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Development and validity of a fern species diversity in Semirang Waterfall Area e-encyclopedia for biodiversity material for high school students

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Abstract

The Semirang Waterfall area in Ungaran is a tourist spot with potential as a location for biodiversity research. This study aims to analyze the validity, readability, and response of students and teachers to the developed media, namely the E-Encyclopedia. A 1 x 1 m square was used for quantitative data collection at the research site, which was divided into four stations, namely around the waterfall, the middle of the climbing path, and the beginning of the climbing path. The qualitative data collected consisted of the characteristics and habitat conditions of each species. The development of learning media was carried out using guidelines from the Alessi & Trollip research and development model. The feasibility scores obtained were in the high category for material validation (0.92), media (0.98), and learning tools such as teaching modules and assessments (1.00), also student worksheets (0.80). The readability test percentage showed that the media enabled students to learn independently (98.89%). The response test involving teachers (93.33%) and students (93.33%) showed a positive category. These findings indicate that the E-Encyclopedia has a category for each test result that is good and positive. This allows the E-Encyclopedia to be used in learning process. This research contributes to the provision of up-to-date data on the composition and diversity of understory ferns in the Semirang Waterfall area and presents a model for integrating local biodiversity research results into context-based digital learning media that supports the strengthening of science process skills and in-depth learning in accordance with the Merdeka Curriculum.

Abstrak. *Kawasan Air Terjun Semirang, Ungaran merupakan salah satu lokasi wisata yang berpotensi sebagai lokasi penelitian kenakeragaman hayati. Penelitian ini bertujuan untuk menganalisis validitas, keterbacaan, serta respon peserta didik dan guru terhadap media yang dikembangkan yaitu E-Ensiklopedia. Kuadrat 1 x 1 m digunakan untuk pengambilan data kuantitatif di lokasi penelitian yang terbagi menjadi empat stasiun yaitu sekitar air terjun, jalur tengah pendakian, dan jalur awal pendakian. Pengembangan media pembelajaran dilakukan menggunakan panduan dari model penelitian dan pengembangan Alessi & Trollip. Skor kelayakan yang didapatkan berada pada kategori tinggi baik untuk validasi materi (0,92), media (0,98), maupun perangkat pembelajaran seperti modul ajar, asesmen (1,00), dan LKPD (0,80). Persentase dari uji keterbacaan menunjukkan bahwa media memungkinkan peserta didik untuk belajar secara mandiri (98,89%). Uji respons yang melibatkan guru (93,33%) dan peserta didik (93,33%) menunjukkan kategori positif. Temuan tersebut menunjukkan bahwa E-Ensiklopedia memiliki kategori untuk setiap hasil uji coba baik dan positif. Hal tersebut memungkinkan E-Ensiklopedia digunakan saat pembelajaran. Penelitian ini berkontribusi pada penyediaan data terkini mengenai komposisi dan keanekaragaman paku bawah di kawasan Air Terjun Semirang serta menghadirkan model integrasi hasil riset biodiversitas lokal ke dalam media pembelajaran kontekstual berbasis digital yang mendukung penguatan keterampilan proses sains dan pembelajaran mendalam sesuai Kurikulum Merdeka.*

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A. Introduction

Mindful, meaningful, and joyful learning is one of the main priorities in science education in the Merdeka Curriculum to teach students through deep learning (Kementerian Pendidikan Dasar dan Menengah, 2025). To improve students' understanding through deep learning, students must be involved in every learning experience, both directly and indirectly, such as field learning that is relevant to their lives. Learning materials for diversity can be sourced from locations outside the classroom, such as local ecotourism sites, which provide great opportunities to create highly contextual learning and involve students in the learning process. However, limitations related to cost, time, and energy often hinder the implementation of contextual learning activities, especially those that take students to places that are quite far away.

The Semirang Waterfall area is located in Gintungan Hamlet, Gogik Village, West Ungaran Subdistrict, Semarang Regency, Central Java. The waterfall is approximately 45 meters high (Dinas Pariwisata Kabupaten Semarang, 2018), making the surrounding area suitable for lower plants such as ferns. This condition also makes the location suitable for biodiversity learning in high school. Although the location has abiotic factors and an ecosystem that are really good for ferns, studies on ferns in Semirang are surprisingly limited. Preliminary studies have only found two studies by Dewi et al. (2023) and Pranama & Nugroho (2023). Both conducted their research in the same year but with different results. Dewi et al. (2023) found 12 fern species in April 2023, while Pranama & Nugroho (2023) found 16 fern species in May 2023. Not all species found by the two researchers were the same. This is possible due to the sampling and data collection methods. In addition, it is also possible due to differences in rainfall, microhabitat diversity, and the adaptability of each species. The lack of recent data analyzing the understory composition in the Semirang Waterfall Area indicates the need for the compilation of recent data.

The selection of fern diversity in the Semirang Waterfall Area as additional material on biodiversity allows students to observe and understand the local diversity around them. In addition, several species of ferns can grow in home or school yards, allowing students to directly recognize and identify existing species. Immersing students in natural environments fosters a deeper, more comprehensive understanding by enabling direct observation and firsthand engagement with the subject matter (Khotimah et al., 2023).

Regarding in-depth learning, interviews conducted with 10th grade biology teachers showed that biology learning still mostly uses student worksheets, textbooks, and modules. Furthermore, the content or material in the media used is still not closely related to the students' environment. This has an impact on the students' underdeveloped scientific process skills. Given this situation, there is a need to develop media that are closer to the students' living environment. The aim is to make it easier for students to understand and visualize the material being presented.

