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Development of Pterydophyte Herbarium Encyclopedia Integrated Augmented Reality to Improve Undergraduate Student's Biodiversity Literacy

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ABSTRACT

Pteridophytes are important part of biodiversity education in universities, but it lack of learning media, especially digital ones. This research is a research and development utilized Lee & Owens model consists of analysis, design, development, implementation and evaluation. The data collection instruments included interviews, field observation, media and material validity expert questionnaire, student's readability questionnaire, and biodiversity literacy test. The subjects of the limited trial consisted of 28 undergraduate students in the Department of Biology, FMIPA, Universitas Negeri Malang. The trial design uses a one group pretest posttest design. The Pterydophyte encyclopedia integrated augemented reality as learning resources categorized very worthy based on the result by media expert 100% categorized as valid, material expert 85.1% categorized as valid, and student 91. 3% categorized as very worthy. Product effectivity is based on N-Gain score with value 0.58, it means that the score in class trial was effective. The paired sample t test shows that the significant value is 0.000. It shows that the significance value is less than 0.05, so there is a significant effect in improving undergraduate students's biodiversity literacy. Books with augmented reality integration influence students' academic performance, as well as increase active involvement in learning.

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1. INTRODUCTION

State of the biodiversity of biological communities worldwide took millions of years to develop. On the other hand, human actions have disrupted ecosystem diversities, and several animal and plant species are no longer found (Cardinale et al., 2012; Aldana-Dominguez et al., 2022). Recently, the world has focused on studies for the protection of biodiversity (European Commission, 2020). This is related to biodiversity, which is a source of basic human needs, starting from food, drinking water and clean air. However, biodiversity is reported to be decreasing day by day, due to unsustainable human activities (WWF, 2020). Indonesia is a source of biodiversity, which is also starting to be threatened. This is caused by several factors, such as massive land conversion, excessive use of species, and climate change (Kubitza et al., 2018; Alisjahbana et al., 2017).

Experts have expressed their concern about the condition of the ecosystem and emphasized the importance of nature conservation. Because nature conservation involves humans, it requires human knowledge and awareness about how to do it. Variations and learning methods are necessary to achieve sufficient knowledge and awareness, because students have different learning styles and cognitive abilities (El-Sabagh, 2021). Thus, innovative strategies bridge the gap between theory and practice to fostering effective environmental awareness (Shutaleva, 2023). This is important to encourage students to be active and participate (Suarez et al., 2018), so that students can understand biodiversity as a whole thing (Zacharia et al., 2016; Saito et al., 2013). Existing studies not only emphasize the physical aspects of conservation but also pay less attention to methodological elements that ensure the acquisition of information and increase public awareness about the importance of biodiversity conservation.

There are around 2,197 species of Pteridophyte in Indonesia, or around 22% of the Pteridophytes that grow in the world, and around 630 species are in Java Island (Murniningtyas et al., 2016), In universities, Pteridophyte is one of the materials in botanical courses. Some universities also include it in plant structure or biodiversity courses. Uniquely, all of these courses are mandatory courses for students. This material is a crucial point studied in college. However, interviews with lecturers of botanical and environmental courses in Universitas Negeri Malang to collected the data about fern learning show that numbers of learning resources discuss the Pterydophyte topic, especially in electronic learning form and using herbarium collection as learning media. Regrettably, the frequent use of herbariums, infrequent maintenance of collections, and errors in preparing herbariums can easily damage herbarium collections.

