



Research-Based Teaching E-Modules on Mangrove Diversity to Enhance Meaningful Learning in Banggai Regency

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Abstract: The importance of mangrove ecosystems such as shoreline buffers, biodiversity habitats, and carbon sinks is increasingly threatened by anthropogenic degradation. This study aimed to develop and validate a meaningful learning-based e-module relevant to the context of mangrove diversity in Banggai Regency. Mangrove diversity was utilized as teaching material in the developed e-learning module to provide students with early knowledge about mangroves, enabling them to protect and conserve mangrove ecosystems in their environment. The method employed was a three-stage Research and Development (R&D) approach: field exploration, e-module development based on field data and meaningful learning principles, and product validation by subject matter experts, media experts, and practitioners through observations and questionnaires. Data were analyzed using descriptive qualitative and quantitative methods. The results showed that this interactive e-module, through a limited trial involving 30 students, achieved an average feasibility score of 89.7%. The discussion confirmed that the application of meaningful learning principles integrated with local contexts proved highly valid and effective in improving students' understanding of mangrove diversity. In conclusion, this e-module is feasible and can be implemented to support conservation efforts and enhance students' understanding. (The total word count is approximately 145, which is concise and covers all essential elements).

Keywords: Banggai; E-module; Mangrove; Meaningful learning

Introduction

Developments in the digital era have significantly transformed education, with the advent of various technological innovations, one of which is e-learning modules. E-learning modules function as digital-based learning tools designed to facilitate a more interactive and engaging learning process. With various multimedia features, e-modules can present more engaging information, thereby increasing student motivation and understanding of the material being taught. E-modules can foster students' learning

independence and broaden their knowledge of local wisdom (Dewi & Suniasih, 2023). The use of e-modules in learning can significantly increase student engagement and learning outcomes, as students are more motivated to learn when they use technology they are familiar with (Delita et al., 2022). The development of electronic learning materials, packaged in the form of interactive e-modules, using a scientific approach and accessible through various digital devices, is not only cognitively oriented but also fosters collaborative skills, creative thinking, and a positive attitude (Fahru et al., 2024; Sidauruk et al., 2025). Teachers are free to develop

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their own learning modules, modifying and selecting them according to the context, characteristics, and needs of their students. However, teachers' use of technology has not been optimal in facilitating independent student learning, such as through self-study modules containing practice questions. The current learning process tends to leave students feeling bored and tired, as it relies solely on printed textbooks, which are also limited in availability. The total mangrove area in Banggai Regency is 7.38 hectares, of which 5.65 hectares are severely damaged, and there are 25 true mangrove species. A 2024 study in East Luwuk District, one of the areas with the largest mangrove coverage in Banggai Regency, found only five mangrove species (Haruna et al., 2022). This has raised serious concerns regarding the decline in mangrove species diversity. An important topic integrated into the e-learning module in this study is biodiversity, particularly the mangrove ecosystem.

Mangrove diversity can be used as teaching material in the e-learning module to be created, thus providing early knowledge about mangroves to students so they can protect and maintain the mangrove ecosystem in their environment. The ecological learning carried out has a significant positive influence on students' self-efficacy and self-concept (Surjanti et al., 2020). Self-efficacy also contributes to sustainable behavior. (Susanti, 2021) in her research demonstrated that students perceived the mangrove ecosystem as an interesting learning resource. This was evident in the increased interest in learning about mangroves. Furthermore, students felt more able to think critically and contribute to mangrove conservation. The impacts and problems arising from curriculum demands require teachers to further hone their skills and abilities in providing learning tools tailored to students' needs to create an active, creative, and innovative learning process. Many teachers still rely on textual textbooks, but these are now being replaced by digital products such as e-books (Samala et al., 2021).