One solution to this problem is to make colorful media based on research conducted in the students' surrounding environment. The results of the observations are presented in an encyclopedia as a supplementary learning medium. Furthermore, according to Pusat Pengembangan dan Pelindungan Bahasa dan Sastra (2019), encyclopedias are divided into two types: general and specialized. The encyclopedia developed contains specific information about the species of ferns found at the research site and their characteristics. Since learning activities at school allow students to use gadgets, the encyclopedia is in electronic or digital form. This is to suit the habits of students and save time and money.

This study aims to analyze the level of validity, readability through cloze tests, and the responses of teachers and students to the developed media.

B. Material and method

This study used a mixed methods approach with an explanatory sequential design. This design prioritized quantitative data as the main source and qualitative data as supporting data. The quantitative data collected included the results of analyses of the Shannon-Wiener diversity index, importance value index, alpha test, and beta test. Interviews with biology teachers and questionnaires distributed to students also constitute preliminary quantitative data. Qualitative data consists of morphological characteristics, abiotic environmental factors, and the identity of each species. This research is classified as R&D using the research and development model developed by Alessi & Trollip (2001). The research and development stages are divided into planning, design, and development, with each stage consisting of several sub-stages. These sub-stages are tailored to the media development process. Further details on each stage are as Figure 1.

Planning

This stage includes determining the objectives of media development, material coverage, and technical limitations. The scope of the material was determined based on interviews with biology teachers who taught 10th grade classes and questionnaires distributed to 120 10th grade students from three schools located near the research site. Data on the diversity of fern species was collected in the Semirang Waterfall area, Ungaran, using a 1 x 1 m quadrat method in 20 units at four stations selected based on habitat conditions.

Data collection was conducted in December 2024, followed by species identification in January 2025 using expert reference books such as Flora of China, Flora of North America: Pteridophytes and Gymnosperms, Flora of Australia: Ferns, Gymnosperms and Allied Groups, Flora of Korea: Pteridophytes & Gymnosperms, Flora Malesiana: Pteridophyta, and The Kew Plant Glossary: An illustrated dictionary of plant terms.

The rainy season is expected to peak around November-December 2024, right when data collection was carried out at the research site. Badan Meteorologi Klimatologi dan Geofisika (2024) indicate low-moderate rainfall (20-50 mm/decade) for December. This anticipated rainfall is highly relevant to the measured abiotic factors, particularly air humidity, soil moisture, and soil pH, and must be carefully considered in the analysis.

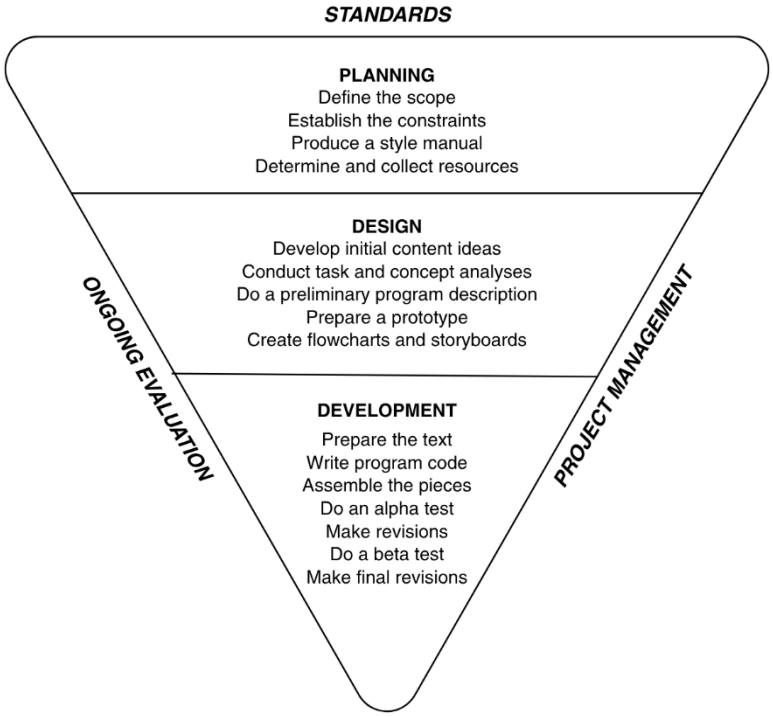

Figure 1 The modification of Alessi & Trollip development model

Design

The design phase is used to combine various prepared data into a functional E-Encyclopedia prototype. Then, to ensure linguistic suitability with the students' abilities, alternatives for biological terms and words were sought using the online KBBI (Big Indonesian Dictionary). This design and development process start from February to May 2025.

Development

This development stage is used to test the suitability and feasibility of the E-Encyclopedia, which explains the characteristics, habitat features, and geographical distribution of each family and species. The E-Encyclopedia is tested through two stages, namely alpha testing and beta testing. Valuable input collected during these trials directly forms the basis for critical improvements and refinements to the media.

Alpha test

During the alpha testing phase, media validation was conducted to identify and eliminate potential problems in the learning resources (Alessi & Trollip, 2001). This critical validation process involved expert review by three specialists, covering media and material validation. Specifically, teaching modules, student worksheets, and assessments also underwent in-depth review by teachers. A Guttman scale questionnaire was used as a validation tool (1 = accepted, 0 = requires revision). The Item-Level Content Validity Index (I-CVI), formulated by Polit and Beck, (2006), was used to calculate the validity score, as Formula 1. Then categorized according to Table 1.

$$\mathrm{I-CVI} = \frac{\text{Expert that say "accepted"}}{\text{Total expert}} \quad \text{.....Formula 1}$$

Beta test

Beta testing serves as a crucial follow-up trial, ensuring the creation of a polished and effective program or learning media (Alessi & Trollip, 2001). More importantly, this phase rigorously evaluates the practical application of the developed media by directly engaging end-users—teachers and students. Media practicality was definitively assessed through

measures of readability and comprehensive user feedback.