Several studies show that students lack of biodiversity literacy (Aslan et al., 2022; Hooykaas et al., 2021). Biodiversity literacy refers to an individual's capacity to comprehend the concept of biodiversity, its ecological, societal, and economic significance, and to engage in actions that promote biodiversity conservation (Leksono, 2015). Biodiversity literacy is the ability to understand interactions between humans and nature and make sustainable decisions (MEA, 2002). The extinction of biodiverse is a serious threat especially caused by the students who have an ability to biodiversity literacy will have a sensitivity character to any changes that occur in the surrounding environment (Kaitli, et al., 2020). The biodiversity literacy indicators refers to Leksono et al. (2015) consists of student biodiversity literacy such as (1) the objectives of ecological principles and processes, (2) biodiversity matters knowledge, (3) strategy and restoration actions for biodiversity, and (4) attitude and sensitivity to biodiversity values. The lack of biodiversity literacy is reinforced by preliminary research conducted at the State University of Malang, which shows an average biodiversity literacy value of 27.29, which is relatively low. This problem can be solved by developing interactive learning media.

One of interactive learning media that is suitable for biodiversity material is an encyclopedia (Kundariati & Rohman et al., 2020; Setyorini et al., 2022). Dana (2021) further stated that encyclopedias are an interesting learning tool for students (Dana, 2021). Encyclopedia refers to references used to add insight and contain more detailed information from learning resources used in education (Hermato et al., 20121). Encyclopedia contains various images to make more interesting media. The completeness of the material and several examples of images can be observed directly by the learners (Djunaedi & Permatasari, 2018). However, encyclopedias must use modern technology to compete in the rapidly developing technology and information (Szymkowiak et al., 2021).

Technological advances change traditional ways to modern ones with services provided by technology and information (Porpiglia et al., 2020). Therefore, an electronic form is needed to maintain the existence of the encyclopedia because complex information such as sound, video, games, animation, and others can be used to make it more interactive and fun (Dewi et al., 2020; Arslan et al., 2020; Solé -Llussà et al., 2019). The use of AR media can advance the feeling of "being there" (presence), involve cognitive processes during activities (immersion), and allow students to interact closely (immediacy) with ideas in the learning environment (Weng et al., 2020). Furthermore, AR improved students' understanding of complex science content Martin-(Gutierrez et al., 2017). AR materials also help middle school students with writing activities and reduce cognitive load during anatomy learning (Küçük, 2015). The research conducted by Savindya Somakeerthi et al., (2020) revealed that learning with applications incorporating image processing and augmented reality can address difficulties in comprehending plant classification and detection. The findings of Sulisetijono et al. (2023) indicated that the development of an AR e-module for floral structure content is quite effective in teaching, as evidenced by an n-gain score of 0.7. Augmented reality can be integrated into a book platform with a better presentation of 3D objects compared to 2D objects, animations, videos, text, or audio (Koparan, et al., 2023). Chen et al. (2017) asserted that books integrated with augmented reality can enhance reading experiences, academic performance, and active learning engagement. Research generally shows that integration of AR has positive effects, especially on motivation and learning outcomes.

This research intends to develop a valid, practical, and effective Pteridophyte Herbarium Encyclopedia learning media integrated with augmented reality in improving biodiversity literacy. The research results can be used as a groundwork for further research, especially those related to studying biodiversity. These results also help develop interactive encyclopedias for teaching biology, increasing students' understanding of the potential uses of augmented reality.

2. RESEARCH METHOD

Research Design

This research is research and development (Research and Development) use the Lee and Owens development model (2004). The model stage consists analysis, design, development, implementation, and evaluation. This model was chosen because this model is focuses on interactive and digital media learning, its align to learning media that integrating digital tools such as augmented reality (AR). This research conducted in July-November 2023 in Department of Biology Universitas Negeri Malang. In the analysis stage student characteristic, learning facilities, and curriculum used are carried out. At the design stage the development of material and product design are carried out. At the development stage the validity test conduct media and material validity, as well as the

practicality test conduct readability by students are held. Thus, at the implementation stage, the product developed are tested to measure the effectivity. At the evaluation stage, the product tested evaluate to the final stage. The diagram of Lee and Owens step shown in Figure 1.