The limited availability of electronic teaching modules in schools reflects the underutilization of technology in the learning process. Particularly in Banggai Regency, most teachers have not yet optimally utilized technology, and electronic-based teaching materials are lacking to support classroom learning. The teaching materials included in the e-module, which focus on mangrove diversity, are vital, given the increasingly threatened nature of mangrove species. Therefore, the specific objective of this research is to provide an alternative learning tool in the form of an e-module based on research on mangrove diversity in Banggai Regency. It is hoped that this will be a solution to enhance meaningful learning among students. E-modules are considered effective in facilitating independent learning, character development (Syahrial

et al., 2021), enhancing environmental awareness (Asrial et al., 2021) and enhancing literacy (Utari et al., 2024).

Method

This research is based on research on mangrove diversity and utilizes a research and development (R&D) model, a method used to develop a teaching e-module. Bagno et al. (2023) stated that the research and development process involves 10 steps, but in this study, these steps are simplified into three: gathering information and conducting preliminary research (research and information gathering), planning, and developing a format or model (developing a preliminary form of the product). This simplification is based on Roper et al. (2016) opinion: producing a design, conducting research and development, creating a new product, and testing its effectiveness. The three-stage division is intended to simplify the research process and does not diminish the significance of each step.

This stage includes school observations to obtain a profile of the learning system implementation, particularly those related to the learning activities or objects whose quality is to be improved. Furthermore, the preliminary study by conducting research and information collecting activities has two main activities, namely literature study (literature review and research results related to the diversity of mangrove species) and field study (collecting data on mangrove diversity in the largest mangrove area in Banggai Regency and data on environmental factors that influence it). The next stage is the preparation of the initial design (draft) of the e-learning module. The basis for the preparation used is the results of the preliminary study, theoretical basis, model development theory, and its feasibility test. At this stage, trials are carried out by experts (material experts and media experts) to assess the feasibility of the e-learning module draft, both regarding the feasibility of the basic concepts and theories used.

Based on the validation results, the e-model is refined by conducting a feasibility test by practical practitioners, namely 2 teachers (Teachers of SMAN 1 Luwuk and SMAN 1 Masama) and 30 students (15 students of SMAN 1 Luwuk and 15 students of SMAN 1 Masama). The instruments used in this study were questionnaires administered to content experts, design experts, and practitioners as respondents. The instruments assessed for the material experts included curriculum, language, and evaluation. The instruments assessed for the media experts included the design of the e-learning module and its material. The instruments for practitioners consisted of response instruments covering aspects of the e-learning module's appeal, ease of use, and usefulness. Data analysis was conducted using a quantitative descriptive approach to process the

questionnaire data, which was presented in descriptive form as a percentage, using a conversion of achievement levels based on a 5-point scale as shown in Tables 1 and 2.

Table 1. Validity Test Categories (Alhakiki et al., 2020)

Percentage (%)	Validity Category
86-100	Quite Valid
66-85	Valid
46-65	Less Valid
25-45	Invalid

Table 2. Conversion of Achievement Levels

Percentage (%)	Validity Category	Description
90 -100	Excellent	No revisions needed
75 - 89	Good	Minor revisions
65 - 74	Poor	Sufficient revisions
55 - 64	Invalid	Many revisions
0 - 54	Very Poor	Repeat product creation

Results and Discussion

This research employed a research and development (R&D) model, aiming to produce a teaching e-module. The research and development process involved three stages: exploration, e-module development, and product validation. The exploration phase involved collecting field data on mangrove species. This was followed by a review of various articles covering mangrove species and mangrove ecosystem damage in Banggai Regency. Observations at several high schools in Banggai Regency indicated that textbooks were still the dominant learning resources and media used in biology instruction, particularly for ecosystems. Available facilities and infrastructure have not been optimally utilized for digital learning media, thus failing to meet the demands of the current curriculum. These findings provide a strong basis for the research, given that most students already own smartphones, facilitating the development of interactive digital teaching tools appropriate to modern learning contexts.

