AUGMENTED REALITY MEDIA TO ENHANCE DIGITAL LITERACY AND EXPLANATION SKILLS OF HIGH SCHOOL STUDENTS ON VIRUS MATERIAL

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Abstract. This study aimed to assess the effectiveness of Augmented Reality (AR)-based learning media in enhancing students' digital literacy and explanatory skills, focusing on the topic of Viruses and Their Roles. A quasi-experimental design was implemented, involving two groups: an experimental group using AR media and a control group using PowerPoint presentations. The research adopted a Nonrandomized Control Group Pretest-Posttest Design, with cluster random sampling employed for participant selection. Validated written tests, analyzed using the RASCH model, were utilized to measure digital literacy and explanatory skills. Data analysis involved ANCOVA to examine post-intervention differences between the groups. Preliminary tests confirmed that the data were normally distributed and exhibited homogeneous variances. The ANCOVA results revealed a significant positive impact of AR media on students' digital literacy and explanatory skills compared to PowerPoint, with a significance level of 0.001 ($<\alpha = 0.05$). The AR media group showed higher average post-test scores, indicating its effectiveness in fostering these skills. In conclusion, AR-based learning media offers substantial advantages over traditional PowerPoint in improving students' digital literacy and explanatory skills, making it a highly effective and recommended tool for biology education.

Keywords: Augmented Reality, Learning Media, Digital Literacy, Explanation

INTRODUCTION

The 21st century, often referred to as the knowledge era, is characterized by a strong reliance on knowledge in various aspects of life. In this period, efforts to meet needs are increasingly based on knowledge: education is guided by knowledge-based approaches, economic growth is driven by knowledge-based economies, social development focuses on knowledge-based empowerment, and industrial progress relies on knowledge-based industries (Mukhadis, 2013).

He Partnership for 21st Century Learning (AACTE & P21, 2010) introduced a framework identifying essential skills for students to thrive in modern education. These skills include: (1) critical thinking and problem-solving; (2) effective communication and teamwork; (3) creativity and innovation; (4) literacy in information and communication technologies (ICT); (5) contextual learning abilities; and (6) proficiency in information and media literacy (BNSP, 2010).

21st-century skills are a primary focus in creating learning environments that support the enhancement of digital literacy (Moon et al., 2020). Digital literacy encompasses the ability to use digital tools and facilities to identify, access, manage, integrate, evaluate, analyze, and synthesize digital resources, as well as to build new knowledge (Martin & Grudziecki, 2006). It also includes the skills to recognize information obtained through computer networks and the ability to utilize information in the digital era (Park et al., 2020).

Digital literacy refers to the capacity to effectively utilize digital devices and communication tools, such as computers, laptops, tablets, or smartphones, to access, evaluate, manage, and share information, as well as to create new knowledge and communicate responsibly with others (Martin,

2008). Digital literacy encompasses six main aspects: 1) Accessing: The skill of identifying information sources and retrieving relevant data. 2) Managing: The ability to organize and structure information from credible sources. 3) Evaluating: The competence to judge the relevance, quality, utility, and efficiency of gathered information. 4) Integrating: The capability to synthesize, summarize, compare, and differentiate information from diverse sources. 5) Creating: The skill to produce new knowledge by adapting, applying, or designing information. 6) Communicating: The ability to share or present information effectively using suitable media (Karpati, 2011).

According to (Facione, 2015), critical thinking skills can be assessed through several key indicators: explanation, interpretation, analysis, evaluation, inference, and self-regulation. Explanation involves a student's ability to present arguments supported by data or evidence. This includes clarifying cause-and-effect relationships within a problem, articulating the outcomes of investigations, and forming well-grounded opinions. It also entails providing logical reasons for conclusions based on specific theories or materials (Agustine et al., 2020; Rahmawati et al., 2019; Solikhin & Fauziah, 2021). Moreover, the explanation indicator reflects the capacity to assess or determine the validity of an idea by applying specific principles or theories in a systematic and conceptual way. This skill highlights a student's methodological approach to reasoning and their ability to substantiate their conclusions effectively (Cahyani et al., 2021; Sanjaya & Ratnasar, 2021; Syafitri et al., 2021).

Augmented Reality (AR) integrates 3D virtual objects into a device's display, blending them with real-world environments to enable real-time interaction, facilitated by computer technology (Afissunani et al., 2014). The primary purpose of AR is to allow users to view and interact with virtual objects as if they are part of the real world. This technology provides specific information in a virtual format and displays it in the real world using devices such as webcams, computers, Android smartphones, or specialized glasses (Lorena et al., 2017). In essence, AR serves as a tool for delivering information by projecting digital content, such as 2D or 3D objects, into the physical world, enhancing the user's perception and interaction with their environment.