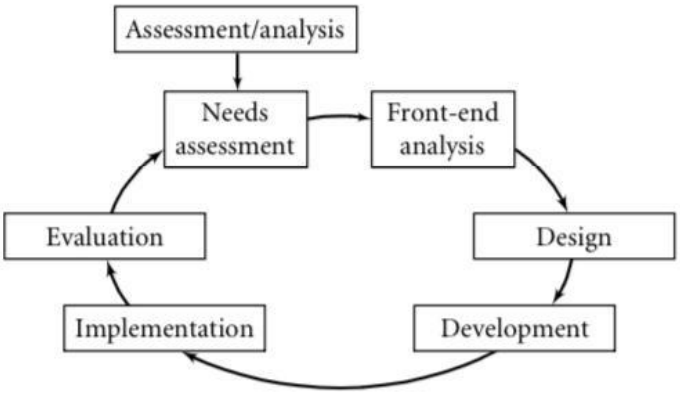


Figure 1. Lee and Owens Development Model Diagram
Source: Lee and Owens (2004)

Research Site and Participants

The participants of this research consist of material expert, media expert, and users. The material expert as material validator is a practitioner who has an S3 botanical background and has a deep understanding of his filed. The media expert as media validator is a practitioner in learning media development who has qualified as S2 educational background and has and experienced in educational technologies. The participant selection technique uses the random sampling method. The users on implementation consist of 28 Biology Education students (N=28), FMIPA Universitas Negeri Malang, Indonesia that has attend a botanical subject course.

Data Collection and Analysis

The data collection instruments included interviews, field observations, media and material validity expert questionnaire, student's practicality questionnaire, and biodiversity literacy test. Material and media validation measurements were taken using material and media expert validation sheets. Product readability was measured involving 28 students. The biodiversity literacy instrument essay refers to Leksono et al. (2015) consists of student biodiversity literacy such as (1) the objectives of ecological principles and processes, (2) biodiversity matters knowledge, (3) strategy and restoration actions for biodiversity, and (4) attitude and sensitivity to biodiversity values.

This research uses quantitative and qualitative descriptive analysis techniques. The media was validated by material and media experts. Furthermore, in the implementation, the effectivity resolved with one group pretest-posttest design. The research design is clearly described and appropriate for the purpose of the study. The research design is clearly described and appropriate for the purpose of the study. The participants, their characteristics and their selection methods are described in detail and justified. The product validity and practicality questionnaire use the rating scale 1-5. The equation to calculate the average score of the validity and readilibility is as follows (Arikunto, 2010).

$$X = \frac{\sum Xi}{N} \text{ x } 100\%$$

Information:
X : Mean
$\sum Xi$: Total Score of Each Component
N : Total of subject

The criteria of validation results use to measure the validation rate of the product developed are refer by the following table:

Table 1. Percentage Criteria for Validation Results

Percentage (%)	Category
80-100	Valid/Eligible for use
60-70	Quite valid/Quite worthy of use
40-59	Less valid/Not suitable for use
0-39	Invalid/Not suitable for use

Source: Arikunto (2010)

The data analysis from the questionnaire results of practicality by students responses to measure the existence of Pterydophyte herbarium encyclopedia. The criteria of practicality results use to measure the practicality rate of the product developed are refer by the following table.

Table 2. Percentage Criteria for Validation Results

Percentage (%)	Category
0-20	Not feasible
21-40	Not worth it
41-60	Quite decent
61-80	Worthy
81-100	Very worthy

Source: Arthana (2005)

The qualitative data was obtained by using open-ended questions designed to gather response and experience from validator and students as user. To enhance the reliability of qualitative data, the study employed three types of triangulation. Thus, analysis of effectiveness of the pterydophyte herbarium encyclopedia product conducted to know the improvness of student's biodiversity literacy. The data used in assessing product's effectiveness are prestest and posstest score of biodiversity literacy. The analysis carried out use inferential statistical analysis. The difference before and after learning use Pterydophyte Herbarium Encyclopedia measure with expected gain value (<g>). The equation to calculate the standard gain equation is as follows:

$$g = \frac{Postest\ Score - Pretest\ Score}{100 - Pretest\ Score}$$

The results of the n gain analysis are then compiled and concluded based on the categories for potential increase in pretest and posttest scores. The categories showed in Table 2.

