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Development of Virtual Reality (VR) Media on Ecosystem and Environmental Materials Using the Problem Based Learning (PBL) Model to Improve Digital Literacy and Critical Thinking Skills in Biology Education Students

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ABSTRACT
This research was conducted at PGRI Argopuro University Jember to determine students' digital and critical thinking abilities using VR learning media. The learning model used in this research is problem-based learning in ecology courses. This research aims to explore the potential of VR learning media to answer the challenges of 21st century skills, namely digital skills and critical thinking skills, as well as providing innovative learning designs to universities. Media applications use ADDIE. Before being given treatment, respondents will fill out a digital skills pretest questionnaire and critical thinking skills pretest. The results of survey activities and Question Validation are valid, so you can distribute the survey and questions to your respondents. Validation activities carried out by material experts are 100% in the "very effective" category. In the validation carried out by two media experts, an average score of 92.27% was obtained, so it was included in the "very effective" category. Achieved a score of 96.67% (very practical) on media practicality criteria according to education experts. Students scored an average of 85.99% on the practical test, placing them in the “very practical” category. The results of the evaluation of the implementation of the activities showed that there were differences and increases in digital literacy and critical thinking skills between students in the experimental and control classes.

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1. INTRODUCTION

Current advances in information technology and the internet have resulted in an abundance of digital information resources which has given rise to thinking about the importance of digital literacy, including in the world of education (Kunianingsih et al., 2017). Digital literacy also supports students in looking for learning references on online sites. This will then be applied to their daily lives, from the educational environment to the wider community environment to form better resources in the future. Digital literacy is an individual's attitude, awareness and ability to utilize digital facilities and tools appropriately to access, identify, integrate, manage, analyze, evaluate and synthesize digital resources, build new knowledge, create media expressions and communicate with people. others, in the context of certain life situations (Nahdi & Jatisunda, 2020; Raharjo *et al*., 2021).

Digital literacy can support students to be confident and competent in the use of technology in a way that will enable them to develop their subject knowledge by encouraging their curiosity, supporting their creativity, understanding and enabling them to make careful use of the increasing number of digital resources available to them (Helsper & Smahel, 2020; Yasdin et al., 2021). In the 21st century, apart from digital literacy, students also need to improve critical thinking skills. Digital literacy and critical thinking skills will help students to understand and use information correctly. This is in line with research conducted by (Prayogi et al., 2018), digital literacy has a positive correlation with critical thinking skills. As also stated by Handayani (2020) states that STEM-based digital literacy learning can improve students' critical thinking skills. With critical thinking skills, a person can know the strengths and weaknesses of a development in himself (Sari et al., 2019) so that he is able to solve problems in difficult situations and have effective communication with other people. Critical thinking is a process

that leads to activities such as learning to make decisions, analyzing skills and conducting scientific research, as well as knowing the strengths and weaknesses of one's own development (Khoiriyah & Husamah, 2018; Sari *et al*., 2019; Wahyudi, 2020).

From the results of a preliminary study conducted at PGRI Argopuro University Jember, it shows that digital literacy and critical thinking are low. The level of digital literacy and critical thinking skills of students really needs to be improved. This can be seen from the results of the questionnaire which shows that the student's digital literacy level is 58.73%. This value means that the student's digital literacy level is relatively low. Even though in terms of the ability to search on the Internet you get sufficient results, in other aspects everything is said to be still relatively low. Likewise, students' critical thinking skills are 39.47% which can be interpreted as low, but in the basic clarification aspect they get sufficient results. One solution to increase digital literacy and critical thinking skills is that researchers want to develop learning media with virtual reality (VR) technology. Several other studies also agree that VR or other virtual reality-based applications have proven effective in improving student learning achievement (Chang et al., 2018; Hwang et al., 2022; Ogbuanya & Onele, 2018).

