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The Effect of Virtual Laboratory using Ethnoscience Concept "*Mangeppi Agara*" on Students' Digital Literacy and Science Literacy

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Abstract: In this digital age, digital literacy and science literacy are key to comprehending and applying knowledge efficiently. However, modern science education often overlooks local wisdom and ethnoscience, which are rich in cultural values and traditions. Ethnoscience studies can provide material for creating virtual laboratories to help students increase their digital literacy and science literacy. The purpose of this research is to analyze the effect of virtual laboratories using the "mangeppi agara" ethnoscience concept on students' digital and scientific literacy. The present study employed a quasi-experimental design to generate a virtual laboratory that embodies the ethnoscience idea "*Manggeppi Agara*". The product comprises simulations/demos, videos, assessments, and images created with Augmented Reality (AR) technology. The ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) was implemented to produce the laboratory. The product was examined by experts in the field and tried out to 202 biology students. The result showed that the laboratory was valid. The research instruments consisted of tests to assess pupils' digital and science literacy. The study's findings revealed that employing a virtual laboratory based on the "*Manggeppi Agara*" Ethnoscience idea improved students' digital literacy and science literacy. virtual laboratory using the Etnosains concept "*Manggeppi Agara*" had an impact on students' digital literacy and science literacy. These findings are expected to help advance the quality of learning design in university and enhance students' science competencies in the face of rapid global change.

Keywords: Digital Literacy; *Manggeppi Agara;* Science Literacy; Students Biology; Virtual Laboratory.

Introduction

Digital literacy and science literacy are critical abilities for students to possess as they face the industrial revolution and increasingly rapid global development. Digital and science literacy play important roles in the learning process, education, and society (Lukitasari et al., 2022; Saputra & Al Siddiq, 2020). These two skills contribute to the learning process's efficacy and efficiency, as well as students' adaption to the skills required in the workplace (Amin et al., 2024; Khan et al., 2022). The use of digital literacy as an effective learning resource increases learning quality, creates an interactive learning environment, and promotes a deeper knowledge of scientific ideas (Bayadilova-Altybayeva et al., 2023; Kamalova et al., 2022; Zeng et al., 2020). Access to technology and a concentration on digital literacy provide several opportunities for future learners to prosper (Scanlon et al., 2000; Statti & Torres, 2020). However, our preliminary findings indicated that digital literacy among pupils in schools in South Sulawesi, Indonesia, remained relatively low. Digital literacy includes a virtual media world that can be integrated into education to help pupils develop science literacy (Amin et al., 2023; Corbit et al., 2005; Siebers & Cobley, 2024).

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The instillation of science literacy through science learning happens when students comprehend theories, regulations, or cognitive skills (Dewantari et al., 2020). The process will continue until students achieve goals in scientific processes, products, and behavior. Science literacy facilitates the mastery of knowledge to examine natural occurrences and make sound decisions based on the information available (Amin et al., 2020; Hartono et al., 2023; Machado & Nahar, 2023). Science literacy can help students understand and critically assess scientific material, as well as acquire the ability to perform scientific research (Amala et al., 2023; Elhai, 2023; Fatmawati et al., 2023; Hur et al., 2020). Effective science education necessitates not only a strong conceptual understanding but also the ability to apply knowledge in a variety of contexts, including the use of digital technologies (Amin & Adiansyah, 2023; Elhai, 2023; Gökdaş & Çam, 2022; Preetha et al., 2005). Students' poor science literacy skills will have an impact on their tendency to form negative constructivist conceptions in applying science to learning, as well as their self-confidence and digital learning skills (Aladağ et al., 2021).