Table 3. Category of Gain Value

Range Value	Category
$g > 0.7$	High
$0.3 \leq g < 0.7$	Moderate
$g < 0.3$	Low

Source: Hake (1998)

After measuring the gain value, an analytical test conducted to determine wheter the differences of significance or nor effectivesness using an independent sample T test. Statistical analysis uses statistical analysis software with a significance level of <0.05.

3. RESULT AND DISCUSSION

Results

The product developed in this research and development is the pteridophyte herbarium encyclopedia which consists of an encyclopedia based on the Pteridophyte herbarium, 3D modeling augmented reality, and an augmented reality scanning application. The media development stage consists of analysis, design, development, implementation and evaluation following the research and development model of Lee & Owens (2004).

Analysis

The first stage was an analysis carried out on Biology students, FMIPA, Universitas Negeri Malang, Indonesia. The analysis consists of needs analysis and front-end analysis with the results that technology-based biology learning media facilities to facilitate botany subjects are still lacking. At need analysis stage, based on the observation in the botanical courses in Department of Biology the learning media in class are still limited due to the limited human resources and innovation about botanical learning media, especially in semester lecture plan in pteridophyte botanical biodiversity learning resource such as herbarium collection in Herbarium Malangensis. Based on the define the job activity, students have an interesting to 3D graphic and innovative learning media used in the gadget, actually in smartphone. Thus, the learning media based on technology are prefer to be accepted by students. Based on the survey, students lack on the skill to recognize the plant biodiversity cause the do not has many accesses to explore the material and the low interest to plant.

Design

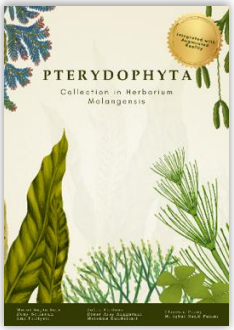
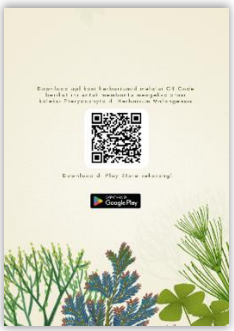
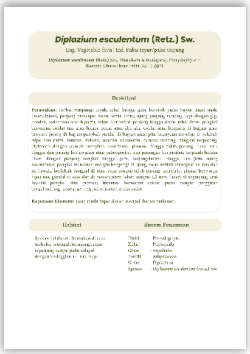
The design stage consists of material design and product design. The material design was prepared based on the semester lecture plan of the biology department, FMIPA, Universitas Negeri Malang on the material of botanical course which is related to biodiversity literacy. Meanwhile, the media design is arranged in a storyboard

to see the media flow chart. The storyboard was realized in 2D UI/UX media design and layout design from the botanical fern encyclopedia from the collection of the Herbarium Malangensis, Biology, State University of Malang. The design is adapted to the fern material by displaying elements of various types of ferns in the collection.

Development and Implementation

The development stage is the realization stage of the media storyboard that has been prepared. The media development stage consists of compiling an encyclopedia book which begins with sorting the selected herbarium collection. The next stage is to prepare a description of each herbarium collection which is curated based on the atlas, observations with botanists, and references. The Pteridophyte Herbarium Encyclopedia consist of 4 parts: 1) the encyclopedia cover; 2) the introduction consists table of content, acknowledgment, foreword, and introduction; 3) the content division consists the diversity of Pteridophytes in Herbarium Malangensis, the description of specimen, habitats, systematic name, the use of plants, herbarium specimen photos, QR-Code 3D modeling scan, and identification label; 4) the closing section consists of an index and references. The representations of Pterydophyte Herbarium Encyclopedia are shown in the Table 4.