Technology such as VR makes it possible and has the potential to develop the quality of education (Ripka *et al*., 2020). As stated by Verner *et al*., (2022) VR has considerable potential so that the world of education can evolve well with technological sophistication. Chan *et al*., (2022)further stated that VR technology will be able to replace conventional learning methods in the future. Virtual reality-based learning media can help understand how ecological concepts can be applied in the real world. Students can see how ecological thinking is applied in different contexts. By combining interactive technology with ecological content, students can experience more enjoyable and effective learning (Kapitzke et al., 2011). This will help them understand ecological concepts and give them more opportunities to get involved in the environment. It is very necessary for teachers to develop innovations in learning media to meet students' needs in learning activities (Dewantara et al., 2020). According to research results by Osman & Kaur (2014) stated that the ICT-assisted PBL group produced the highest scores compared to the PBL only group and the control group. By combining ICT, the PBL process becomes more systematic, structured and improves student achievement in biology. The aim of this research is to design and produce VR media using the PBL learning model, determine the feasibility and validity of the media, and determine the effectiveness of the media.

2. RESEARCH METHOD

This research is a type of research and development (Research and Development). The product development in this research is Ecological VR media in the form of a website. The material of this product is ecosystem and environment. The development model used adheres to the ADDIE Model developed by Brach (2009). ADDIE is an abbreviation for Analyze, Design, Develop, Implement, Evaluate (Figure 1).

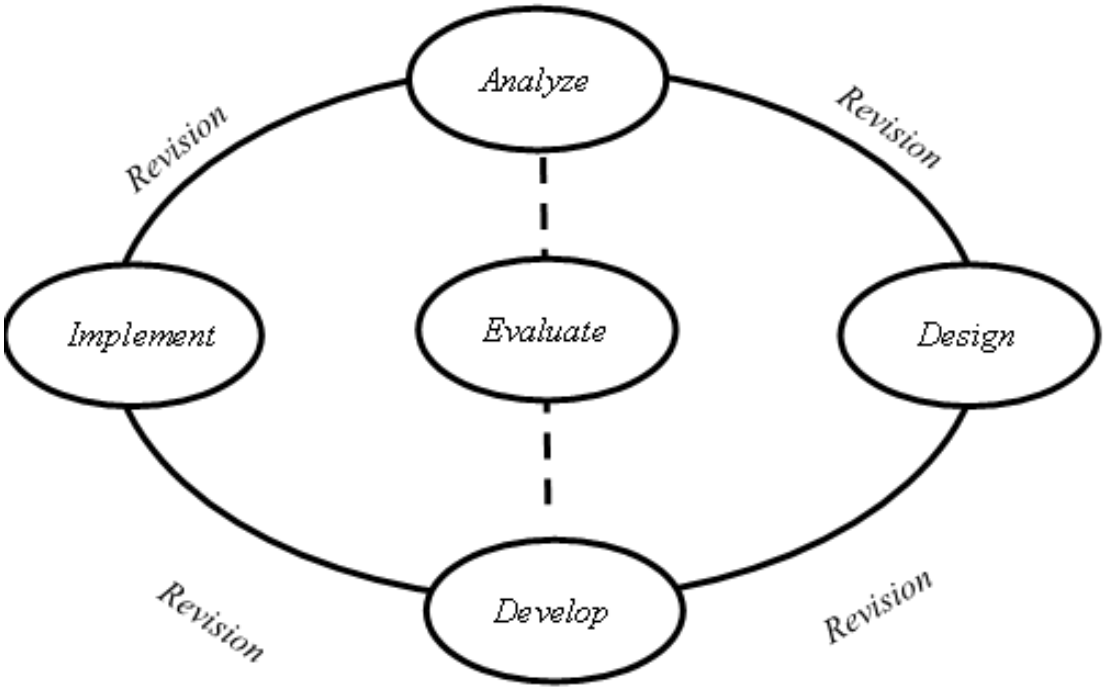

Figure 1. ADDIE Development Model Flow (Branch 2009)

The needs analysis and preliminary study stages were carried out to determine potential and problems such as developments in science and technology (IPTEK), curriculum, ecological learning problems, as well as difficulties with the material. After that, data is collected for product planning materials and data is selected that will be used for design development. The product design is validated by experts so that several inputs are obtained at the design revision stage. The revised product is tested on a limited and wide scale, then refined until the final product is produced.