The next stage involved developing and designing the e-module. At this stage, the activity of designing the conceptual framework of the e-module teaching product based on research on mangrove diversity in improving meaningful learning in Banggai Regency was carried out along with the compilation of research instruments. The e-module product developed was designed comprehensively with a structure consisting of: a cover containing the title of the e-module, the education level (high school), and the author's name; an introductory section that includes a table of contents, foreword, concept map, and instructions for using the e-module; teaching materials containing a summary of learning

materials, videos and images of the mangrove ecosystem in Banggai Regency accompanied by evaluation questions to support meaningful learning; a glossary containing definitions of difficult-to-understand terms to support student understanding; and a bibliography located on the last page as a reference to material sources. Figure 1 displays the e-module cover, which shows the initial appearance when the product is opened for the first time.

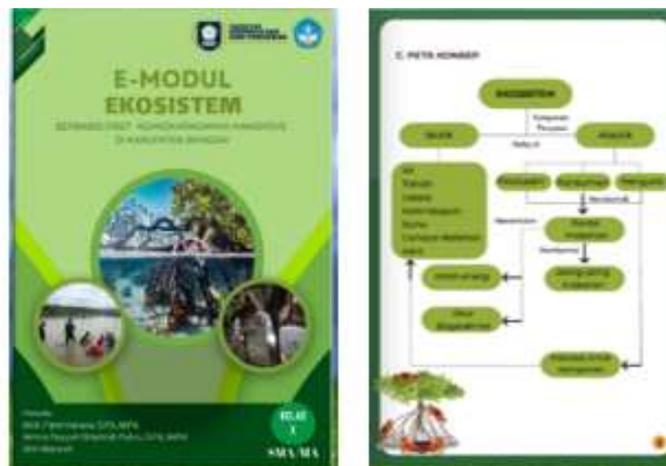


Figure 1. Design of a mangrove diversity-based e-learning module

The final step in the research was the validation phase, which was conducted to assess the feasibility and meaningfulness of the e-learning module product through the use of a systematically developed validation instrument. This phase involved assessments by three groups of validators: material expert validators, media expert validators, and practitioners, consisting of one Biology teacher from each school. Testing was conducted at two schools: SMAN 1 Luwuk and SMAN 1 Mansama, with 15 students from each school participating as practitioner respondents. The validation results aimed to evaluate the product's quality from various aspects, including content, media design, appeal, and relevance to real-life learning contexts. The test results at this stage can be seen in Tables 3, 3, and 4 below.

Table 3. Results of the Validation Test by Material Experts

Aspects Assessed	Percentage (%)	Category
Content Appropriateness	96	Quite valid
Language	86	Quite valid
Presentation	86	Quite valid
Meaningful Learning Approach	85	Valid
Total	353	
Average	88.25	A little revision

Table 4. Media Expert Validation Test Results

Aspects Assessed	Percentage (%)	Category
Media Appearance	90	Quite valid
Media Suitability Aspect	90	Quite valid
Interactivity Aspect	86.60	Quite valid
Media Presentation Aspect	90	Quite valid
Meaningful Learning Aspect	90	Quite valid
Total	446.60	
Average	A little revision	A little revision

Table 5. Results of the Practicality Test of the E-module by Teachers

Aspects Assessed	Percentage (%)	Category
Content Aspect	95	Very Good
Presentation Aspect	95	Very Good
Display and Media Aspect	95	Very Good
Engagement & Interactivity Aspect	96	Very Good
Benefit Aspect	100	Very Good
Total	481	
Average	96.30	No revision needed

Table 6. Results of the Practicality Test of the E-module by Students

Statement	Percentage (%)	Validity Category
The meaningful learning e-module, based on research on mangrove ecosystem diversity in Banggai Regency, is attractive and engaging.	91.30	Excellent
The text and images in the e-module are easy to read and understand.	91.60	Excellent
The material in the meaningful learning e-module, based on research on mangrove ecosystem diversity in Banggai Regency, aligns with the lesson being studied.	80.60	Good
This e-module helped me understand the ecosystem material better.	95.30	Excellent
The instructions for use in the e-module are clear and easy to follow.	92	Excellent
I feel more motivated to learn using the meaningful learning e-module, based on research on mangrove ecosystem diversity in Banggai Regency.	89	Good
The questions in the e-module helped me practice understanding the mangrove ecosystem material.	89.60	Good
The e-module is easily accessible through the device I use.	85.90	Good
The e-module can be used for both independent and group learning.	94.60	Excellent
I intend to use this e-module in future lessons.	87.30	Good
Total	897.20	
Average	89.70	A little revision