Table 4. Development Result of Pterydophyte Herbarium Encyclopedia

Part	Result
Encyclopedia cover	 
Introduction	 
Content division	 

Index and references

The next stage is creating 3D modeling of each selected collection using the blender application. The final stage is the development of an augmented reality scanning application that will be used to scan markers on the encyclopedia. This augmented reality scan will display interactive 3D modeling that can be zoomed in, zoomed out, or rotated 180˚. This development stage will produce an application output in .apk format that can be installed on a minimum of Android 6.0. Thus, to expand the accessibility, researchers develop a progressive web app (PWA) herafter. So it could accessed by anyone who interest to the whole species augmented reality media. The representation of the application is shown in Figure 2.

Figure 2. Herbarium Augmented Reality Projection Assisted by Herbariumid Application

Evaluation

The result of the product development was validated by media expert and material expert. The result of the media expert is shown in Table 5.

Table 5. Media Expert Validation Results

Aspect	Maximum Value	Assessment Result
Graphic	100%	100%
Instructional component	100%	100%
Mean	100%	100%
Category		Valid/Eligible of use

Based on the Table 1, the validator was assessed with 100% value in all aspect, which means that the Pterydophyte Herbarium Encyclopedia is very valid for use as a learning resource in botanical learning. In addition, the results of the assessment of material expert are shown in Table 6.

Table 6. Material Expert Validation Results

Aspect	Maximum Value	Assessment Result
Material suitability	100%	85.7%
Presentation technique	100%	91.6%
Language	100%	78.1%
Mean	100%	85.1%
Category		Valid/Eligible of use

Based on the Table 6, the validator was assessed material suitability 85.7%, presentation technique 91,6%, and language 78,1%. The assessment result shows the media get 85.1% that categorized as valid. It is mean that the quality of Pteridophyte Herbarium Encyclopedia Kit is valid to use as learning resources. Material validator provide suggestion to consistently use the object especially in the description aspect that still use scientific, English, and Indonesian. As well as remark the fault of punctuations in text. The media developed has passed the validation process and revised twice based on the suggestions form media and material expert. The Pteridophyte Herbarium Encyclopedia includes material of description, habitat, the use of botany, herbarium label, and herbarium specimen that could be scanned to show the augmented reality. The augmented reality necessary accessed in Play Store namely Herbariumid application.

After the product is declared valid on the material and media aspect validity as well as feasible on the practical aspect by the teacher, the product is tested on the learning. The implementation was conducted in limited trial scheme. This test aims to obtain student practicality responses of the developed product. The subjects consist of 28 students. Students are directed and allowed to access and study the entire material content in the encyclopedia of Pteridophyte and Herbariumid application. Next, student fill out a product readability questionnaire distributed online via Google Form. The results of student responses to the product are shown in Table 7.

Table 7. Practicality Test Results

Aspect	Maximum Value	Assessment Result
Information layout	100%	90.4%
Material presentation	100%	90.6%
Ease of use	100%	91.3%
Category		Very worthy

Based on Table 7, the result of the student's practicality of the product is very practical with result 90.4% information layout aspect, 90.6% material presentation, and 92.6% ease of use. So, the assessment result show the percentage of readability product is 91.3% categorized as very feasible. Augmented reality was developed according to the material in the encyclopedia. The lack of visualization makes students difficult to understand the material, with augmented reality can provide a clearer visualization picture. Some inputs and suggestion from students are as follows.

"It would be better if the application is also provided for iOS users".... 1st students
"This application can be very useful in helping to find various species of Pterydophyte plants."..... 2nd students
"The images, AR, and informations in media are very helpful as learning materials".... 3rd students
"It is good to provide an introductory menu feature in the application before using it".... 4th students

The encyclopedia of Pteridophyte and Herbariumid application products declared feasible and tested on a limited trial, then implemented in field trials to measure the effectivity. The field trial aims to determine the effectiveness of using the products to improve student's biodiversity literacy. Student's biodiversity literacy was measured by giving written pretest and posttest questions to the classes. The content of the written test questions contains indicators of student biodiversity literacy, which consist of the objectives of ecological principle and process, biodiversity matters knowledge, strategy and restoration actions for biodiversity (Leksono et al., 2015). The results of the biodiversity literacy test are shown in Table 8.