The development of students' scientific literacy is a complex process influenced by factors such as learning methods, open media, scientific learning steps, student and educator perceptions, parental support, social and cultural factors (Roy et al., 2025). Factors that influence students' scientific literacy are the learning process, enjoyment in learning science, and interest in science. Constructivist learning activities need to be prioritized to stimulate a significant increase in students' scientific literacy (Setyowati, et al., 2022). Students with scientific literacy skills are able to apply their knowledge to real-life situations (Altun & Kalkan, 2021). A constructivist learning environment encourages students to reflect on experiences, learn to analyze real-world problems, improve social negotiation, learn to communicate well, and apply and integrate what is learned (Cetin-Dindar, 2016).

One of the primary challenges in building students' science literacy is a lack of student involvement and enthusiasm to master science concepts (Cho, 2022). Many students regard science as a challenging topic that is not directly applicable to their daily lives (Amala et al., 2023). This is frequently caused by less attractive teaching approaches or traditional methods that do not help students connect scientific principles to their practical applications (Fatmawati et al., 2023). Furthermore, there are obstacles in developing students' critical thinking skills and a firm understanding of the scientific method, which are at the heart of science literacy (Elhai, 2023). Students are frequently given scientific information without being taught how to evaluate the reliability and validity of that information. This teaching technique has the potential to have an impact on students' ability to make scientifically informed decisions.

Science learning in schools continues to encounter numerous challenges. It is usually held one-way, with the instructor serving as the primary informant (Junaidi, 2020); (Kertih, 2020). Science literacy is rarely promoted in science classes (Hasanah & Nasir Malik, 2020; Kembara et al., 2020). In science classes, the use of information technology as a learning medium is extremely limited, particularly in Indonesia's remote areas (Fahmi et al., 2021; Sumiati et al., 2020). In fact, science literacy and digital literacy are vital for students to keep up with technological and scientific changes. Besides, science classes also hardly incorporate local knowledge into their curriculum (Kurnianto & Lestarini, 2020; Lestari et al., 2020) Science curriculum sometimes overlooks the importance of local values and culture in enriching students' knowledge and providing meaningful learning for the pupils.

Utilizing local wisdom as a learning resource makes learning more contextual and applicable for students. This is because local wisdom includes knowledge and practices that have been proven effective and tested in the local environment (Julita et al., 2019). Learning that integrates local wisdom actively involves students in scientific exploration and discovery (Primayana, 2019). Local wisdom can be integrated into science learning through ethnoscience studies.

The virtual laboratory developed in this study contains material from ethnoscience studies. The virtual laboratory includes simulations/demonstrations, videos, assessments, and images created utilizing Augmented Reality (AR) technology and ethnoscience. The virtual laboratory provides students with significant ethnoscience skills and information, as well as critical analysis, science literacy, and digital literacy skills. The virtual laboratory allows students to conduct practical exercises anywhere and at any time without the need for full teacher supervision. Virtual laboratories can encourage students to investigate natural occurrences and improve their critical thinking abilities (Noris et al., 2023); (Sapriati et al., 2023). The usage of virtual laboratories in the classroom has been shown to have a considerable impact on scientific reasoning, attitudes, accomplishments, and student inventiveness (Alneyadi, 2019; Hendratmoko et al., 2023; Okono et al., 2023).

Currently, the development and utilization of virtual laboratories in schools, particularly in South Sulawesi, is still very limited in research studies. The development of learning designs utilizing laboratories that integrate technology, scientific concepts, and local cultural wisdom is still rarely implemented by science teachers in Bone Regency, South Sulawesi. Therefore, research on virtual laboratories using the "mangeppi agara" ethnoscience concept is expected to increase teacher innovation in empowering students' digital and scientific literacy. The seaweed cultivation process, particularly in the Bugis Bone community, contains indigenous knowledge.

The integration of ethnoscience into science learning is expected to not only increase the relevance of the subject matter to students' lives but also promote appreciation for cultural diversity and local knowledge. The use of local wisdom actively engages students in scientific exploration and discovery. Virtual laboratories can be used to simulate practical activities before carrying out actual activities in school laboratories. Developing virtual laboratories with ethnoscience content can integrate indigenous knowledge into learning. The purpose of this research is to analyze the effect of virtual laboratories using the "mangeppi agara" ethnoscience concept on students' digital and scientific literacy.