Readability (Cloze test)
To rigorously assess readability, we employed the cloze test technique, systematically deleting 30 words from the text. The resulting readability percentage was then calculated using the Formula 2. Then categorized according to Table 2.

$$\text{Percentage } (\%) = \frac{n}{N} \times 100\% \ldots\ldots \text{Formula 2}$$

Description:
n = Number of correctly filled words
N = Total number of deleted words

Teachers' and Students' Response
Data regarding media responses were gathered from 27 students in class XI-3 and one biology teacher from class X at SMA Negeri 1 Ambarawa. A 4-point Likert scale was employed to measure these responses (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). The response rate was then calculated using the Formula 3. Then categorized according to Table 3.

$$P = \frac{f}{N} \times 100\% \ldots\ldots \text{Formula 3}$$

Description:
P = The score obtained
f = Total score obtained
N = Maximum possible score

Table 1 Media validity categories

I-CVI point	Categories
0.33 < V < 0.67	Not valid
0.67 ≤ V < 0.78	Quite valid
0.78 ≤ V ≤ 1.00	Valid

(Source: Polit and Beck, 2006; Polit et al., 2007; and Zamanzadeh et al., 2015)

Table 2 Readability categories

Percentage (%)	Categories
C < 44.00	Frustration reading (not understood by the reader)
44.00 ≤ C ≤ 56.00	Instructional reading (needing the support of an educator)
C ≥ 57.00	Independent reading (understood by the reader)

(Source: Bormuth, 1968)

Table 3 Teachers and students' response categories

Percentage (%)	Categories
25.00 ≤ R ≤ 43.75	Strongly disagree
43.75 < R ≤ 62.50	Disagree
62.50 < R ≤ 81.25	Agree
81.25 < R ≤ 100.00	Strongly agree

C. Results and discussion

Planning
The planning phase revealed critical shortcomings within schools, most notably the absence of compelling supplementary media to bolster student learning. Teachers reported that student motivation continues to decline, despite the use of various learning resources. This was evident from interviews with three 10th grade biology teachers from three different schools. The teachers stated that students' enthusiasm and motivation were lacking, as evidenced by their inactivity after giving presentations. In addition, the statement regarding the decline in student motivation is supported by the high percentage (58.33%) of students who find it difficult to learn about biodiversity from the books provided. Furthermore, 74.17% of the 120 students in class X feel that they need additional learning resources on the subject of biodiversity.

Questionnaire data further underscored this issue, revealing a strong student preference for media characterized by vibrant colors, relatable imagery, and lucid explanations of complex concepts. These converging findings definitively demonstrate the inadequacy of conventional learning materials in fostering student motivation and sustained interest. Contextual learning, which leverages real-world and locally relevant resources within the classroom, emerged as a promising strategy to dramatically elevate student engagement.

Field data collection in the Semirang Waterfall area robustly demonstrates the presence of 20 distinct fern species, showcasing significant diversity across various habitats. This rich diversity offers compelling potential as a contextual learning resource, powerfully illustrating species-level biodiversity within local ecosystems. The twenty fern

species successfully identified in the study area are detailed in Table 4. Figure 2 compellingly demonstrates that several fern species have become the dominant vegetation in the Semirang Waterfall area.

Table 4 Fern species in Semirang waterfall area

No.	Family	Genus	Species	Habitat
1.	Athyriaceae	*Deparia*	*D. boryana*	Terrestrial
2.	Cystopteridaceae	*Cystopteris*	*C. fragilis*	Terrestrial
3.	Dennstaedtiaceae	*Microlepia*	*M. speluncae*	Terrestrial
4.	Dryopteridaceae	*Dryopteris*	*D. cristata*	Terrestrial
5.	Dryopteridaceae	*Dryopteris*	*D. filix-mas*	Terrestrial
6.	Dryopteridaceae	*Dryopteris*	*R. adiantiformis*	Terrestrial
7.	Pteridaceae	*Adiantum*	*A. lunulatum*	Terrestrial/lithophytic
8.	Pteridaceae	*Pteris*	*P. biaurita*	Terrestrial
9.	Pteridaceae	*Pteris*	*P. ensiformis*	Terrestrial
10.	Pteridaceae	*Pteris*	*P. fauriei*	Terrestrial
11.	Selaginellaceae	*Selaginella*	*S. plana*	Terrestrial
12.	Selaginellaceae	*Selaginella*	*S. sinuosa*	Terrestrial
13.	Tectariaceae	*Tectaria*	*T. fernandensis*	Terrestrial
14.	Tectariaceae	*Tectaria*	*T. subsageniacea*	Terrestrial
15.	Tectariaceae	*Triplophyllum*	*T. hirsutum*	Terrestrial
16.	Thelypteridaceae	*Christella*	*C. dentata*	Terrestrial
17.	Thelypteridaceae	*Christella*	*C. hispidula*	Terrestrial
18.	Thelypteridaceae	*Christella*	*C. subpubescens*	Terrestrial
19.	Thelypteridaceae	*Oreopteris*	*O. limbosperma*	Terrestrial
20.	Thelypteridaceae	*Phegopteris*	*P. connectilis*	Terrestrial

(A) **(B)** **(C)**

Figure 2
Species dominating the Semirang Waterfall Area: (A) *Selaginella sinuosa*, (B) *Pteris biaurita*, and (C) *Phegopteris connectilis*.

Design

Encyclopedias and E-Encyclopedias are Encyclopedias and E-Encyclopedias are generally organized into several sections: an introduction, a main body, and a conclusion. The introductory usually provides a user guide, while the main body section presents the species name, local name, morphological description, classification, habitat, distribution, and potential benefits of each plant. Additional supporting sections often include a glossary of terms, bibliography, multimedia features such as introdoctury videos, and author profiles.