Mangrove species data collection in the field was conducted by identifying mangrove species in four villages (four sub-districts) that have mangrove ecosystems, namely Lambangan Village, Pagimana District, Rata Village, West Toli District, Sinorang Village, Batui Seltan District and Nuhon District. The most dominant mangrove species found are *Avicennia*, *Sonneratia*, *Rhizophora*, *Bruguiera*, *Xylocarpus*, and *Lumnitzera*. Mangrove vegetation in Indonesia generally consists of 5 flora groups, namely *Rhizophora*, *Sonneratia*, *Bruguiera*, *Avicennia* and *Nypa*. The genus *Rhizophora* is the most commonly found genera in all mangrove locations in Indonesia (Nugraha et al., 2024). The extent of cover and dominance of *Rhizophora* species are supported by the environmental conditions of the research location, both environmental factors and the substrate where they live (Muhtadi et al., 2023; Sunkur et al., 2023). Furthermore, data on environmental factors, the presence of fauna supporting the ecosystem, and factors affecting mangrove ecosystem damage were collected. The dense mangrove growth in this location is thought to be due to environmental factors favorable for the growth and development of the mangrove species found, along with suitable habitat substrates.

The waters, with a pH of 6.5-7.5, are considered productive (Dewiyanti et al., 2021). The study revealed a diverse fauna within the mangrove ecosystem. Examples include crabs, snails, insects, birds, and various other animal species that inhabit the mangrove area. Mangroves are a habitat for invertebrates (mostly insects, polychaetes, nematodes, mollusks, and crustaceans), vertebrates (fish, birds, and mammals), and possibly many other taxa/groups (Ferreira et al., 2024). Mangroves serve as habitats and have the potential to support the growth and development of various crab species (Katharoyan et al., 2025; Akram et al., 2023). The presence of crabs that eat or peel off the skin of seedlings and hypocotyls can inhibit the growth of mangrove seedlings (Gao & Lee, 2022; Riska et al., 2023). Various factors identified as contributing to mangrove ecosystem damage include the clearing of ponds, oil palm plantations, and residential expansion (Yamamoto, 2023; Arifanti et al., 2025).

Field data collection on mangrove species and a search for articles on mangrove ecosystems in Banggai Regency served as the foundation for developing interactive, locally context-based e-learning modules. The primary objective was to gather scientific information and actual facts about the existence, species

diversity, and ecological and economic functions of mangrove forests in the region. The e-modules serve as effective learning tools, enhancing the learning experience and encouraging active engagement during learning (Alyoussef, 2023), thereby improving self-efficacy, motivation, and learning outcomes (Gunawan et al., 2024). All observation results were processed into interactive learning materials in the form of images, diagrams, and videos that are easy for students to understand. The resulting e-module not only presents scientific knowledge, but also invites students to participate in field observation simulations, observation journal writing, and small project ideas such as mangrove conservation in the school environment, with the aim of creating a young generation that is environmentally intelligent and cares about the region's natural wealth.

This validity test was carried out by asking an expert, namely a validator lecturer, to assess the e-module product. The purpose of validation is to determine whether or not the product that has been developed is feasible to be implemented in the learning process. Based on the assessment of the material expert validator lecturer, Table 3 shows a percentage result of 88.25%, and Table 4 above shows that the assessment of the media expert validator lecturer obtained a percentage result of 89.32%. This shows that the meaningful learning-based e-module on mangrove diversity in Banggai Regency that has been developed is categorized as valid and suitable for use in learning. However, minor improvements are required according to the suggestions provided by the validators, including the need to add more examples of local context-based practice questions so that students are more involved in strengthening critical thinking. In some parts, the presentation also needs to add trigger questions before the main material to be more interactive, and it is necessary to add navigation to return to the home page of the e-module.