Method

This study employed a quasi-experimental design. In this study, the independent variable was a virtual laboratory, and the dependent variables were digital literacy and science literacy. The study's product, the virtual laboratory, embodied the concept of ethnoscience "*Manggeppi Agara*". The laboratory comprised simulations/demonstrations, videos, assessments, and images created with Augmented Reality (AR) technology. The resulting virtual laboratory was developed using the ADDIE approach (analysis, design, development, implementation, and evaluation). The laboratory was declared valid after being tested by specialists in their respective domains. Table 1 depicts the design of the virtual laboratory trial study.

Table 1. Pre-Test-Post-Test Three Treatment Design Research Design

Group	Pre-test	Treatment	Posttest
Experimental	O_1	Virtual Laboratory	O_2

Note:
O_1 = pretest score of the experimental group (before implementing the virtual laboratory).
O_2 = post-test of the experimental group (after implementing the virtual laboratory).
X = Treatment, which is the implementation of the virtual laboratory created using the ethnoscience concept "*Manggepi Agara*"

The study population consisted of 507 students from the three schools in Bone, South Sulawesi. Meanwhile, the study sample was 202 tenth grade students. Sampling was done randomly. Data related to digital literacy were obtained through a digital literacy questionnaire using a Likert scale. This questionnaire assessed the following dimensions: (1) Internet searching; (2) hypertextual navigation; (3) content evaluation; and (4) knowledge assembly. Prior to its use, the instrument had gone through expert and empirical validation tests. The results of the validation tests showed that the questionnaire was valid and reliable for collecting data on students' digital literacy.

This ethnoscience research was conducted in Bone Regency, Tanete Riattang Timur District, Toro Village, Limpenno Hamlet, South Sulawesi, considering that seaweed cultivation is a source of livelihood for the people of Bone Regency. The researchers developed the virtual laboratory product using the ADDIE design in the multimedia laboratory of Muhammadiyah University of Bone, South Sulawesi. The virtual laboratory product trial was conducted at SMAN 3 Bone, SMAN 5 Bone, and SMA 18 Bone. The total population of the three schools was 507 students. The study sample consisted of 202 eleventh-grade students, consisting of 67 students from SMAN 3 Bone, 69 students from SMAN 5 Bone, and 66 students from SMA 18 Bone. The sampling method used was random sampling. This study was conducted in the odd semester of the 2024/2025 academic year.

The research will be conducted in two main stages: ethnoscience research on manggepi agara cultivation and development of a virtual laboratory with ethnoscience content. The research began with a Focus Group Discussion (FGD) with the team and a literature review. The ethnoscience research phase involved observation, interviews, and documentation. Interviews with local practitioners in Bone Regency, South Sulawesi, included qualitative data obtained through in-depth interviews with 10 seaweed farmers and 10 biology teachers. Qualitative data obtained through in-depth interviews with 10 seaweed farmers and 10 biology teachers indicated that local knowledge about seaweed cultivation strongly relates to biological concepts. The seaweed cultivation method they use is the Long Line method, which involves tying seaweed seedlings to a rope with a spacing of one inch (15-25 cm) between seedlings. The next phase of the research and development of an ethnoscience-based virtual laboratory was conducted using the ADDIE model.

The needs analysis phase in the ADDIE model was carried out by developing an ethnoscience-based virtual laboratory. Furthermore, in the design phase of the Ethnoscience-Based Virtual Laboratory, a task inventory was conducted based on the results of a storyboard analysis focused on the topic of Eucheuma cottonii seaweed cultivation for 11th-grade high school students. The development phase involved validating the product prototype of the ethnoscience-based virtual laboratory. The implementation phase was then conducted with a limited trial at three high schools in Bone Regency, South Sulawesi. The evaluation phase analyzes the results of the research trials, including validity, practicality, and effectiveness.