Encyclopedias and E-Encyclopedias are typically structured into three key sections: an introductory, a comprehensive main body, and a conclusion. The introduction serves as a vital user guide, while the main body delivers detailed information on each plant species, including its scientific name, common names, morphological characteristics, taxonomic classification, habitat, geographical distribution, and potential uses. To further enhance understanding and accessibility, encyclopedias often incorporate supplementary sections such as a glossary of technical terms, a comprehensive bibliography, engaging multimedia elements like introductory videos, and informative author profiles (Azizah et al., 2021; Renita et al., 2020; Sunandar & Rahayu, 2024).

The fern species diversity E-Encyclopedia developed in this study is organized into three key sections. First, the introduction provides essential context, featuring a foreword, table of contents, research location details, an overview of the research locations, and a comprehensive description of fern structure. Second, the main body delivers in-depth information, including distribution data, habitat conditions, detailed family and species descriptions, high-quality images illustrating fern structures, and critical notes on the conservation status of selected species. Finally, the conclusion section offers valuable resources, presenting a glossary of terms, a comprehensive bibliography, and informative author profiles. The layout of the E-Encyclopedia is presented in more detail in Figure 3.

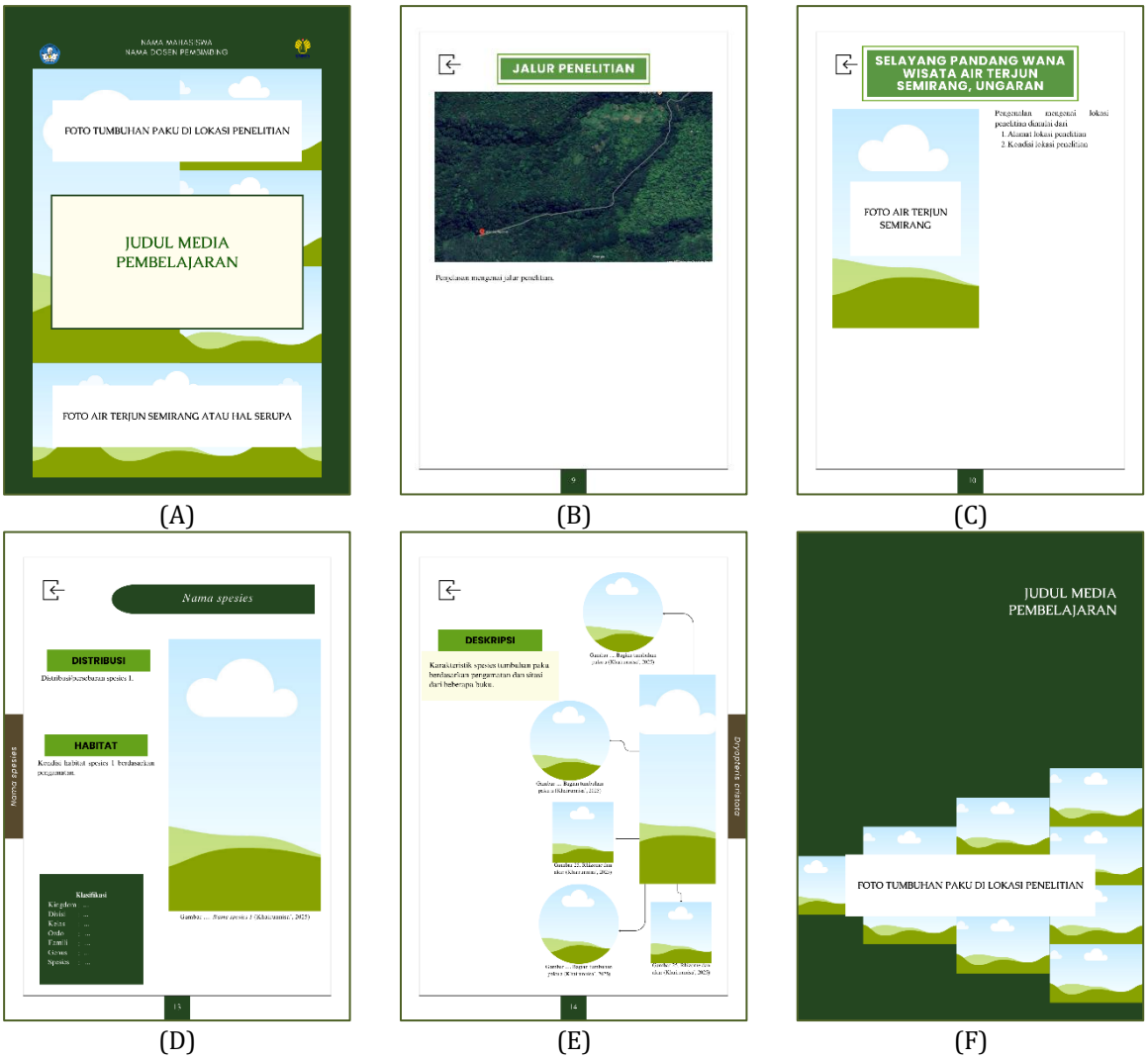

Figure 3
Layout plan for the E-Encyclopedia: (A) Front cover, (B) Sampling point, (C) Introduction to the location, (D) Family characteristics, (E) Species characteristics, and (F) Back cover (in Indonesian)

Development

This stage focuses on delivering an E-Encyclopedia specifically designed to meet the needs of both students and teachers. Figure 4 shows the media that has been developed and has undergone a revision process. The development phase incorporates rigorous alpha and beta testing.

Alpha Test

Material validation encompasses six key aspects: general content, introduction, specific content, conclusion, language, and learning tools, each evaluated against established validity criteria. Expert feedback primarily focuses on terminology, strongly recommending standardization using Indonesian. To achieve this, terms should be rigorously verified using authoritative sources such as pasti.kemdikbud.go.id, kbbi.kemdikbud.go.id, or the KBBI application. Furthermore, to enhance the E-Encyclopedia's accessibility, experts advise refining sentence structure to ensure clarity and ease of comprehension for students. This recommendation is substantiated by research from Zulaekah et al. (2023), which yielded a Content Validity Index (CVI) of 0.85. This robust CVI score confirms that the material is highly suitable for use, contingent upon incorporating minor improvements based on expert suggestions and input.

