vertical (head-down) swimming behavior. The encyclopedia explores these unique species to enrich students' understanding of morphological adaptation and the classification of living things in context.

**Design**

The design phase was based on the results of the needs analysis in the define phase. The encyclopedia's structure was designed to encompass the diversity of unique biota found in the coral reef ecosystem of Sabang Island. After that, learning objectives and competency achievement indicators were formulated. Concept analysis was conducted to integrate biology materials in the school curriculum with local natural resources. The material elaborated in this encyclopedia includes: Biodiversity and Ecosystems, Ecology and Interactions of Living Things, Classification of Living Things (Animalia), and Environmental Change.

The activities carried out in this research were also carried out by other researchers, who have developed innovative biology textbooks using design and development methodologies (Hakim et al., 2023; Siburian & Sadikin, 2024), demonstrating a consistent and rigorous approach, focusing on contextual relevance, technology integration, and pedagogical innovation (Asmawati, 2023; Ikhsan et al., 2024; Rahmani et al., 2021).

The next step was selecting expert validators to assess the product's feasibility. Validator selection was based on the relevance of their expertise, grouped into four areas: Biology Education Experts, Biology & Environmental Experts, Curriculum Experts, and Linguistics. Validation aimed to obtain theoretical assessments, constructive feedback, and legitimacy for the product's feasibility before moving on to the trial phase. Additionally, educational practitioners (teachers) were selected to test the product for practicality and usability in teaching and learning activities.

**Development**

The development phase began with preparing an initial draft of the encyclopedia, which seven experts validated: four subject matter experts (biology/environment and biology

education), one curriculum expert, and two language experts. Validation aimed to ensure the appropriateness of the material, construction, and language before field testing. Based on the assessment, the encyclopedia validation results are presented as follows:

**Table 3.** Encyclopedia validation test results

| Aspect | Expert Assessment - | | | | | | | Average | Criteria |
|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 | R6 | R7 | | |
| General Appearance | 24 | 25 | 21 | 24 | 24 | 25 | 25 | 24.00 | Very Good |
| Word Usage & Language | 23 | 25 | 20 | 23 | 24 | 23 | 22 | 22.86 | Very Good |
| Presentation | 23 | 25 | 20 | 22 | 25 | 25 | 25 | 23.57 | Very Good |
| Content Suitability | 17 | 20 | 17 | 17 | 18 | 20 | 20 | 18.43 | Very Good |

Based on Table 3, the developed of the encyclopedia meets the "Very Good" criteria for all indicators. The high score for the general appearance aspect (X= 24.00) indicates that the encyclopedia's visual design presents information aesthetically and in a structured manner. This high score is achieved through a balanced layout integrating structured text and high-resolution images of Sabang Island's marine biota. By organizing complex ecological data into intuitive, color-coded sections, this design enhances information clarity and readability. Combining descriptive text with realistic visuals serves as a strategic instructional tool that supports conceptual understanding rather than mere decoration, thereby confirming the validity of the developed product. This aligns with several other studies, which state that the validation process typically involves expert assessment and feedback, with scores of "very good" or "good" indicating a robust development methodology (Irawati, 2019; Vebrianto & Syafaren, 2020).

Although experts declared it valid, several revisions were made based on validator suggestions, namely sharpening species descriptions from characteristics to general descriptions and simplifying scientific terminology to make it more inclusive for lay readers (see Table 5). After the validity test was completed, the product's practicality was tested. The practicality test involved five practitioners (Biology teachers) to assess the encyclopedia's ease of use in learning. Based on the assessment, the results of the encyclopedia's practicality test are presented as follows:

Overall, the encyclopedia is considered practical, with most aspects falling into the "Very Good" category. The ease of use aspect received the highest score (23.40), indicating that the book's navigation structure is easy for teachers to understand. Meanwhile, the "Interest" aspect received a score of 14.40, placing it in the "Good" category. This lower relative score, however, highlights the specific functional role of a print encyclopedia. Amidst the dominance of digital media, which is prone to distraction, the print

