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Development of Bryophyta modules based on moss diversity in the Mandiangin tropical rainforest biodiversity park, South Kalimantan

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Abstract

This study was motivated by the limited availability of contextual and locally-based biology teaching materials, particularly on the topic of mosses (Bryophyta), which requires high conceptual and visualization skills. This study aims to develop and test the feasibility and practicality of a locally-based biology learning module on Bryophyta for 10th grade high school students. The research method used the Four-D (Define, Design, Develop, and Disseminate) development model from Thiagarajan et al. Data collection was carried out through field exploration of the diversity of moss species in the Mandiangin Tropical Rainforest Biodiversity Park, South Kalimantan, followed by validity testing by experts and practicality testing by students. The validation results by two expert lecturers showed that the module was highly valid with an average score of 93.06%, covering aspects of content feasibility, language, and presentation. Meanwhile, the practicality test obtained an average score of 87.56% with a highly practical category. These results indicate that the developed module is feasible, interesting, and effective in helping students understand the concept of Bryophyta through real examples from the surrounding environment. The integration of local potential in the module also supports contextual learning and strengthens students' ecological literacy. This module contributes to the enrichment of local potential-based biology learning resources and can be used by teachers as an alternative innovative teaching material for independent learning. Further research is recommended to integrate digital technology and test the effectiveness of the module in improving student learning outcomes, critical thinking skills, and environmental awareness.

Keyword: bryophyta; biology module; local potential; validity; practicality

Abstrak. *Penelitian ini dilatarbelakangi oleh masih terbatasnya ketersediaan bahan ajar biologi yang kontekstual dan berbasis potensi lokal, khususnya pada topik tumbuhan lumut (Bryophyta) yang menuntut kemampuan konseptual dan visualisasi tinggi. Penelitian ini bertujuan untuk mengembangkan serta menguji kelayakan dan kepraktisan modul pembelajaran biologi berbasis potensi lokal pada materi Bryophyta untuk peserta didik kelas X SMA. Metode penelitian menggunakan model pengembangan Four-D (Define, Design, Develop, dan Disseminate) dari Thiagarajan et al. Pengumpulan data dilakukan melalui eksplorasi lapangan terhadap keanekaragaman jenis lumut di Taman Keanekaragaman Hayati Hutan Hujan Tropis Mandiangin, Kalimantan Selatan, dilanjutkan dengan uji validitas oleh ahli dan uji kepraktisan oleh peserta didik. Hasil validasi oleh dua dosen ahli menunjukkan kategori sangat valid dengan skor rata-rata 93,06%, meliputi aspek kelayakan isi, kebahasaan, dan penyajian. Sementara itu, uji kepraktisan memperoleh skor rata-rata 87,56% dengan kategori sangat praktis. Hasil ini menunjukkan bahwa modul yang dikembangkan layak, menarik, dan efektif dalam membantu peserta didik memahami konsep Bryophyta melalui contoh nyata dari lingkungan sekitar. Integrasi potensi lokal dalam modul juga mendukung pembelajaran kontekstual dan memperkuat literasi ekologis siswa. Modul ini berkontribusi terhadap pengayaan sumber belajar biologi berbasis potensi lokal dan dapat digunakan guru sebagai alternatif bahan ajar inovatif untuk pembelajaran mandiri. Penelitian lanjutan disarankan untuk mengintegrasikan teknologi digital serta menguji efektivitas modul terhadap peningkatan hasil belajar, keterampilan berpikir kritis, dan kesadaran lingkungan peserta didik.*

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INTRODUCTION

Biology education, particularly the subject of mosses (Bryophyta) (Purnawati et al., 2025), requires students to understand the morphological characteristics and classification of various types of mosses belonging to this division (Xusanovich et al., 2024). This understanding depends not only on field observation activities, but also greatly on the quality of the teaching materials used (O'Leary, 2020). Teaching materials—whether in the form of textbooks, worksheets, handouts, or modules—play an important role as learning resources that help students acquire information and broaden their knowledge of biology (Amos et al., 2022).