Media validation rigorously assessed five key aspects: introduction, content, conclusion, product durability, and navigation, confirming the media's overall validity (see Table 5). Expert feedback significantly enhanced the design and usability. Revisions included a redesigned front cover to ensure the title doesn't obscure the background image, a streamlined table of contents consolidated onto a single page, and the removal of extraneous elements like separate teacher and student guides, species classification boxes, and decorative background colors. Crucially, the determination key was strategically relocated to the Student Worksheets,

allowing the E-Encyclopedia to focus solely on observational material. This aligns with research by Zulaekah et al. (2023), which supports this approach. A high suitability score of 0.98 further validates the media's strong appearance and design, demonstrating its effectiveness as an educational tool.

Table 5 Validation results

Expert	I-CVI points	Categories
Material	0.92	Valid
Media	0.98	Valid
Teaching module	1.00	Valid
Assessment	1.00	Valid
Student worksheets	0.80	Valid

The E-Encyclopedia is enhanced by powerful learning tools: teaching modules, student worksheets, and formative assessment quizzes. Each tool's design incorporates five key questions, ensuring comprehensive coverage. To guarantee suitability for both media integration and classroom application, these three tools underwent rigorous validation by experienced teachers.

The teaching modules are rigorously structured, leveraging scientific principles and process skills expertly adapted to the developed media. Validation results confirm the modules' suitability for classroom instruction on biodiversity, demonstrating strong content validity, seamless integration, and effective presentation. Specifically, the learning objectives empower students to compare ferns based on key characteristics, utilize dichotomous keys for identification, and implement practical fern conservation strategies at the research site. Student learning is further reinforced through engaging worksheets and quizzes, providing valuable formative assessment data after students interact with the E-Encyclopedia. These teaching modules are expertly crafted to ensure students master science learning outcomes. They achieve this through a focus on developing essential process skills and fostering mindful, meaningful, and joyful learning experiences. To facilitate the deep learning, module incorporates an interactive E-Encyclopedia, rich with compelling images, informative text, and direct links to resources like the IUCN and GBIF. This empowers students to think critically, analyze information effectively, and truly understand the concepts presented.

These student worksheets are specifically crafted to cultivate essential process skills, empowering students to excel in: observing phenomena, formulating insightful questions and predictions, meticulously planning and executing investigations, skillfully processing and analyzing data and information, critically evaluating and reflecting on findings, and effectively communicating results. The student worksheets were also designed to effectively teach students about biodiversity at a specific level and the application of dichotomous keys, while also prompting them to analyze fern conservation strategies. The group-based format of the worksheet fostered critical thinking, collaboration, and creative problem-solving skills among students. However, the worksheet's validity score was lower compared to other assessment tools due to ambiguities in the language and unclear instructions. Following material validation (0.92), all ambiguous language and instructions are rigorously clarified to ensure students comprehend instructions with ease and precision. Input from experts on linguistic matters emphasized that the use of terms should be standardized in Indonesian, sentences should be made more fluid, and should not focus on morphological characteristics in botanical terms.

A quiz effectively reinforced previously learned biodiversity concepts. This reinforcement was crucial because the E-Encyclopedia covered only a single, limited level of biodiversity. The quiz, administered via Google Forms, employed a multiple-choice format and was completed individually by students. The quiz's validity is demonstrated by its ability to accurately assess students' understanding of both previously learned and future biodiversity material. Furthermore, the clear and high-quality language used in the questions, aligned directly with the presented material, further supporting its validity.

E-Encyclopedias are powerful tools that not only direct students to reliable information, but also empower them to develop critical problem-solving skills. This active learning approach significantly enhances students' knowledge. By formulating solutions and planning problem-solving strategies, starting with tasks like identifying and classifying fern species, students engage in deeper learning. Furthermore, E-Encyclopedias cultivate essential technological literacy skills (Ayuningtyas & Kuswandi, 2024).

Beta Test

1) Readability (Cloze test)

The cloze test yielded a remarkably high completion rate (98.89%), strongly suggesting that students were adept at inferring the missing paragraphs based on the E-Encyclopedia's context. This impressive percentage further demonstrates that the language, vocabulary, sentence structure, and terminology employed within the E-Encyclopedia were readily accessible and comprehensible to the students.

However, a recurring error observed was confusion among the blanks themselves.

A total of 30 words were omitted to test readability by students (see Table 6). The conjunctions omitted included the words *yang, dan, atau, hingga*, and *dengan*. Only three terms were omitted, namely *epilitik*, *indusium palsu*, and *monomorfik*. These two terms were omitted using Indonesian to assess students' ability to understand the context of the sentence. The highest percentage (100%) was obtained by most students. The lowest percentage (93.33%) was obtained by three students. This reinforces that the E-Encyclopedia has language that is easy for students to understand. Replacing botanical terms with Indonesian terms can be said to be effective in improving the readability of the E-Encyclopedia. This is demonstrated by the few errors made by students in filling in the terms shown in number 17. The choice of conjunctions was appropriate, even though there were seven words that were filled in incorrectly by students.

Dina et al. (2022) research similarly demonstrated a high readability percentage, a crucial indicator of a product's accessibility for students. Such straightforwardness not only ensures comprehension but also suggests the media's potential to stimulate critical thinking, warranting further investigation. As Panjaitan et al. (2021) highlight, teaching materials tailored to students' needs foster independent learning and enhance interaction. Several factors are known to influence readability: 1) sentence length, 2) syllabic density, and 3) grammatical complexity (Gopal et al., 2021). Priatno and Zulfadhli (2023) concur, emphasizing that concise sentence structure is a key determinant of high text readability.