Research data collection methods include media suitability assessment data by media experts and material obtained using expert assessment sheets, student and lecturer questionnaires to measure teacher and student responses regarding VR media, then tests are given to determine the results of digital literacy abilities and critical thinking skills. The population of this study were students at PGRI Argopuro University, Jember, with the subjects obtained through random sampling techniques in this study being students studying ecology. This research uses digital literacy indicators from Gilster which consist of Internet Searching, Hypertextual Navigation, Content Evaluation and Knowledge Assembly. Meanwhile, for critical thinking skills, indicators from Ennis are used, namely Basic Clarification, Basis for making decisions, Conclusion, Further Clarification, Assumption and Integration. At this stage a Quasi-experimental design was carried out with a Group Pretest-Posttest Design research design which can be seen in Table 1 below:

Table 1. Quasi-Experimental Research Design

Group	Pre-test	Treatment	Post-test
Kelas X	X 1	Y	X 2
Kelas K	K 1	X	K 2

Information:
X 1 : Initial measurements of the Control class
X 2 : Final measurement of control class
K 1 : Initial measurements of the Experiment class
K 2 : Final measurement of the Experiment class
Y : Treatment of VR Media with the PBL model
X : Treatment without VR Media with the PBL model

Analysis using the ANCOVA test with a significance level of 5% was used to test hypothesis using student pretest and posttest scores. Before the data is analyzed using the ANCOVA test, a First, a normality test was carried out using Kolmogorov-Smirnov and a homogeneity test using Levene's Test of Equality of Error Variances. Analysis of the level of effectiveness of e-modules using N-gain with formulas and categories.

$$\mathbf{N-gain} = \frac{\boldsymbol{Posttest\ value - Pretest\ value}}{\boldsymbol{Maximum\ Value}}\ \boldsymbol{x}\ \mathbf{100}\ \%$$

The results of data analysis are interpreted using the following assessment criteria:

Table 2. Criteria *N-Gain*

No	Score	Category
1	N-Gain > 7	High Effectiveness
2	0,3 < N-Gain > 0,7	Medium Effectiveness
3	N-Gain < 0,3	Low Effectiveness

Source: (Oktavia et al., 2019)

3. RESULT AND DISCUSSION

This research and development procedure is an adaptation of the ADDIE research and development steps developed by Branch (2009) in designing a learning system, which consists of five stages, Analysis, Design, Development, Implementation, Evaluation.

Analysis Stage

The analysis stage aims to explore problems and find solutions or mistakes. Validation of this needs or problem analysis was obtained from field observation data, questionnaires and interviews to analyze the GAP or harmony that occurs in learning ecology courses, while a preliminary study was carried out with initial testing to obtain a picture of students' digital literacy scores and critical thinking skills. The results of the Performance Gap Validation stage are presented in Table 3. following:

Table 3. Results of the Validate the Performance Gap stage assessment

Result	Objective	The main cause	GAP (%)
Needs Analysis Stage regarding learning models There has been no development of a PBL model that supports digital literacy and critical thinking skills.	Identify learning models that can improve students' digital literacy and critical thinking skills.	1. There has been no development of a PBL learning model that is integrated with digital literacy. 2. There has been no development of a PBL learning model that is integrated with critical thinking skills. Source: Observations and interviews.	10
Needs Analysis Stage regarding Learning Media or Teaching Materials **Student:** More than 40% of students assume that PPT media needs to be developed (conventional media). **Lecturer:** There are suggestions for developing VR media for ecology	Identification of learning media in Ecology courses in the Education Study Program for Ecology Courses	1. Lecturers still use the same media as previous lessons. 2. There has been no learning innovation that leads to new technology. 3. Have never used VR media in learning. Source: Researcher data processing results	15%
Needs Analysis Stage regarding ecological material Student Students: more than 60% of students hope that learning can use laptops or cellphones more. Lecturer/Facilitator Lecturer: There is great hope for the development of learning media by following technological developments such as VR.	Identify facilities and infrastructure that support VR media learning	1. Internet use is only used to search for material from Google. 2. Students have never used VR media either from cellphones or laptops. 3. Lecturers who have never used VR media from cellphones or laptops. 4. Learning media only uses projector facilities to display ppt. Source: Observation and questionnaire.	15%
Preliminary Study Stage **Digital Literacy:** The results of a preliminary study showed that students' digital literacy level was an average of 31%, which is interpreted as low.	Identify digital literacy skills in biology education student's class of 2022.	Results of needs analysis using digital literacy questionnaires.	30%
Preliminary Study Stage **Critical Thinking Skills:** The results of the preliminary study show that the level of students' critical thinking skills is an average of 26%, which is interpreted as low.	Identify critical thinking skills in biology education student class of 2022.	Results of needs analysis with critical thinking skills questions.	30%
	Amount		100%
Summary of results	The aim of this research is to develop VR media with a PBL model that is able to improve students' digital literacy and critical thinking skills.		