According to Eliyanti et al. (2020), educators have the authority to evaluate and develop the learning process, including through the preparation of teaching materials that are relevant to students' needs. Well-designed teaching materials can support independent learning and improve students' understanding of biology. However, in practice, teachers often face obstacles when explaining the characteristics and identification of mosses in detail. Therefore, teaching materials are needed that can facilitate students in comprehensively understanding the concepts of Bryophyta. Biology teaching materials for 10th grade high school students are generally compiled based on the applicable curriculum standards. However, the integration of local potential in teaching materials is important so that students can learn about the biodiversity in their environment (Ule et al., 2021). A local potential-based approach also supports the development of scientific thinking skills and fosters awareness of the surrounding environment.

In the era of the Fourth Industrial Revolution, teachers are required to be able to develop innovative teaching materials that are adaptive to technological developments. One form of effective teaching material is a module, because it is self-learning and allows students to learn independently through systematic instructions and easy-to-understand language (Deviana, 2018). Modules designed with the principle of independent learning have been proven to increase student participation in biology learning. Well-designed learning modules not only guide students through the learning stages but also build connections between biological concepts and practices. Thus, modules serve as a structured and effective learning tool in supporting the learning process in the classroom.

Based on preliminary survey results, the availability of learning modules that specifically discuss mosses is still limited. In fact, this topic requires a high level of conceptual understanding and visualization. Modules with attractive (eye-catching) displays and interactive features are needed to motivate students and make it easier for them to understand the principles of classifying mosses according to their characteristics. Several previous studies have shown the effectiveness of developing biology modules on various materials, such as e-modules on cells (Mahrawi et al., 2021), modules based on science process skills on the human excretory system (Sumbayak et al., 2025), and modules based on exploring the natural environment on ecosystems (Ule et al., 2021). However, research related to the development of specific biology modules on bryophyte (Bryophyta) material with the integration of local potential and a visual-interactive approach is still rare.

Therefore, this study aims to develop and test the feasibility of a local potential-based biology learning module on bryophyte (Bryophyta) material in 10th grade high school. This module is expected to be an alternative teaching material that is interesting, feasible, and effective in improving students' conceptual understanding of Bryophyta.

RESEARCH METHODS

This study is a research and development study that uses the Four-D model developed by Thiagarajan et al. (1974), which consists of four main stages, namely Define, Design, Develop, and Disseminate. The research was conducted in two main stages, namely the descriptive research stage and the product development stage. The descriptive research stage was conducted to obtain data on the diversity of moss species found in the Mandiangin Tropical Rainforest Biodiversity Park, South Kalimantan.

Data were collected using the exploration technique by recording the morphological characteristics of each moss species found. The species identification process was carried out using the moss identification key compiled by Lukitasari (2018) in the book Mengenal Tumbuhan Lumut (Bryophyta): Deskripsi, Klasifikasi, Potensi, dan Cara Mempelajarinya (Getting to Know Moss Plants (Bryophyta): Description, Classification, Potential, and How to Study Them). The results of these observations and identifications

were used as contextual material in the development of the Bryophyta learning module for 10th grade high school students.

The Define stage began with a needs analysis aimed at identifying learning problems and teaching material needs relevant to the conditions of the students and the applicable curriculum. Data was obtained through interviews with teachers and 10th grade students at SMAN 1 Anjir Pasar. The results of the analysis show that Bryophyta material is still difficult for students to understand due to the lack of contextual and interesting learning media, as well as the lack of locally-based modules that can be used independently.

The Design stage was carried out by compiling a preliminary design for the learning module based on the results of the needs analysis. The module design included the selection of formats (text, images, and illustrations), content compilation, page layout design, selection of supporting media, and the development of evaluation tools. The module was designed to be self-learning, so that students could learn independently with communicative language and systematic learning instructions.

The development stage aims to produce a module product that has been validated and tested for practicality. Validity testing was conducted by two expert validators (biology education lecturers) using a validation sheet covering three aspects, namely content/material, language, and appearance. The assessment instrument used a Likert scale of 1–4 (1 = very poor, 2 = poor, 3 = good, and 4 = very good). The validation and practicality results were analyzed using a percentage Formula 1. The criteria for interpreting the validation results are as follows: 81–100% = very valid/very practical, 61–80% = valid/practical, 41–60% = fairly valid/fairly practical, and <40% = less valid/less practical.

$$\text{Validity/Practicality Percentage} = \frac{\sum \text{assessment scores}}{\sum \text{maximum scores}} \times 100\% \text{.....Formula 1}$$

Next, a practicality test was conducted on nine tenth-grade students using a practicality questionnaire that was also compiled on a 1–4 Likert scale. The aspects measured included the practicality of the module in terms of material, language, and appearance. The practicality test data were analyzed using the same formula as in the validity test to obtain the product's practicality percentage.