Table 6 Readability categories results

Point	Percentage (%)	Categories
Highest	100.00	Independent reading
Lowest	93.33	Independent reading
Average	98.89	Independent reading

Table 7 Response results

Response	Percentage (%)	Categories
Teachers	93.75	Strongly agree
Students	85.68	Strongly agree

2) Students' and Teachers' Response

The overwhelmingly positive response (85.68%) to the biodiversity e-encyclopedia in the response test questionnaire strongly suggests its viability as a valuable classroom learning tool. While the e-encyclopedia shows great promise, further refinements are necessary to fully optimize its effectiveness in supplementing biodiversity material. These findings align with previous research by Setyawan and Saptono (2022), Aminin et al. (2024), and Sutiwi et al. (2025), which reported student perceptions of similar educational resources as helpful and engaging, with approval rates ranging from 81% to 89.6%.

Furthermore, the percentage based on Table 7. either for teachers or students strongly suggests that both e-encyclopedias and traditional encyclopedias are valuable reference sources for learning. The learning media is highly effective, demonstrably meeting key criteria such as clear material presentation, accessible language, engaging graphic elements, and overall usability. Moreover, the overwhelmingly positive student response to these materials underscores the success of the biodiversity literacy approach in enhancing student learning outcomes (Katili et al., 2025).

Teachers' responses received an average score of 93.75%, indicating that the E-Encyclopedia is in line with the learning objectives set. The E-Encyclopedia also provides opportunities for students to think critically, understand concepts, discuss, and solve problems based on the exercises provided. However, the E-Encyclopedia still has several shortcomings, including the lack of success indicators to test students' mastery of concepts, the lack of features that can be used by students to collaborate, and the fact that the E-Encyclopedia is not yet suitable for the characteristics of the students. Teacher responses were divided into ten aspects, namely methodology, interactivity, cognitive abilities, cooperative learning, learning metaphors, learning strategies, user control, availability of questions, availability of answers to questions, and evaluation. The highest percentage was found in the aspects of interactivity, learning metaphors, learning strategies, user control, and availability of questions and answers (100.00%), indicating that the media was able to provide an active, flexible learning experience that supported independent exploration of the material.

The aspects of methodology, cognitive abilities, and cooperative learning received very good responses (87.50%), indicating the suitability of the media for learning objectives, opportunities for critical thinking, and support for group discussions, although the integration of concepts and collaborative

features still needs to be improved. Meanwhile, the evaluation aspect received the lowest percentage (75.00%) with a good rating, indicating the need to strengthen learning success indicators. Overall, the average teacher response of 93.75% confirms that the E-Encyclopedia is suitable for use as a learning medium with minor improvements in the evaluation aspect.

The evidence strongly suggests that local wisdom-based learning media are exceptionally well-suited for facilitating effective learning (Prawati et al., 2024). Moreover, these media demonstrably enhance students' comprehension of local potential, cultivate a stronger sense of environmental stewardship, and promote self-directed learning habits (Rini et al., 2024). While this study does not directly assess the effectiveness of media on student learning abilities, existing research strongly suggests a positive impact of E-Encyclopedias. For instance, Maryani and Dewanti (2025) demonstrate that digital encyclopedias significantly enhance students' scientific literacy. Similarly, Ayuningtyas and Kuswandi (2024) found that utilizing electronic encyclopedias leads to improved information literacy skills in experimental groups compared to control groups.