Design Stage

The next stage is designing learning media. Researchers design media with the direction of the analysis that has been carried out. Some of the things that researchers do are compiling a list of tasks, developing goals or media direction, and developing an assessment strategy. After designing, the next step is developing the design that has been created. The media display in terms of color, layout and font type is made as attractive and easy as possible so that it can be used well. Some content results can be seen in Figure 2

Figure 2 initial media display

Development Stage

This stage is carried out by determining the criteria that will be used to carry out the evaluation. The evaluation criteria determined include the validity criteria of the learning design, the validity criteria and the practicality of the media which can be seen in the table below:

Table 4. Learning Design Interpretation Criteria

Score	Criteria
85,01 % - 100,00 %	Very Valid
70,01 % - 85,00 %	Valid
50,01 % - 70,00 %	Less Valid
00,00 % - 50,00 %	Invalid

Table 5. Validity Interpretation Criteria

Score	Criteria
85,01 % - 100,00 %	Very Valid, can be used, needs revision according to suggestions
70,01 % - 85,00 %	Valid, can be used but needs minor revisions
50,01 % - 70,00 %	Less Valid, it is recommended that it not be used because it needs major revision
00,00 % - 50,00 %	Invalid, or may not be used

The percentage of media practicality is adjusted to the evaluation criteria for the data analysis results presented in table 6. following:

Table 6. Practicality Interpretation Criteria

Score	Criteria
85,01 % - 100,00 %	Very Practical, can be used without revision
70,01 % - 85,00 %	Practical, Usable but needs minor revision
50,01 % - 70,00 %	Less Practical, it is recommended not to use it because it needs revision
00,00 % - 50,00 %	Impractical, cannot be used

This validation aims to ensure that there are no misconceptions or material errors when using the media. This is in line with research by Dian Hendrayana et al., (2022) which stated that validation was carried out by Learning Media Expert and Material Expert in order to determine the suitability of the product. The aspect of the lecture event unit assessment or SAP that must be revised is the integration of Sub-CPMK with digital literacy and critical thinking skills. SAP validation was carried out by lecturer, SAP validation results by validators get an average score of 96.47 in the very valid category. Learning design assessment consists of aspects of component completeness, learning achievement aspects, content feasibility aspects and development aspects. This is reinforced by Fitriyah & Hayati, (2020) who state that the feasibility of a learning plan is in accordance with its content, including aspects of construct validity, content, learning activities.

Table 7. Validation Results of Lecture Event Units After Revision

No	Assessment Indicators	Percentage (%)	Category
1	Aspects of Component Completeness	100,00	Complete / Very Practical
2	Aspects of Learning Achievements	95,00	Very Valid
3	Content Feasibility Aspect	94,67	Very Valid
4	Development Aspects	96,00	Very Valid
Average Value (%)		**96,47**	**Very Valid**

The media is then validated by media experts and material experts. The design that has been validated by experts is then revised according to input from the two experts (Table 8 and Table 9).