The Disseminate stage aimed to introduce and disseminate the developed product to potential users, such as biology teachers and students. However, in this study, the Disseminate stage has not been fully implemented due to time constraints and post-pandemic conditions that limit face-to-face activities at schools. Therefore, dissemination was only carried out on a limited scale through product trials with validators and biology teachers at partner schools.

The limitations of this study lie in the relatively small number of test subjects, namely nine students, so that the results of the practicality test cannot be generalized widely. In addition, the product dissemination stage has not been optimally implemented, so that the effectiveness of the module in a broader learning context still needs to be further tested in subsequent studies.

RESULTS AND DISCUSSION

This study aims to develop and test the validity and practicality of a module on mosses (Bryophyta) based on species diversity in the Mandiangin Tropical Rainforest Biodiversity Park. The validation process was carried out by two expert lecturers who teach the Cryptogamae Botany course, while the practicality test was conducted through the responses of 10th grade high school students to the use of the module in learning. Validation was conducted to assess the suitability of the content, language, and presentation of the module. The assessment results from two validators are presented in Table 1.

Table 1 Results of Content Expert Validation

Assessment aspects	Average (%)	Criteria
Content suitability	85.42	Very valid
Language suitability	100.00	Very valid
Presentation suitability	93.75	Very valid
Overall average	**93.06**	**Very valid**

The overall average score of 93.06% indicates that the Moss Plants module is very valid and suitable for implementation. Suggestions for improvement from the validators include adding vocabulary to the glossary, enlarging the images and adding captions, and using different colors for each subconcept of the concept map to clarify the content. These findings indicate that the developed module has met the teaching material feasibility elements as stipulated by the National Education Standards Agency (BNSP), namely feasibility of content, presentation, language, and graphics. The success of the module in meeting these criteria shows that the design and content of the module are in line with the needs of students and support contextual learning. This is in line with Hamdani's opinion in Fajarini et al. (2016), which emphasizes that effective modules must be designed in accordance with the curriculum and characteristics of students in order to optimize their benefits.

Empirically, these results are consistent with the findings of Nurus Sobah and Wardhani (2022), who reported that the plant taxonomy module they developed obtained a validity score of 89.28% and was declared suitable for use. Similar results were also shown by Renita et al. (2020), who obtained a validity score of 77% (valid category) from media experts, particularly in terms of design and physical appearance. Thus, the validity of the Moss Plant module, which reached 93.06%, shows an improvement in quality compared to previous studies, mainly because this module uses authentic specimens documented in the field that are relevant to the local context of tropical rainforest ecosystems.

The main advantage of this module lies in the presentation of images of moss species taken directly from their natural environment. This contextual approach supports real-world experience-based learning so that students can more easily understand the morphological and ecological characteristics of the moss around them. Thus, the validation results not only confirm the technical feasibility of the module but also demonstrate its ecological and pedagogical relevance in biology education.

Table 2 Practicality Results Based on Student Response Questionnaires

Assessment aspects	Average (%)	Criteria
Material	90.74	Very practical
Language suitability	87.50	Very practical
Layout	84.44	Very practical
Overall average	**87.56**	**Very practical**

Practicality testing was conducted by distributing questionnaires to students regarding the content, language, and appearance of the material. The results are presented in Table 2. A practicality score of 87.56% indicates that the module falls into the highly practical category, with the majority of students responding positively to its ease of use and clarity of content. Students stated that this module helped them understand Bryophyta material through real visualizations of their surrounding environment.

These results are in line with Thiagarajan (1974) theory in the Four-D model, which emphasizes that the Development stage must end with readability and practicality tests so that the product is truly ready to be implemented in the classroom. The positive responses from students indicate that this module effectively supports independent learning and motivates students to explore the relationship between biological concepts and phenomena in their surrounding environment.