**Table 4.** Results of the encyclopedia's practicality test in biology learning

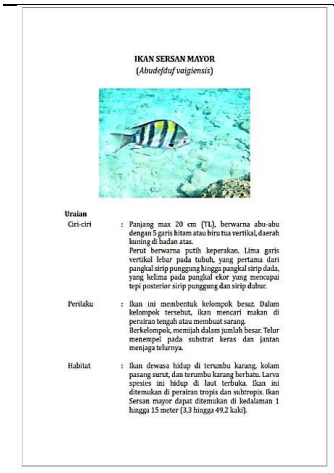
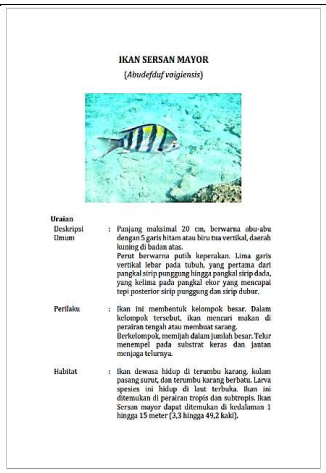
| Aspect | Practitioner Assessment - | | | | | Average | Criteria |
|---|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | P4 | P5 | | |
| Ease to Use | 22 | 24 | 25 | 21 | 25 | 23.40 | Very Good |
| Interest | 13 | 18 | 15 | 13 | 13 | 14.40 | Good |
| Usefulness | 20 | 20 | 19 | 20 | 20 | 19.80 | Very Good |
| Efficiency | 20 | 18 | 17 | 18 | 16 | 17.80 | Very Good |

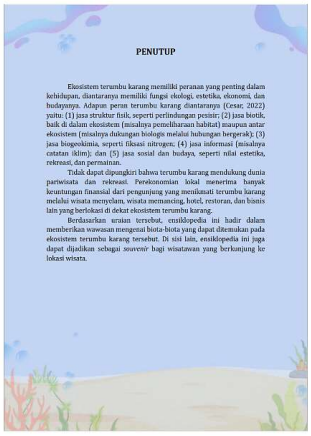
format of "*Umbak Gembara*" offers advantages in facilitating deep reading and sustainable attentional focus. Its accessibility, without dependence on electricity or internet connections, makes this product inclusive and ready to use in various coastal school infrastructure conditions.

These findings reinforce the critical importance of high-quality visual elements in developing print-based biology teaching materials. Given the crucial role of object visualization in biology learning, maximizing visual clarity is essential to maintaining student engagement and comprehension without relying on digital interactivity. This step aims to maximize student engagement while synergizing the depth of print literacy with digital interactivity, given the crucial role of object visualization in biology learning. This aligns with research by Soltész (2025), which found that learning materials with real-world images produce better learning outcomes than simple drawings. Zenki-Dalipi & Osmani (2022) noted that visual representations directly influence students' comprehension and attention retention. This evidence suggests that visual elements are not merely complementary but fundamental to maintaining student engagement in self-directed learning materials (Regondola & Astorga, 2025; Yousuf & Conlan, 2018).

Following validation and practicality testing, the final layout revision (Table 5) concluded the structural development phase. The product then entered the initial effectiveness evaluation phase in the field and pedagogical implementation through limited trials in contextual coastal schools.

**Table 5.** Results of encyclopedia revisions based on expert suggestions

| Before Revision | After Revision | Description |
|---|---|---|
|  |  | Redesigned the cover layout by adding a high-resolution photo of a marine ecosystem, adjusting the title font size to 24 pt Bold, and changing the background color contrast for improved visual clarity. |
|  |  | Changed the wording of the description (from characteristics to general description)<br>Improved the use of more general words for easier understanding (For example, the abbreviation TL = Total Length)<br>Addressed spelling and grammar errors<br>Completed the table of contents for easier searching |

| | | |
|---|---|---|
| - |  | Add Chapter entitled “Marine Conservation Efforts”, which details local conservation strategies and relevant policy frameworks |
|  |  | The Closing Section was expanded by adding a summary paragraph of the main findings |

The next phase is an initial pilot test of the encyclopedia among high school students in a socio-ecologically comparable coastal area. This limited effectiveness test measured the impact of encyclopedia use on learning outcomes in the Underwater Ecosystems topic. Data were collected through pretests and posttests. The improvement in learning outcomes was analyzed using N-Gain, as summarized below:

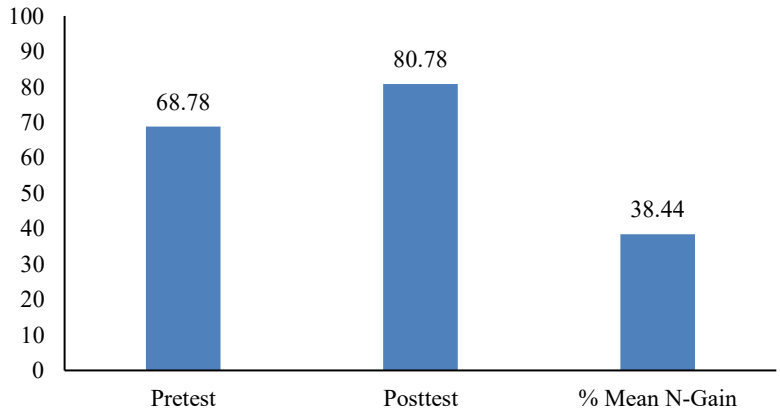



**Figure 2.** N-Gain score test results

The results show that the average student score increased from 68.78 in the pretest to 80.78 in the posttest, with an average N-Gain of 0.3844 (38.44%), which falls into the moderate category. To evaluate whether the observed difference between pretest and posttest scores was statistically significant, normality tests were first conducted on the dataset. The Shapiro-Wilk normality test indicated a non-normal distribution for both pretest and posttest data ($p < 0.05$), as detailed in Table 6.

Since the pretest ($p = 0.001$) and posttest ($p = 0.034$) data deviated significantly from a normal distribution, hypothesis testing was conducted using the non-parametric Wilcoxon Signed Rank Test. The results are presented in Table 7.

**Table 6.** Normality test

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | **Statistic** | **df** | **Sig.** | **Statistic** | **df** | **Sig.** |
| Pre | .104 | 46 | .200* | .905 | 46 | .001 |
| Post | .116 | 46 | .149 | .946 | 46 | .034 |
| *. This is a lower bound of the true significance. | | | | | | |
| a. Lilliefors Significance Correction | | | | | | |

**Table 7.** Wilcoxon signed rank test

| | **Post - Pre** |
|---|---|
| Z | -4.463[b] |
| Asymp. Sig. (2-tailed) | 0.000 |
| a. Wilcoxon Signed Ranks Test | |
| b. Based on negative ranks. | |

The non-parametric analysis yielded an Asymp. Sig. (2-tailed) value of 0.000 ($p < 0.05$), with a $Z$-score of $-4.463$. These statistical findings confirm a statistically significant improvement in students' learning outcomes following the intervention. To visualize the distribution of individual student improvements and identify potential outliers, Figure 3 presents a scatter plot of pretest and posttest scores.

These results confirm that the encyclopedia significantly enhances student comprehension, resulting in a moderate yet meaningful improvement in learning outcomes. This improvement shows that the encyclopedia effectively reinforces concepts. Encyclopedias

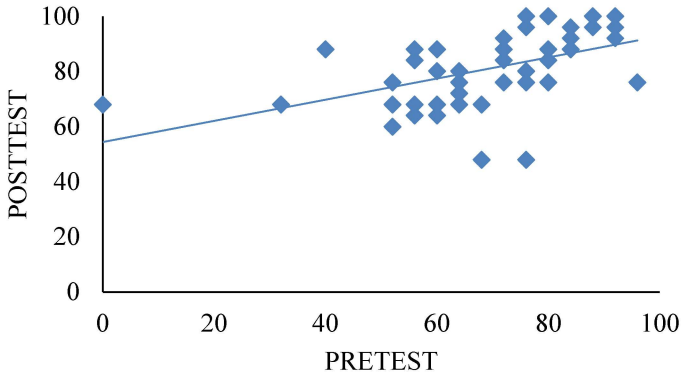



**Figure 3.** Individual Student Improvement and Score Distribution (n=46)

that prioritize visualizations of real objects in the marine ecosystem help students understand abstract concepts in concrete terms. This supports Dual Coding Theory (Kurniawan et al., 2022; Listiyani et al., 2025; Wooten & Cuevas, 2024), which states that combining text and

images strengthens long-term memory and improves learning outcomes. Furthermore, Nisa et al. (2022) state that this theory's strength lies in its ability to help students visualize content, increase motivation, and improve information retention across various educational contexts.

The significant improvement in student learning outcomes after using the encyclopedia (N-Gain of 0.3844) confirmed that the local potential-based biota encyclopedia is more relevant to students' cognitive structure. This finding is due not only to the availability of materials but also to cognitive efficiency mechanisms that occur during the learning process. The excellence of the "*Umbak Gembara*" encyclopedia lies in integrating dual coding theory (Paivio) with local potential. Using typical Sabang biota objects familiar to students provides strong prior knowledge. Because these visual objects are already stored in the students' long-term memory, connecting the new academic concepts to their familiar environment becomes more intuitive. This integration supports foundational principles of learning theory, which emphasize that connecting instruction to existing knowledge structures significantly enhances comprehension and meaningful learning in biology education (Azman & Johari, 2022; Koæ-Januchta et al., 2022; Sweller, 2024; Toh & Tasir, 2024).