Table 8. Validation Results by Media Experts After Revision

No	Aspect	Expert Media 1		Expert Media 2	
		Percent (%)	Category	Percent (%)	Category
1	Display / Media Design Aspects	100.00	Very Valid	100,00	Very Valid
2	Characteristic Aspects	95,00	Very Valid	97,50	Very Valid
3	Access and Usage Aspects	97,78	Very Valid	95,56	Very Valid
Average Value (%)		**97,27**	**Very Valid**	**97,27**	**Very Valid**
Average Total Score (%)		97,27			
Category		Very Valid			

Table 9. Validation Results by Material Experts After Revision

No	Aspect	Expert Media 1	
		Percent (%)	Category
1	Display / Media Design Aspects	100.00	Very Valid
2	Characteristic Aspects	100.00	Very Valid
3	Access and Usage Aspects	100.00	Very Valid
Average Value (%)		100.00	**Very Valid**

Conduct Formative Revisions Stage: This practice is used to determine the suitability of learning media or VR media based on student responses. The test stages consist of: there are 3 phases of this practice evaluation, namely, One to One Trial, Small Group Test, Field Trial and finally the Conduct a Pilot Test.

Table 10. Media Eligibility Test

No	Eligibility test	Score (%)	Category
1	One to One Trial	81,68	Practical
2	Small Group Trial	85,89	Very Practical
3	Field Trial	87,12	Very Practical
4	Conduct a Pilot Test	87,51	Very Practical

Implementation Stage

At the implementation stage, all media plans that have been developed are implemented after revisions, namely preparing educators, preparing students/subjects, time and place of research, analysis techniques and variables, and research instruments.

Evaluation Stage

Evaluation is the final stage of the ADDIE development model. Because this research only included limited trials, the evaluation referred to here is an evaluation of implementation activities. The evaluation results were obtained from testing the effectiveness of the media through digital literacy questionnaires and critical thinking questions, learning analysis, suggestions from teachers and students during the trial, so that from this evaluation stage final revisions were carried out. The results of the average digital literacy score were known based on a questionnaire distributed to the control class and experimental class. An overview of students' digital literacy results can be seen in Figure 3. When a teacher rarely carries out outdoor learning activities or does not use reality media, only uses conventional open materials which causes students not to be interested and does not help students in finding, selecting and providing resources (Fitriyati et al., 2023)

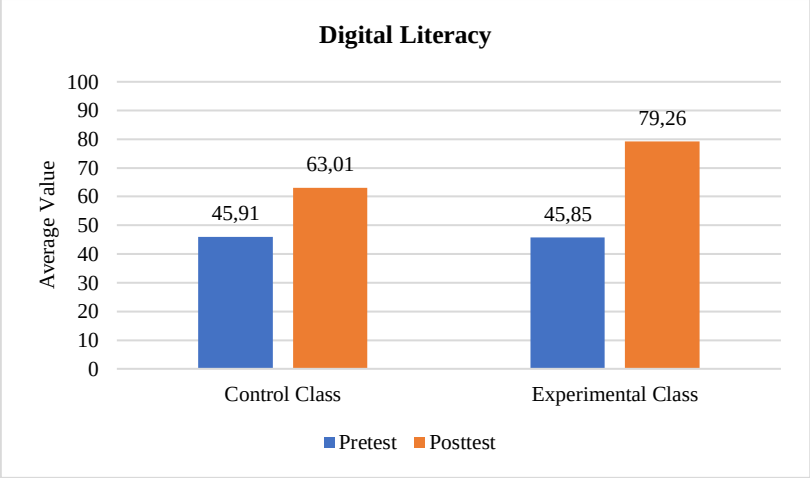

Figure 3. Figure of Comparison of Mean Digital Literacy Scores for Control Class and Experimental Class Students

This research is also supported by the opinion of (Anggeraini et al., 2022) that digital literacy has a positive impact on the learning process, such as helping the learning process, distinguishing useful and significant learning resources, and making teachers more productive in creating learning media. Testing is also carried out to measure students' critical thinking skills. It can be seen in Figure 4 that in the experimental class the critical thinking skills score was 83.03 while in the control class it was 71.41. This means that there is a difference or influence from the media on critical thinking skills. Virtual reality media is used as an educational goal which has the potential to encourage student learning retention (Supriadi & Hignasari, 2019). Students are given the opportunity to build their own knowledge that they have learned and are given active encouragement to interact with the learning environment in order to gain a higher understanding (Hasan et al., 2021).