These findings are also consistent with the research by Aziszah et al. (2021), which reported a practicality level of 93.97% for context-based biology modules. Similar results were obtained by Maisyura et al. (2021), who developed a Plantae subconcept Bryophyta booklet with a practicality score of 84.21% (very valid and feasible category). Meanwhile, Kartika et al. (2020) reported a student response of 86.87% to the biology learning module, showing a similar practical category to the results of this study. Based on this comparison, the Moss Plants module developed shows a relatively higher level of practicality, mainly because it integrates the results of local field exploration and reflective activities in each sub-material. The attractive visual design, use of communicative language, and presentation of authentic images make this module less monotonous than conventional textbooks.

Theoretically, practical modules support effective learning processes because they provide learning tools that are easy to use, interesting, and tailored to the needs of students (Bachtiar et al., 2022; Purnawati et al., 2025). Good modules are also able to motivate students to learn independently and

increase their involvement in the learning process. In this context, the Moss Plants module has fulfilled these pedagogical functions well. In addition, the field documentation from the Mandiangin Tropical Rainforest Biodiversity Park provides added value in the form of authenticity and ecological relevance, which are important in environment-based biology learning. Thus, this module is not only technically valid and practical, but also supports the contextual teaching and learning (CTL) approach in an effort to strengthen students' ecological literacy.

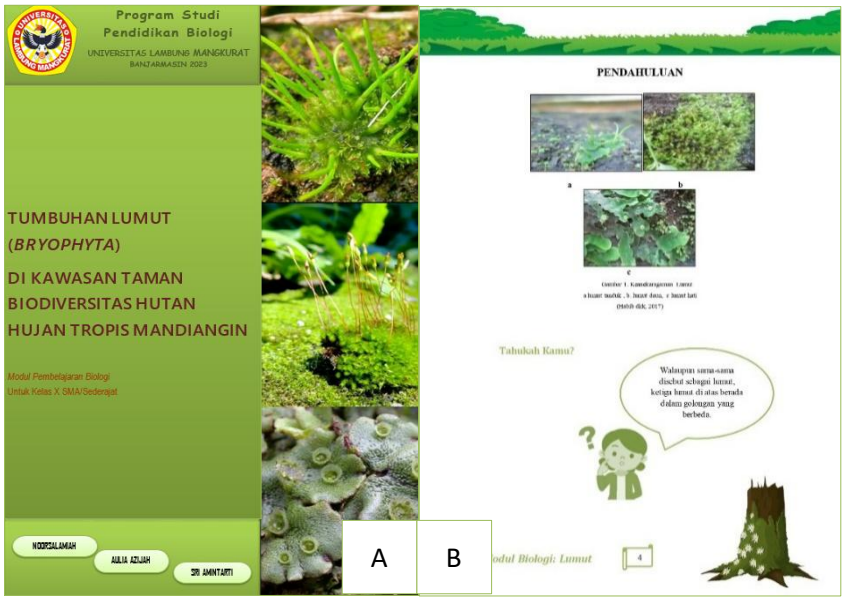


Figure 1 (A) Front cover and (B) contents (in Indonesian)

CONCLUSION

Based on the results of the research and discussions that have been conducted, it can be concluded that the Bryophyta concept teaching module developed for the Mandiangin Tropical Rainforest Biodiversity Park has met the criteria for high feasibility and practicality. The validity test results showed an average score of 93.06% in the very valid category, covering aspects of content feasibility, language suitability, and presentation. Meanwhile, the practicality test results based on student responses obtained a score of 87.56%, which is classified as very practical, indicating that the module is easy to use and helps students understand the material through real and contextual visualization. This module makes an important contribution to biology learning based on local potential, as it presents examples of moss species found directly in the environment surrounding students. This approach not only strengthens scientific understanding of the concept of Bryophyta, but also fosters ecological awareness and a sense of concern for local biodiversity. For teachers, this module can be used as an alternative teaching material that is relevant and contextual to support project-based learning activities or outdoor learning. For further research, module development can be directed towards the integration of digital technologies such as augmented reality (AR) or mobile learning to make the material more interactive and accessible. In addition, testing the effectiveness of the module in improving student learning outcomes, critical thinking skills, and environmental awareness is also necessary to strengthen empirical evidence of its benefits in biology learning in various school contexts.

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