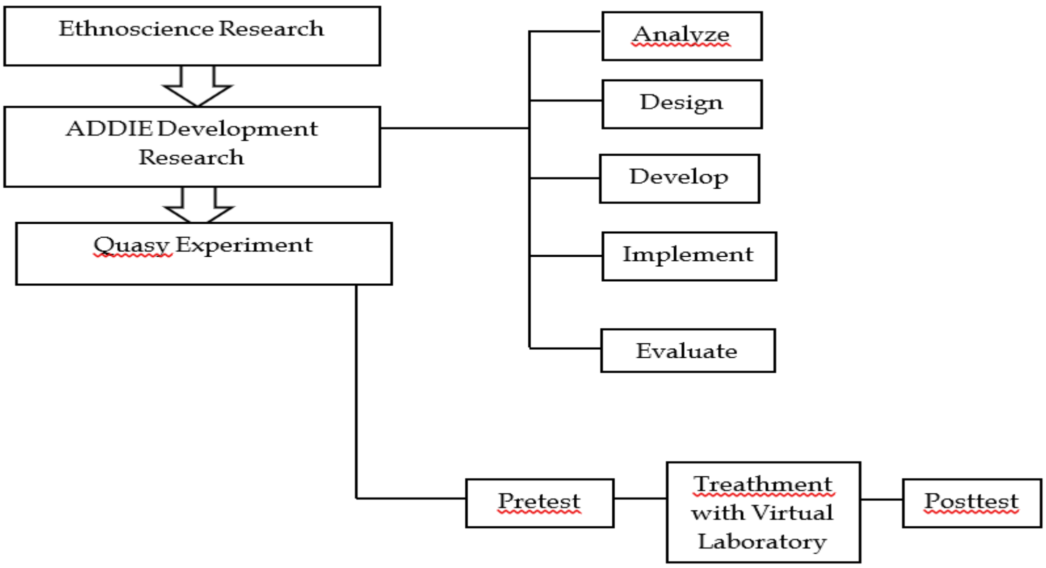

Figure 1. Research Design

Data obtained from the ethnoscience research were analyzed using phenomenological analysis. The results of the development research were analyzed qualitatively and quantitatively. The effectiveness test data for the product development were analyzed using: 1) descriptive analysis, used to calculate the average scores for the initial and final tests of conceptual understanding and scientific literacy; 2) inferential analysis, used to test the effect of the learning design on the dependent variable. The data analysis used was the ANOVA test. Prior to conducting the ANOVA test, prerequisite tests, namely normality and homogeneity tests at a 5% significance level, were conducted to determine the effectiveness of the ethnoscience-based virtual laboratory in empowering students' scientific and digital literacy.

Students' science literacy was measured using eight essay questions covering four dimensions, namely scientific knowledge/content, scientific processes, and scientific applications that refer to the following indicators: *identifying scientific questions, explaining phenomena scientifically,* and *using scientific evidence*. This instrument had gone through expert and empirical validation processes and had been declared valid and reliable for use in collecting data on students' science literacy. Table 2 presents the mean scores resulting from expert validation, empirical validation and reliability tests for digital literacy and science literacy instruments

Table 2. Results of Empirical Validity and Reliability Tests of the Research Instruments

Research Instrument	Average Score of Expert Validation	Validty Test Result	Reliability Test Result
Digital Literacy	3.88 (valid)	0.582 (all items are valid)	0.937 (all items are consistent or reliable)
Science Literacy	3.70 (valid)	0.593 (all items are valid)	0.922 (all items are consistent or reliable)

The research hypotheses were (1) the virtual laboratory with the Ethnoscience concept "*Manggeppi Agara*" has an impact on students' digital literacy; (2) the virtual laboratory with the Ethnoscience concept "*Manggeppi Agara*" has an impact on students' science literacy. Data were analyzed using the t-test with a significance level of 5%. Before the data were analyzed, normality and homogeneity tests were carried out. The normality test used the One-Sample Kolmogrov-Smirnov test. The homogeneity test used Levene's Test of Equality of Error Variances