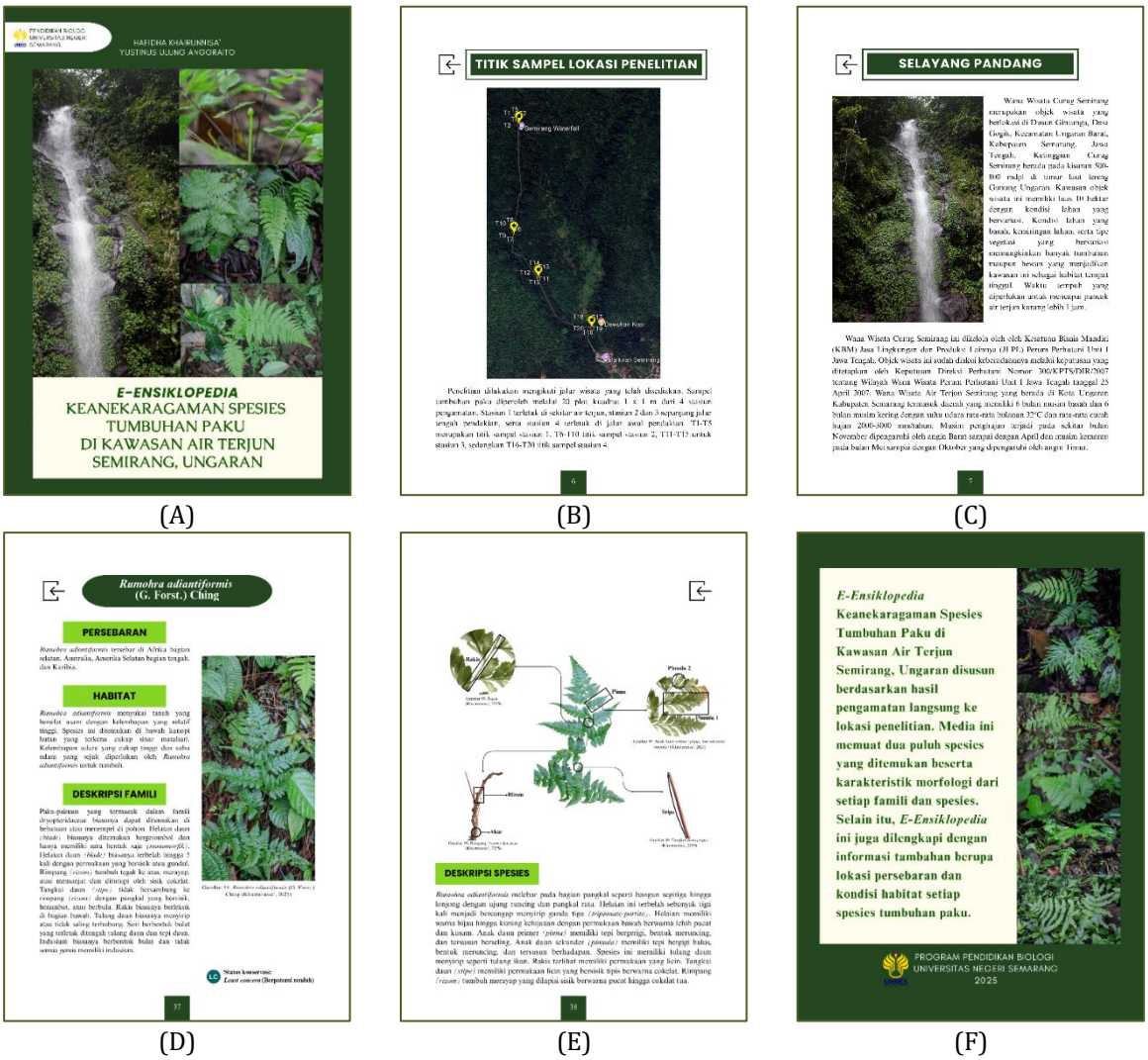

Figure 4
The developed media: (A) Front cover, (B) Sampling point, (C) Introduction to the location, (D) Family characteristics, (E) Species characteristics, and (F) Back cover (in Indonesian)

The innovative E-Encyclopedia doesn't just dominate in reading comprehension; it empowers students to master information literacy by teaching them how to effectively search for and select credible sources. Furthermore, this dynamic resource cultivates crucial process skills, including observing, questioning, predicting, planning and conducting investigations, processing and analyzing data and information, evaluating and reflecting, and communicating results. Observation skills are sharpened through detailed observation of fern species morphology. Questioning and predicting abilities are honed by predicting family and species names using the readily available dichotomy key

within the student worksheets. Mastering planning and conducting investigations is achievable by building upon previously acquired skills and, crucially, by designing targeted conservation measures for each fern species. Sharpening data and information processing and analysis skills is effectively accomplished by rigorously comparing and contrasting different conservation approaches. Furthermore, evaluation and reflection skills are honed through collaborative verification of findings, leveraging authoritative resources like the GBIF and IUCN websites for each fern species. Finally, the ability to communicate results persuasively is strengthened by delivering presentations and providing constructive feedback to other groups.

D. Conclusion

This study documents the macroscopic diversity of fern species in the Semirang Waterfall area, Ungaran. These findings are processed and applied in the development of an E-Encyclopedia as a supporting learning resource for biodiversity material, especially for 10th grade high school students. The validation results show that the E-Encyclopedia meets the requirements for material, media, and learning tools for classroom learning. It also has a high level of readability and user response. In addition, the results of the analyzed fern diversity also provide additional data on the habitat conditions in the Semirang Waterfall Area. The development of this contextual learning resource supports meaningful biology learning by connecting the concept of biodiversity with real examples around the participants. These examples can raise students' awareness of plant diversity and habitat conservation in the Semirang Waterfall Area. Therefore, this media has the potential not only as a learning support medium but also to make students aware of the importance of conserving biodiversity in their surroundings.

E. References

Alessi, S. M., & Trollip, S. R. (2001). *Multimedia for learning: Methods and development* (3rd ed.). Allyn and Bacon.

Aminin, N., Dew, N. K., & Sulistyarsi, A. (2024). Penyusunan e-ensiklopedia SMP kelas VII berbasis analisis keanekaragaman vegetasi lantai di sekitar Sumber Mata Air Plalar Kabupaten Madiun. *Prosiding Simbiosis VI*, 28–38. Retrieved from https://prosiding.unipma.ac.id/index.php/simbiosis/article/viewFile/6232/5458

Ayuningtyas, D., & Kuswandi, P. C. (2024). Pteridophyta e-encyclopedia of Kelud Mountain to study of the diversity of fern species in the environment on the RICOSRE model to improve student's information literacy. *Jurnal Penelitian Pendidikan IPA*, *10*(1), 254–260. DOI: https://doi.org/10.29303/jppipa.v10i1.5917

Azizah, Y. N., Lathifah, S. S., & Hidayat, N. (2021). Pengembangan e-ensiklopedia keanekaragaman talas di Kabupaten Bogor berbasis ESD untuk meningkatkan literasi digital siswa. *Pedagogia: Jurnal Ilmiah Pendidikan*, *13*(2), 52–56. DOI: https://doi.org/10.55215/pedagogia.v13i2.4247

Badan Meteorologi Klimatologi dan Geofisika. (2024). *Prediksi musim hujan 2024/2025 di Indonesia*.

Bormuth, J. R. (1968). Cloze test readability: Criterion reference scores. *Journal of Educational Measurement*, *5*(3), 189–196. DOI: https://doi.org/10.1111/j.1745-3984.1968.tb00625.x

Dewi, N. H., Rahmawati, N. A., Saputri, A., Indriastuti, C. A., & Dewi, L. R. (2023). Inventarisasi pteridophyta di Air Terjun Semirang. *Prosiding Webinar Biofair 2023*, 174–188. Retrieved from https://conference.upgris.ac.id/index.php/biofair/article/view/4190

Dina, N., Amintarti, S., & Putra, A. P. (2022). Pengembangan modul elektronik materi pteridophyta di Taman Buah Lokal Kawasan Mangrove Rambai Center sebagai bahan ajar di SMA. *Jupeis: Jurnal Pendidikan dan Ilmu Sosial*, *1*(3), 173–187. DOI: https://doi.org/10.55784/jupeis.Vol1.Iss3.171

Dinas Pariwisata Kabupaten Semarang. (2018). *Laporan akhir penyusunan naskah akademik RIPPARDA Kabupaten Semarang 2018*.