Table 8. The Result of Student's Biodiversity Literacy Test

Test	Assessment Average Result	N Gain Value	Category
Pretest	27.29	0.58	Moderate
Posttest	75.57		

Table 8 shows that the average of biodiversity literacy in class has increased. The result of the gain score analysis <g> is 0.58, so it means that the score in class trial was effective after media developed use. In this step, students could describe and classify pteridophyte by classification and extinction rate. The product's effectiveness is shown on the results by comparing the pretest and posttest results of the students during the learning process. This test is carried out with statistical analysis software with paired sample t test. The results of biodiversity literacy are shown in the Table 9.

Table 9. Paired Sample T Test Result

t	df	Sig. (2-tailed)
3.537	54	0.000

Table 9 shows a significance of 0.00, this shows that the development of an encyclopedia and application can train students in biodiversity literacy. So, it can be concluded that the Pteridophyte herbarium encyclopedia integrated augmented reality is effectively used as learning resources in botanical courses. This evolve also shown by the student's attitude after knowing the collections of Pteridophyte instead of the encyclopedia. The student's need for engaging learning media and increase student insight. Before exposed, students prefer to provides theoritical knowledge but lacks direct interaction with real specimens in nature. After the using the Pterydophyte herbarium encyclopedia students could developed their deeper conceptual understanding by recogniz ing morpholofical traits, habitat preferens, and their interaction between 3D media. This hand on-experience have enhanced memory recal by visual and physical engagement likely increased nterest and active participation, sparking curioustiy and encouraging discussion, observations, and classification activities in the classroom.

Furthermore, the experience of observation the structure analysis particularly enhanced botanical awareness. This showed by students enable to describe, classifiy, and relate plant characteristic to ecological, pharmacological, and economical functions more effectively. Overall, the significant difference found in the test result suggests that using a digital Pterydophyte collection in Pterydophyte herbarium encyclopedia provided a more engaging, effective, and holistic learning experience. This emphasize students pertaining to the importance of hands-on interaction with plant specimens in enhancing botanical learning.

Discussion

Encyclopedia Integrated Augmented Reality Acceptance as Learning Media

The longer the herbarium as learning media and collection of conservation will be damaged and important parts of the ferns such as the sorus and strobilus will be lost. The lack of learning media will have the effect of an interest lack in students' learning (Knekta et al., 2020). Thus, the decreased interest in studying botany will cause low literacy of rare plants among students (Colon et al., 2020). So, encyclopedia of herbarium pteridophyte integrated to augemented reality is chosen in this media development. Design adjustments will make readers understand the material better and make it more interesting (Handayani et al., 2020). The design was drawn up using Adobe Illustrator while the fern illustration was drawn using the Procreate application (Kellner et al., 2022). The digitization of plant designs is based on real plants so as not to cause misconceptions in readers (Makarov et al., 2021).

Herbarium selection is based on the level of completeness of plant parts, the physical condition of the herbarium, and the correctness of the description (Brenskelle et al., 2020). The complexity of content is valuable in the learning media. The importance of correct information will reduce the level of misconceptions among students (Sunarmi & Sari, 2021). Thus, the criteria for images and design used in the encyclopedia are adjusted to the criteria good brightness, not blurry or fragmented, color combinations in the design can visualize objects and provide an enjoyable atmosphere for readers (Saraswati & Linda, 2019). This is in accordance with Arslan et al. (2020) that learning with visual memory becomes more efficient. AR design with 3D modeling allows students to have a realistic experience compared to two-dimensional modeling (Fidan & Tuncel, 2019).

The function of 3D modeling in herbarium collections is to provide 3D image projections of the original forms of plants in nature (Shi et al., 2019). The herbarium displays dried preservation of plants, most of the color of the plants being black or brown (Albani Rocchetti et al., 2021). Changes in the color of the herbarium can give rise to misunderstandings in students, this can be overcome by 3D modeling projections of real plants (Nagasubramanian et al., 2019). The resulting 3D modeling can display the original shape of the plant and its morphological structure (Bloch et al., 2015).