Result and Discussion

Digital Literacy

Before conducting the hypothesis test, the digital literacy data was first tested for normality and homogeneity. The result of the normality test for digital literacy data using the Kolmogorov-Smirnov technique showed that the data collected from all groups showed a significance level > 0.05, indicating that they were distributed normally. Each school demonstrated a significance value of > 0.05, so it can be concluded that the digital literacy scores before and after treatment in each school were homogeneous. Mean scores before and after the research treatment in each school and the result of the t-test can be seen in Table 3.

Table 3. The t-test Result

Name of School	Test	Mean	Std. Deviation	p value	Description
School-A	After	89.67	1.87	0.000	Significantly different
	Before	38.63	2.31		
School-B	After	89.34	2.08	0.000	Significantly different
	Before	38.47	2.38		
School-C	After	89.46	1.91	0.000	Significantly different
	Before	38.26	2.41		

Based on Table 3, it can be concluded that the virtual laboratory using the Etnoscience concept "*Manggeppi Agara*" had an impact on the digital literacy of students.

Science Literacy

Before conducting the hypothesis test, the science literacy data was first tested for normality and homogeneity. The result of the normality test for science literacy data using the Kolmogorov-Smirnov technique showed that the data collected from all groups showed a significance level > 0.05, indicating that they were distributed normally. Each school demonstrated a significance value of > 0.05, so it can be concluded that the science literacy scores before and after treatment in each school were homogeneous. Mean scores before and after the research treatment in each school and the result of the t-test can be seen in Table 4.

Table 4. The t-test Result

Name of School	Test	Mean	Std. Deviation	p value	Description
School-A	After	85.65	2.51	0.000	Significantly different
	Before	38.11	2.31		
School-B	After	85.34	2.48	0.000	Significantly different
	Before	37.89	2.63		
School-C	After	85.21	1.89	0.000	Significantly different
	Before	38.26	2.11		

Based on Table 4, it can be concluded that the virtual laboratory using the Etnoscience concept "*Manggeppi Agara*" had an impact on the science literacy of students.

The study's findings revealed that the virtual laboratory based on the Ethnoscience idea "*Manggeppi Agara*" had an impact on students' digital literacy and science literacy. Students can use the virtual laboratory to watch and comprehend the steps of growing *Eucheuma cottonii* seaweed, such as seed selection and optimal environmental conditions for the plant. As a result, students can learn how to merge modern scientific approaches with traditional traditions that are still used today. This theme supports the ethnoscience-based virtual laboratory approach, which not only teaches students about biology but also introduces them to environmental management technologies.

Traditional cultivation practices for *Eucheuma cottonii* seaweed (*Mangeppi Agara*) have been passed down from generation to generation. With the creation of a virtual laboratory, this information may be documented and accessed electronically. The virtual laboratory can also help to preserve this valuable local knowledge, allowing the new generation to study it as part of formal education. The virtual laboratory allows students not only to learn biological concepts but also to understand cultural values and local wisdom through interactive simulations, which are relevant to improving students' science literacy and digital literacy. A virtual laboratory can present theories and experiments in real time without having to apply them directly in the laboratory room (Manyilizu, 2023; Yakob et al., 2023). A virtual laboratory plays an important role in scenarios where traditional laboratories are not possible because it can increase accessibility, scalability, and cost efficiency (Asare et al., 2023; Reginald, 2023).