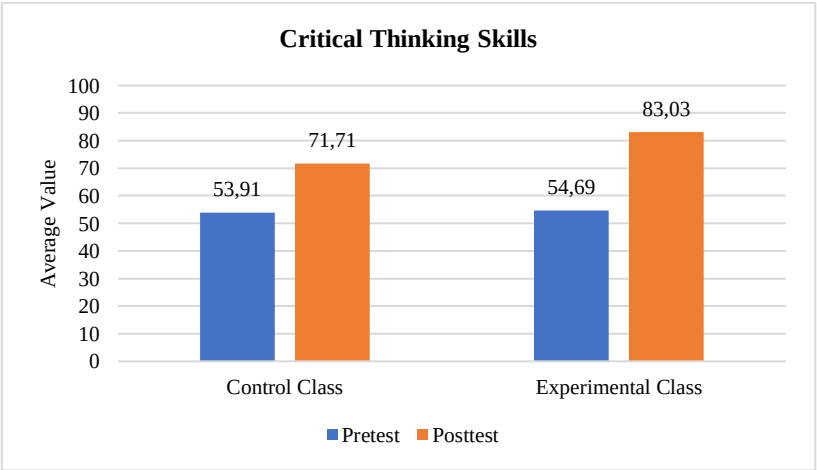

Figure 4. Figure Comparison of Mean Values of Critical Thinking Skills in the Control Class and Experimental Class

Knowledge evaluation was carried out to determine the effectiveness of the e-module implemented in the control and experimental classes. Data were analyzed based on the Anova test which had previously been carried out for normality and homogeneity tests. The normality test results show that the significance value of pretest and posttest critical thinking skills is > 0.05. Therefore, the variance of the pretest and posttest data is normally distributed, as shown in.

Table 11. Normality Test Table on Digital Literacy

Class - Group	Normality Test Value	Category
Experimental class pretest	0,873	Normal
experimental class posttest	0,656	Normal
Control class pretest	0,887	Normal
Control class posttest	0,634	Normal

Meanwhile, critical thinking skills can be seen in table 12 below:

Table 12. Normality Test Table for Critical Thinking Skills

Class - Group	Normality Test Value	Category
Experimental class pretest	0,230	Normal
experimental class posttest	0,110	Normal
Control class pretest	0,109	Normal
Control class posttest	0,088	Normal

The homogeneity test results show that the pretest and posttest significance values for digital literacy and critical thinking skills scored greater than 0.05 (Sig > 0.05). Therefore, the variance of the pretest and posttest data is homogeneous, as shown in Table 13.

Table 13. Homogeneity Test Table on digital literacy and Critical Thinking Skills

Aspect	Homogeneity Test Value	Category
Literacy Digital	0,414	Homogeneous
Critical Thinking Skills	0,145	Homogeneous

After the data is normally distributed and homogeneous, then the Anacova test is carried out. The results of the ANCOVA test show that the significance value for digital literacy and critical thinking skills is greater than 0.05 (sig < 0.05). There, the variance of the pretest and posttest data is homogeneous as seen in Table 14 and Table 15.

Table 14. Anacova test on digital literacy

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Correted Model	215,002[a]	2	1075,011	23,869	,000	,622
Intercept	478,025	1	478,025	10,614	,003	,268
Pretest	37,522	1	37,522	,833	,369	,028
Class	**2117,292**	**1**	**2117,292**	**47,011**	**,000**	**,618**
Error	1306,107	29	45,038			
Total	165387,843	32				
Correted Total	3456,129	31				

Table 15. Anacova Test on Critical Thinking Skills

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Correted Model	1960,900[a]	2	980,450	57,491	,000	,799
Intercept	1002,400	1	1102,400	58,778	,000	,670
Pretest	7,775	1	7,775	,456	,505	,015
Class	**1913,522**	**1**	**1913,522**	**112,203**	**,000**	**,796**
Error	494,569	29	17,054			
Total	203275,000	32				
Correted Total	2455,469	31				

The table above shows based on the SPSS ANCOVA test output table, a significance value of 0.000 is obtained, which means it is smaller than α 0.05 (Sig < 0.05). This identifies significant differences between classes that use VR media and learning that does not use media. Therefore, it can be concluded that the use of VR media has a significant effect on students' digital literacy abilities and critical thinking skills.