Developed products must undergo a validation or expert assessment phase, which aims to assess the product and provide suggestions for improvements. This phase also allows for the development of modified teaching materials based on expert advice and will be tested with students (Andiopenta, 2023; Syarifah et al., 2023). Learning media should be supported by engaging content, such as images and instructional videos, to attract student interest and minimize boredom (Kiswandini et al., 2023). After undergoing validation by the validator team, the e-module product is then tested for practicality to assess teacher responses. The practicality test aims to determine the ease of use of the content and the suitability of the developed e-module for implementation in biology learning. The developed e-module was piloted in two schools in Banggai

Regency: SMAN 1 Luwuk and SMAN 1 Masama. Table 5 above shows that the e-module achieved a practicality score of 96.30% in biology learning, and can be categorized as practical for use in biology learning. This indicates that the developed e-module is suitable for use in biology learning. A product is considered practical if it achieves a percentage of $\geq 66\%$ (Daryono et al., 2023).

Table 6 above shows a limited trial conducted with 30 students, showing a percentage of 89.70% for the meaningful learning-based e-module, based on research on mangrove diversity in Banggai Regency. The results were reviewed in terms of the e-module's attractiveness, ease of use, accessibility from any device, and student motivation to learn using the meaningful learning e-module based on research on mangrove ecosystem diversity in Banggai Regency. Based on these results, the developed e-module is suitable for implementation in biology learning, particularly for the Ecosystem topic. E-modules with collaborative learning are most effective in producing significant improvements in self-efficacy, motivation, and learning outcomes (Doyan et al., 2020; Marzani et al., 2023). E-modules can be a source of learning media that can improve thinking skills and 21st-century skills (Doyan et al., 2025). According to Yulianti et al. (2025), electronic media can foster students' attention to the learning process.

Through local culture and traditional values, ecological guidelines can promote environmental conservation and the sustainability of natural resources. This research provides important implications for the development of interactive learning media in early childhood education (Fransiska et al., 2025), utilizing digital technology and local wisdom to support character development and social skills in young learners. E-modules can be an alternative to enhance students' creative thinking skills. Students' creative thinking skills can enhance their creativity and innovation in utilizing existing local potential (Putri et al., 2024). Integrating local wisdom into digital learning materials has the potential to strengthen character education and environmental values (Subayani et al., 2025). The e-modules developed are also based on research and article reviews related to the condition of mangroves in Banggai Regency. They can enhance students' in-depth understanding because the learning materials are easy to understand, contain visual content (maps, photos, diagrams), and provide exploratory activities for students, such as mangrove rehabilitation simulations or case studies on coastal communities. Thus, the resulting e-module is not only informative but also fosters a love for the environment (Candeloro & Tartari, 2025) and a passion for sustainably preserving the region's natural resources. This e-module also helps master difficult concepts, increasing interest,

motivation, understanding, and practical skills (Azizah et al., 2025; Dedeker, 2017).

Conclusion

This research successfully developed a meaningful learning-based e-module for the topic of mangrove ecosystem diversity in Banggai Regency. High scores in the aspects of engagement, interactivity, and ease of use indicate that the module is able to increase student learning motivation, conceptual understanding, and ownership of mangrove conservation. With proven validity, the e-module has the potential to become a standard medium for mangrove biology learning at the high school level and can be adapted to other regions by adjusting to local mangrove species.

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Author Contributions

Conceptualization, M.F.H; methodology, M.F.H and A.R.S.F; validation, A.S.K and A.H.O.; formal analysis, M.F.H and A.R.S.F; investigation, M.F.H and A.R.S.F; resources, M.F.H A.R.S.F and S.M.S; data curation, M.F.H and S.M.S : writing—original draft preparation, M.F.H and A.R.S.F.; writing—review and editing, M.F.H. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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