Integrating the "*Umbak Gembara*" encyclopedia into enjoyable learning is conceptually driven by its realistic visualization, which presents biological objects concretely. Additionally, the print format's portability supports flexible learning outside the classroom without technical constraints. These design elements are carefully structured to foster positive affective engagement. When learning occurs in an engaging and accessible environment, it can improve learning outcomes by helping transform emotional engagement into deeper cognitive focus. Furthermore, the synergy between realistic visualization (dual coding) and content familiarity (local potential) facilitates the formation of new knowledge schemas, directly supporting the observed improvement in students' post-test scores.

These results reinforce previous findings that reported that learning materials based on local potential demonstrated significantly higher relevance for cognitive structure and improved critical thinking skills (Fajeriadi et al., 2025; Rahmi et al., 2023; Setiyanika et al., 2023), enhanced 21st-century skills, including learning outcomes and conceptual understanding (Kamila et al., 2024), and bridged science and culture and enriched students' scientific understanding through culturally relevant contexts (Aswita et al., 2018; Nurfaizah et al., 2025; Ramadani, 2025). Collectively, these studies validate the cognitive benefits of contextualizing learning through local potential, as applied in the development of this encyclopedia.

Furthermore, integrating local natural resources into the biology curriculum can increase students' intrinsic motivation because the objects studied are located in their immediate environment. Various studies have consistently demonstrated positive effects: learning based on local potential positively impacts student attitudes and improves cognitive outcomes (Fajeriadi et al., 2025), increases student interest and motivation (Ai, 2025; Nurhidayati, 2024), and influences various student skills, with the greatest impact on generic skills (Imtihana & Djukri, 2020). These literature reviews have provided comprehensive insights into leveraging local potential as a basis for transformative education. Purwasih et al. (2025) also expressed the importance of utilizing local potential as a valuable educational resource for students.

Compared with studies developing web-based biology resources (Hadi et al., 2025; Prayitno & Hidayati, 2022; Vekli & Çalik, 2023), this printed encyclopedia offers greater accessibility, particularly for schools in coastal

Aceh with limited digital infrastructure. Thus, this encyclopedia serves not only as a source of information but also as an instrument for environmental conservation through education.

**Disseminate**

This stage concludes with disseminating the developed product through articles published in accredited national journals and an ISBN-certified encyclopedia. The final product is then distributed to partner schools in the coastal areas of Aceh. This distribution is not only a practical contribution but also the initial step in initiating a conservation-based biology learning model that adapts to the geographical characteristics of the islands, which is expected to be replicated in other coastal areas in Indonesia.

## ■ CONCLUSION

This research successfully developed teaching material in the form of an encyclopedia of unique marine biota, "*Umbak Gembara*," based on Sabang Island's local potential, which met high validity and practicality criteria based on expert validation and practitioner evaluations. In the context of implementation, statistical analysis indicated a significant increase in student learning outcomes after using this product, with a medium N-Gain score of 0.3844 (38.44%). This positive trend in learning outcomes demonstrates that integrating familiar local content with concrete photographic visualizations of marine biota effectively bridges abstract biological concepts with students' real-world surroundings. The contextual representation of Sabang's marine ecosystem helps students better visualize and understand biological interactions, ultimately supporting their conceptual understanding. Consequently, the "*Umbak Gembara*" Encyclopedia serves as a valuable supplement to biology teaching materials and a strategic educational tool to build students' environmental literacy regarding vulnerable coastal ecosystems.

The practical implication of this research highlights the strategic advantage of well-structured print media in facilitating deep reading and ensuring educational accessibility, particularly in island regions with limited digital infrastructure. However, this study has a methodological limitation because it relied on a one-group pretest-posttest design without a control group, meaning the observed increase in learning outcomes cannot be definitively attributed solely to the intervention, as external confounding variables could not be fully controlled. To address this limitation, further research is recommended to evaluate the product's product's effectiveness using more rigorous experimental designs with control groups, while also exploring the development of hybrid-based encyclopedias that integrate Augmented Reality (AR) technology to bridge printed literacy with digital interactivity.

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