The evaluation results using N-gain showed an increase in the experimental class score from pretest to posttest. The N-gain value for digital literacy in the experimental class is 0.304, which shows that the effectiveness of using VR media in Ecology courses is in the Medium Effectiveness category. For critical thinking skills in the

experimental class, they got a score of 0.713 which is included in the High Effectiveness category which can be seen in the table 16.

Table 16 N-gain Score Literacy Digital and Critical Thinking Skills

Variable	Group	Pretest	Posttest	N-Gain	Category
Digital Literacy	Control Class	45,91	63,01	0,3,16	Medium
	Experimental	45,85	79,26	0,617	Medium
Critical Thinking Skills	Control Class	53,91	71,41	0,379	Medium
	Experimental	54,69	87,03	0,713	High

In each lesson, choosing a learning model will improve the quality of learning. Learning using the PBL model is able to influence student learning outcomes, apart from that the role of the teacher and learning media can greatly influence it. As stated by Arends, (2012), teachers must assist students in gathering information from various sources, and teachers must ask questions so that students can think about the problem and the type of information needed to arrive at a defensible solution. Learning using PBL can facilitate several skills such as independent learning, interdependent learning, deep learning, assessment, critical thinking, teamwork, time management, and problem solving (Krisanti & Mulia, 2016). The use of Virtual Reality (VR) learning media has had a significant impact on students' digital literacy abilities and thinking skills. With VR, students can engage in deep and immersive learning experiences, allowing them to better understand complex concepts in real contexts. Through the use of VR, students have the opportunity to interact with demanding simulations, allowing them to hone practical analysis, synthesis and evaluation skills in a practical way. Additionally, VR also facilitates adaptive learning, where students can learn at their own pace and learning style, increasing their understanding of digital literacy and expanding their thinking skills in a technological context. Logistical reasoning skills are part of critical thinking skills. Therefore, to improve students' critical thinking skills can be done by: focus on improving students' logistical reasoning abilities (Siburan et al., 2019). Researchers agree that virtual reality media can easily bridge the gap in abstract material by projecting graphics and 3D objects into real environments and help students identify their application in everyday life (Zhao et al., 2023).

Apart from increasing understanding of digital literacy, the influence of VR learning media also helps develop students' overall thinking skills. In a VR environment, students can engage in situations that simulate real-world problems, allowing them to develop problem-solving skills, teamwork, and creativity. By exploring virtual spaces, students are trained to think critically and creatively, creating solutions to complex challenges. In addition, interaction in a VR environment also broadens students' knowledge of various perspectives, helping them become more experienced learners and open to change. Thus, the influence of VR learning media has made a significant positive contribution to students' digital literacy abilities and thinking skills in the context of higher education.

4. CONCLUSION

Judging from the ANCOVA test, a significance value of 0.000 is obtained, which means it is smaller than α 0.05 (Sig < 0.05). Therefore, it can be concluded that using VR learning media in ecology courses can have a significant effect on students' digital literacy abilities and critical thinking skills. Judging from the results of the N-gain test, it shows that the level of media effectiveness is in the medium category with a score of 0.304 for digital literacy and for critical thinking skills it gets a score of 0.809 in the high category. Based on the objectives of this research and development, it was concluded that (1) VR media in this ecology course meets the validity criteria according to teaching materials experts, material experts and educational practitioners; (2) VR media has met the criteria for the practicality of student responses; (3) The use of VR media is considered effective in learning.

The development of VR media was carried out in several stages such as needs analysis, preliminary studies, product development such as design, production and validation. The next stage is to test the product on students and carry out revisions. Products developed based on the results of needs analysis and preliminary studies and validation from media experts and material experts. The results obtained show that the product developed is categorized as very good in terms of material, language and appearance. However, large-scale trials are still being carried out so that it is hoped that in the end a product will be obtained that can be widely used by students and lecturers in the learning and teaching process, especially in online learning at this time.

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