Gopal, R., Maniam, M., Madzlan, N. A., Shukor, S. S. binti, & Neelamegam, K. (2021). Readability formulas: An analysis into reading index of prose forms. *Studies in English Language and Education*, *8*(3), 972–985. DOI: https://doi.org/10.24815/siele.v8i3.20373

Katili, A. S., Retnowati, Y., & Husain, I. H. (2025). Development of biology teaching material supplements based on the potential of Gorontalo Karst Vegetation using a biodiversity literacy approach. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 770–773. DOI: https://doi.org/10.29303/jppipa.v11i1.9640

Kementerian Pendidikan Dasar dan Menengah. (2025). *Naskah akademik pembelajaran mendalam menuju pendidikan bermutu untuk semua*.

Khotimah, M. H., Sutarno, M., Parlidungan, D., Uliyandari, M., & Defianti, A. (2023). Terrestrial fern diversity in Palak Siring Waterfall and its potential to support junior high school science learning. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10832–10844. DOI: https://doi.org/10.29303/jppipa.v9i12.4844

Maryani, I., & Dewanti, A. (2025). The effectiveness of a digital encyclopedia in enhancing scientific literacy. *International Journal of Learning Reformation in Elementary Education*, *4*(02), 73–81. DOI: https://doi.org/10.56741/ijlree.v4i02.888

Panjaitan, K. F., Zaini, M., & Biyatmoko, D. (2021). The practicality of popular scientific books based on

the diversity of tree species on the Puting Riverbank. *Bio-Inoved: Jurnal Biologi-Inovasi Pendidikan*, *3*(3), 183–189. DOI: https://doi.org/10.20527/bino.v3i3.10621

Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing and Health*, *29*(5), 489–497. DOI: https://doi.org/10.1002/nur.20147

Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Focus on research methods: Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Research in Nursing and Health*, *30*(4), 459–467. DOI: https://doi.org/10.1002/nur.20199

Pranama, H. F., & Nugroho, A. S. (2023). Keanekaragaman tumbuhan paku (pteridophyta) Kawasan Curug Semirang Semarang. *Prosiding Webinar Biofair 2023*, 407–420. Retrieved from https://conference.upgris.ac.id/index.php/biofair/article/view/4212

Prawati, L., Sunandar, A., & Setiadi, A. E. (2024). Development of an ethnobotanical encyclopedia on the Antar Ajong Ceremony. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 3957–3967. DOI: https://doi.org/10.29303/jppipa.v10i7.8350

Priatno, B., & Zulfadhli, M. (2023). Uji keterbacaan teks eksposisi dalam artikel ilmiah jurnal online menggunakan teknik tes kloz. *Jurnal Pembelajaran Bahasa dan Sastra*, *2*(2), 273–280. DOI: https://doi.org/10.55909/jpbs.v2i2.258

Pusat Pengembangan dan Pelindungan Bahasa dan Sastra, B. P. B. dan P. (Kementerian P. dan K. R. I. (2019). *Petunjuk teknis penyusunan ensiklopedia*. Pusat Pengembangan dan Pelindungan Bahasa dan Sastra, Badan Pengembangan Bahasa dan Perbukuan, Kementrian Pendidikan dan Kebudayaan.

Renita, A., Setyowati, E., Fauziah, A., & Purwanto, N. (2020). Pengembangan ensiklopedia tumbuhan paku sebagai sumber belajar keanekaragaman hayati. *Jurnal Biologi dan Pembelajarannya*, *7*(1), 1–6. DOI: https://doi.org/10.29407/jbp.v7i1.14797

Rini, R., Sunandar, A., & Rahayu, H. M. (2024). Development of the plant encyclopedia used in traditional foods of Sekadau Regency. *Jurnal Bioedukatika*, *12*(3), 29–37. DOI: https://doi.org/10.26555/bioedukatika.v12i3.27922

Setyawan, R. D. H., & Saptono, S. (2022). The arthropoda diversity booklet as a learning resource for biodiversity materials. *Journal of Biology Education*, *11*(3), 439–447. DOI: https://doi.org/10.15294/jbe.v11i3.59369

Sunandar, S. A., & Rahayu, H. M. (2024). Development of encyclopedia medicinal plants in the Natuna Malay community. *Bio-Inoved: Jurnal Biologi-Inovasi Pendidikan*, *6*(3), 295–304. DOI: https://doi.org/10.20527/bino.v6i3.19533

Sutiwi, S., Maasawet, E. T., Masruhim, M. A., Usman, U., Herliani, H., & Ahmad, A. (2025). Development of biodiversity encyclopedia based on flipbook to improve student learning outcomes in Senior High School 6 Samarinda. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 340–347. DOI: https://doi.org/10.29303/jppipa.v11i7.11660

Zamanzadeh, V., Ghahramanian, A., Rassouli, M., Abbaszadeh, A., Alavi-Majd, H., & Nikanfar, A.-R. (2015). Design and implementation content validity study: Development of an instrument for measuring patient-centered communication. *Journal of Caring Sciences*, *4*(2), 165–178. DOI: https://doi.org/10.15171/jcs.2015.017

Zulaekah, S., Mutalazimah, M., Soetomo, H., & Muwakhidah, M. (2023). Validity of e-booklet media and its effect on increasing obesity prevention knowledge in adulthood. *Journal of Health Education*, *8*(1), 80–90. DOI: https://doi.org/10.15294/jhe.v8i1.66284