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DEVELOPMENT OF FLIPBOOK-BASED INSTRUCTIONAL MATERIALS INTEGRATED WITH VIRTUAL REALITY FOR LOWER PLANT BOTANY LEARNING

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ABSTRACT

This study aimed to develop flipbook-based instructional materials assisted by Virtual Reality (VR) for the Lower Plant Botany. The research employed a Research and Development (R&D) approach using the 4D model, consisting of *define, design, develop,* and *disseminate* stages. At the define stage, a preliminary field exploration and identify lower plant species as learning content. Data were obtained through direct observation and morphological identification of lower plant. The design stage involved developing instructional materials using flipbook and Virtual Reality media based on field data. The development stage included expert validation, product revision, and limited trials with Biology Education students to evaluate feasibility and practicality. The disseminate stage was carried out through limited implementation in lectures and distribution of the developed materials. The results indicated that the developed instructional materials were feasible based on expert validation. Expert validation indicated that the instructional materials were feasible across content, presentation, language, and scientific aspects (75–88.3%), while media validation demonstrated a very high feasibility level (99.07%). These findings indicate that flipbook-based instructional materials integrated with Virtual Reality offer an engaging and immersive learning solution that enhances students' understanding of abstract and microscopic concepts in Lower Plant Botany while supporting scientific and digital literacy.

Keywords: Digital Instructional Materials, Flipbook, Lower Plant Botany, Research and Development, Virtual Reality

INTRODUCTION

The development of digital technology has brought significant changes in various aspects of life, including in the world of education. The use of information and communication technology in learning has become a major requirement in 21st century education to create a more interactive, flexible, and learner-centered learning process (Hodges et al., 2024). The integration of technology in learning not only serves as a tool for delivering material, but also as a means to improve the quality of learning, student engagement, and strengthen science and digital literacy.

Science learning literacy can no longer rely solely on text-based materials, as monotonous presentations reduce learning motivation and hinder students' understanding of abstract concepts (Lin et al., 2017). Therefore, teaching materials need to be developed by integrating various forms of information representation, such as images from direct observation, learning videos, and interactive visualizations. The use of visual and audiovisual media in science education has been proven to improve students' conceptual understanding, observation skills, and scientific thinking abilities (Kurniawan et al., 2020).

One emerging technology with strong potential to address these challenges is Virtual Reality (VR), which enables immersive and interactive learning experiences that support conceptual visualization by providing a simulated environment that closely resambles real–world phenomena. Previous studies have reported that VR can enhance student engagement, motivation, and conceptual understanding in science learning.

However, most existing VR-based learning studies focus on general science topics or higher-level biological concepts, and are rarely designed specifically for lower plant botany content. Moreover, VR applications in biology education are often developed as standalone media and are not systematically integrated into structured instructional materials such as digital flipbooks.

Botany of lower plants is a basic course in biology education that studies the structure, classification, and life cycle of lower plants, including the process of metagenesis. Metagenesis is a complex and abstract concept because it involves the alternation of generations between the gametophyte and sporophyte phases, which are difficult to observe directly and require good visualization skills (Raven, P. H., Evert, R. F., & Eichhorn, 2022). Based on interviews with students, it was found that students had difficulty understanding the concept of metagenesis in lower plants because the material was presented conceptually and limited to textual explanations and two-dimensional images.

Ideally, the study of lower plant botany should be carried out through practical activities and direct observation to help students build meaningful conceptual understanding (Susilo, H., Amin, M., & Rohman, 2021). However, the interview results showed that the implementation of practical activities has not been optimal due to limited laboratory facilities and incomplete observation objects. Not all stages of metagenesis can be observed directly due to limitations in available preparations and specimens. In addition, space and time constraints are obstacles to conducting field observation activities, considering that not all low plants are easily found in the surrounding environment and

some biological processes require a relatively long observation time (Nurhayati, N., & Prasetyo, 2022).

Based on condition, a clear research gap can be identified: there is a lack of instructional materials that integrate Virtual Reality into structured digital learning resources to specifically support the visualization and understanding of metagenesis in lower plant botany. To date, no study has explicitly developed and evaluated VR-integrated flipbook-based instructional materials tailored to lower plant botany learning, particularly to overcome limitations in practical activities and direct observation. This study seeks to address this gap by developing and implementing integrated Virtual Reality-based flipbook instructional materials for lower plant botany learning.

RESEARCH METHOD

This research is a Research and Development (R&D) study that aims to develop VR-assisted Flipbook teaching materials for the Low Plant Botany course using a 4D model that includes the define, design, develop, and disseminate stages. During the define stage, a preliminary field exploration was conducted to identify lower plant species used as learning content. This exploration took place around the Taeno Waterfall, Ambon City, and aimed to collect authentic biological objects relevant to the course material. Data were collected through direct observation and morphological identification of lower plants, including lichens, bryophytes, and pteridophytes, based on observable morphological characteristics and habitat types. The design stage focused on structuring instructional materials and selecting flipbook and Virtual Reality media to present textual explanations, visual documentation, and virtual field trip experiences derived from field data. The develop stage involved expert validation by subject matter, media, and language experts, followed by product revisions and limited-scale trials with Biology Education students to assess feasibility and practicality. The disseminate stage was conducted through limited implementation in lectures and dissemination of the developed instructional materials (Indaryanti et al., 2025)

FINDINGS AND DISCUSSION

The results of the study show that field exploration conducted around the Taeno waterfall in Ambon City successfully identified several groups of low-growing plants. The following are the results of the identification of low-growing plants found around the Taeno waterfall:

Table 1. Results of the Identification of Low-Growing Plants around the Taeno Waterfall, Ambon City

No	Kelompok Tumbuhan	Nama Spesies yang Ditemukan	Habitat
1	Lichenes	*Parmotrema* sp	Tree Trunks
		Usnea sp.	Tree Trunks
		Graphis sp.	Rocks and Tree Bark
2	Fungi	*Auricularia* sp	Rotten Wood
		Ganoderma sp	Dead Tree Trunks
		Trametes sp	Rotten Wood
3	Bryophyta	*Marchantia* sp	Moist Soil
		Funaria sp.	Soil and Rocks
		Anthoceros sp	Damp Soil
4	Pteridophyta	*Nephrolepis exaltata*	Soil
		Pteris vittata	Open Soil
		Selaginella sp	Moist Soil
		Pteris Vittata	Soil
		Asplenium nidus	Soil

Source: Authors' Result.

The results of the identification of low-growing plants around Taeno Waterfall, Ambon City, show the diversity of low-growing plant groups, including lichens, fungi, mosses, and ferns. The presence of species such as Parmotrema sp., Usnea sp., Auricularia sp., Marchantia sp., and Nephrolepis exaltata indicates that the environment around the study site has a level of humidity and ecological conditions that support the growth of low plants. These findings are in line with (Tjitrosoepomo, 2010) opinion that low plants generally thrive in humid environments rich in organic matter. The use of local biodiversity in science education is considered to be able to improve students' understanding of concepts and their connection to the material being studied (Az Zahra et al., 2024)

The results of field observations were then analyzed through a process of morphological identification and low plant habitat identification to be developed into teaching materials in the form of a digital flipbook assisted by Virtual Reality (VR). The use of direct observation data as learning content supports authentic and experience-based learning. Recent research shows that integrating virtual field trips into biology learning can overcome the limitations of fieldwork and still provide students with an exploratory experience (Makransky & Mayer, 2022); (Petersen et al., 2020). Thus, Virtual Reality (VR) is an effective solution for presenting biological objects that are difficult to observe directly, especially microscopic plants. Below are the validation results from subject matter and media experts:

Table 2. Results of Content and Media Expert Validation

No	Assessment Aspect	Percentage (%)	Criteria
	Content Expert		
1	Content Suitability	**88,3**	**Suitable**
2	Presentation	**77,5**	**Suitable**
3	Language	**75,0**	**Suitable**
4	Scientific	**82,14**	**Suitable**
	Media Expert		
1	Visual Display	**99,07**	**Very Suitable**
2	Interactivity	**99,07**	**Very Suitable**
3	Media Integration	**99,07**	**Very Suitable**
	Average	**79,49**	**Suitable**

Source: Authors' Result.

The results of subject matter expert validation show that the teaching materials developed are in the acceptable category, with a content acceptability percentage of 83.3%, presentation 77.5%, language 75%, and scientific aspects 82.14%. These results indicate that the material is in line with learning outcomes, has scientific accuracy, and is presented systematically. These findings are in line with the research (Noviyanita, 2018) and (Syukur* et al., 2025)which states that flipbook-based digital teaching materials can improve concept clarity and support student science literacy. The validation results and input from the validators have been revised so that the Virtual Reality (VR)-assisted Flipbook on Low Plants has been distributed to students of the Biology Education Study Program on a small scale.

The media expert validation obtained a percentage of 99.07% with a very feasible category, indicating that the visual display, interactivity, and media integration aspects have met the standards for digital learning media. These results support the findings of (Radianti et al., 2020) and (de Bruin et al., 2020), which state that Virtual Reality-based learning media can increase learning engagement and provide an immersive learning experience, thereby helping students understand abstract concepts in science learning.

The validated results were revised by the validator, and improvements were made and tested on a small scale. The following are the results of the small-scale trial of the Virtual Reality (VR)-assisted Flipbook:

Table 3. Small-Scale Trial Results (Disseminate Stage)

No	Assessment Aspect	Percentage(%)	Category
1	Interest	85,67	Positive
2	Material	86,67	Positive
3	Language	83,3	Positive
	Average	85,21	Positive

Source: Authors' Result.

At the dissemination stage, the results of small-scale trials showed a positive response from students to the teaching materials developed. The interest percentage of 85.67%, material aspect of 86.67%, and language aspect of 83.3% indicate that the teaching materials are considered interesting, easy to understand, and communicative. These results are in line with the research (Safarati & Zuhra, 2024) and (Arintia Prasasti Setyo Ningrum, 2021) which reported that the use of Virtual Reality and interactive digital media in biology learning can significantly increase student motivation, interest, and learning experiences.

CONCLUSION

This study successfully developed Virtual Reality-assisted flipbook teaching materials for the Lower Plant Botany. Validation by subject matter experts and media experts showed that the teaching materials were rated as acceptable to highly acceptable in terms of content, presentation, language, scientific accuracy, visual appearance, interactivity, and media integration. In addition, small-scale trials at the disseminate stage showed positive responses from students, indicating that the teaching materials were considered interesting, easy to understand, and communicative. Thus, Virtual Reality-assisted flipbook can also serve as an alternative solution to overcome the limitations of field learning and support the strengthening of students' scientific and digital literacy. In the future, it is recommended that trials be conducted on a larger scale and the effectiveness of learning outcomes be measured to obtain a more comprehensive picture of the impact of learning.

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