Ethnoscience-based virtual laboratories offer many benefits from the various potentials they have with local characters and materials. Efforts to improve the quality of science learning can be carried out by teachers by implementing ethnoscience-based learning with environmental learning resources. Having access to diverse learning resources and adequate facilities makes the teaching and learning process more successful. Ethnoscience learning encourages teachers and education practitioners to use cultural knowledge and local wisdom in teaching science to students (Rikizaputra et al., 2021). Ethnoscience is the study of a certain area's local communities through the lens of science and culture. It is very necessary to instil a sense of love for the culture in students so that the culture does not fade along with the times. One thing that must be done is to integrate culture into learning that is already included in the independent curriculum. The seaweed cultivation process, especially that done by the *Bugis Bone* community, has indigenous knowledge content. This cultivation practice can be part of an ethnoscience study in Biology learning.

Digital literacy can affect students' learning outcomes and academic achievement (Purnamasari et al., 2021). Several factors that may influence students' digital literacy include socioeconomic status, cultural/ethnic background, gender, and disciplinary specialization (Kennedy et al., 2008). In addition, the nature and frequency of students' internet use differ based on their age and socioeconomic status (Livingstone & Bober, 2004). Age, educational background, gender, educational institutions, and preferences all have an impact on digital literacy (Karagul et al., 2021). One aspect contributing to a person's high digital literacy in urban areas is the ease of access to infrastructure and network facilities (Rundel & Salemink, 2021).

The results of the needs analysis in the preliminary study conducted by the research team showed that around 62% of students and 70% of teachers believed that the use of virtual laboratories could support the development of students' digital skills, such as the use of learning software and digital information navigation. Virtual laboratories are considered to have strong potential in developing students' digital skills. By utilizing virtual laboratories, students not only learn about biological concepts, but are also trained to use technology effectively, which are important skills in the digital era. Through virtual laboratories, students can observe and understand directly the stages in the cultivation of *Eucheuma cottonii* seaweed, strict seed selection techniques and environmental care, where these concepts can be simulated in virtual laboratories. The right learning process can optimize students' thinking and literacy skills (Fayanto et al., 2023; Urdanivia et al., 22023).

Biology plays an important role in building students' understanding of scientific concepts related to everyday life. However, the main challenge in biology learning is the lack of connection between the theories taught in class and the practical applications that can be found in the students' environment (Flowers et al., 2023). To improve students' thinking skills, teachers as facilitators must choose an effective learning model because an effective learning model can create a complete, interactive, and creative learning atmosphere, making it easier for students to master the learning content (Pertiwi et al., 2024).

Integration of technologies such as Virtual Reality and e-learning platforms has great potential in increasing student engagement in scientific literacy (Mujakir et al., 2024). Contextual collaborative learning based on ethnoscience has been shown to improve students' scientific literacy skills in terms of content, process, and attitude (Dewi et al., 2021). A quasi-experimental study using engaging and contextual digital comics improved students' scientific literacy in the experimental class compared to the control class (Fitria et al., 2023).

The learning materials presented in class tend to be abstract and less contextual, so students often have difficulty linking scientific knowledge to everyday reality (Honig et al., 2024). Therefore, innovation is needed in the development of more contextual biology teaching materials. One of them is through the integration of ethnoscience into the classroom, that is based on indigenous knowledge and traditional wisdom. This contextual approach is believed to provide a more meaningful and relevant learning experience for students. By utilizing the indigenous knowledge of *Mangeppi Agara*, it is hoped that students can better understand the biological concepts taught in schools, especially those related to plant growth and development. In addition, through the integration of ethnoscience, students will also better understand how modern science can go hand in hand with traditional practices that have long existed in society.

Conclusion

Based on the results of the study and data analysis, the virtual laboratory using the Etnosains concept "*Manggeppi Agara*" had an impact on students' digital literacy and science literacy. This study is expected to contribute to improving the quality of biology learning designs. With the development of virtual laboratories, this knowledge can be documented and accessed digitally, allowing valuable local knowledge to be preserved and learned by younger generations within the context of formal education. These virtual laboratories enable students not only to learn biological concepts but also to understand cultural values and local wisdom through interactive simulations, which are relevant to improving students' scientific and digital literacy.

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