Astra & Saputra (2018) said that reference source functions as a book that can complete the deepening of material and discuss material that is not able to be presented in a textbook. Moreover, the encyclopedia provides pictures and descriptions, so students are easy to identify (Cahyanti et al., 2021). The encyclopedia followed with detail explanation topics and accompanied by interested herbarium pictures. Harahap et al (2020), encyclopedias can be used as learning resources because they have detailed explanations of information and are accompanied by interesting pictures for readers. Encyclopedia as learning resource is able to improve students learning outcomes and understanding (Nurdiansyah et al., 2021). The encyclopedia can enrich the material outside the core material which conveyed to student, so student's understanding of the botanical material would be better (Zaimah et al., 2022).

The Effectivity of Encyclopedia Integrated Augmented Reality in Improving Biodiversity Literacy

The world is becoming an era of plant blindness and denial of climate change. Therefore, media must be included further into the curriculum to increase more constructive involvement in botany learning such as plant taxonomy, plant morphology, and plant systematics (Swann & Pye, 2019). Encyclopedia integrated with augmented reality is a solution to overcome environmental problems, especially in the threat of Pteridophyte in Indonesia. Ratminingsih et al. (2018) said that the more comprehensive student's knowledge, the more sensitive they are to surround the conservation. The scientific contexts in this study are Pteridophyte environment, science competences refer to 21st-century skills critical thinking and problem-solving, and the scientific knowledge used is the concept of plant diversity especially Pteridophyte family.

The augmented reality presents the morphology of specimen through application contained. Augmented reality can be integrated into textbooks, allowing the display of 3D objects better than 2D object, animation, video, text, or sound (Aydoğdu & Kelpšiene, 2021; Koparan et al., 2023). Chen et al. (2017) stated that books integrated with augmented reality help enrich students' reading experience because they are more interactive and improve thinking skills. Books with augmented reality integration not only influence students' academic performance, as well as increase active involvement in learning (Gecu-Parmaksiz & Delialioğlu, 2020). The use of smartphones as mobile learning is an essential educational technology in higher education (Naciri et al., 2020).

Student's literacy among rare plant conservation can be developed through education setting, one of the strategies is using electronic media. According to Sari et al. (2024) augmented reality can provide visual and interactive experiences that enrich understanding, appreciation, and public awareness of plants, as well as increase participation in protection and conservation efforts. Learning plant taxonomy and morphology can be done by using herbarium. Also, as the massive electronic based learning media electronic herbarium must be useful for the process. Some technological based learning has been made previously to help better learning in botany, for instance automatic taxonomy identification (Sun et al., 2017), field trip implementation (Diana et al., 2020), as well as electronic based herbarium. Further, the media has developed focus on the Pteridophyte species which is now the distribution impacted by global warming, climate change, and other conservation damages.

4. CONCLUSION

Based on the results, the Pterydophyte Encyclopedia integrated augemented reality as learning resources included in a valid, practical, and effective. This showed by the Pteryophyte reach very worthy category based on the result by media expert 100% categorized as valid, material expert 85,1% categorized as valid, and student 91,3% categorized as very worthy. The data analysis either show that the Pterydophyte Encyclopedia Integrated Augmented Reality is effective to improve the undergraduate student's biodiversity literacy. Product effectiveness is based on N-Gain score with value 0.58, it means that the score in class trial was effective. The T Test shows that the significant value is 0.000. It shows that the significance value is less than 0.05, so there is a significant effect in improving undergraduate students's biodiversity literacy. For further research this should be expand the accessibility of media, researchers develop a progressive web app (PWA) herafter. So it could accessed by anyone who interest to biodiversity study, especially in botanical diversity by hand-on experience of species augmented reality media. Thus, this interactive media could be a potential utilization for increasing students' understanding about another skill and interest of nature life.

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