Augmented Reality (AR) technology is widely used in various sectors, including education, where it serves as a medium for presenting learning materials or information through animated visuals. The integration of AR into the educational process has both strengths and limitations. According to (Mustaqim & Kurniawan, 2017), AR has several advantages: AR provides several key advantages :

1) Promotes Active Interaction: Encourages more intensive engagement between users and the content. 2) High Effectiveness: Proves to be highly effective in educational applications.3) Versatile Integration: Can be adapted to a variety of media formats. 4) Simplifies Modeling: Facilitates object modeling by showcasing selected elements. 5) Cost-Effective: Offers economical production compared to other technologies. 6) User-Friendly: Easy to operate, making it accessible to diverse audiences. These benefits underscore the potential of AR technology as a valuable tool for enhancing the learning experience.

This study aims to design and develop learning media that enhance digital literacy and explanatory skills, specifically focusing on 2D PowerPoint presentations and 3D Augmented Reality (AR) technology for the topic of viruses and their roles. These media are implemented across two research groups. The innovation of this study lies in utilizing 3D AR technology as a novel approach to improving students' digital literacy and explanatory capabilities.

RESEARCH METHOD

This study adopts a quasi-experimental research approach, involving two groups: a control group and an experimental group. The control group utilizes PowerPoint as the instructional medium, whereas the experimental group employs augmented reality (AR) technology. The research design follows a Nonrandomized Control Group Pretest-Posttest format, allowing for the assessment of differences in outcomes between the two groups before and after the intervention. The research design framework is presented in Table 1

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Table 1. Research Design

Kelompok	Pretest	Variabel	Posttest
P	Y_1	X	Y_2
K	Y_1	-	Y_2

Explanation:

P = Experimental class (treatment group)

K = Control class

Y1 = Pretest scores for digital literacy and explanation skills

Y2= Posttest scores for digital literacy and explanation skills

X = Treatment using Augmented Reality media

The study population comprises 10th-grade students from a high school in Indonesia, with a total of 109 students divided into three classes: X1, X2, and X3. The sample was selected using a cluster random sampling technique, which involves choosing groups rather than individual students, ensuring all members of the population have an equal chance of selection. Before the study, an equivalence test was conducted to ensure there were no significant differences among the classes. The results confirmed that all classes were comparable, allowing any group to serve as a research sample. Classes X1 and X3 were ultimately chosen, with a total of 73 students participating—35 students from Class X1 and 38 students from Class X3.

Data on digital literacy and explanatory skills were gathered through a written test consisting of six cognitive questions, each with a maximum score of four points. These questions were specifically designed to evaluate students' digital literacy and explanation abilities, based on established indicators. The test instrument underwent validation by expert item developers and was piloted with students. Its suitability was assessed using RASCH analysis. The results of the validity test indicated that all test items for digital literacy and explanation met the necessary conditions, confirming that each item was of good quality and appropriate for measuring the targeted skills. Additionally, the questions were tested for reliability and were found to be both valid and reliable for assessing students' competencies.

The data on digital literacy and explanatory skills were analyzed using Analysis of Covariance (ANCOVA). Descriptive results from the inferential statistical analysis were used to evaluate the effectiveness of augmented reality learning media, based on a problem-solving framework, in enhancing digital literacy and explanatory skills. The ANCOVA was conducted with a significance level set at 5%.

For ANCOVA to be valid, certain assumptions must be met, including the data being normally distributed and having homogeneous variances. The ANCOVA test was carried out after conducting prerequisite tests, such as normality and homogeneity tests, to ensure these assumptions were satisfied.

RESULT AND ANALYSIS

The results of the prerequisite tests confirmed that the samples used in the study were normally distributed and homogeneous, which enabled the use of the parametric statistical test ANCOVA for further analysis. Digital literacy and explanatory skills were analyzed using ANCOVA, with the analysis conducted using SPSS 27. The findings from the ANCOVA test, which evaluated the digital literacy and explanation scores as well as the types of learning media used, are presented in Table 2.

The results of the ANCOVA test show a significance value of 0.001 (<α = 0.05), leading to the rejection of the null hypothesis (H0). This indicates that there is a significant difference between the pretest and posttest scores for digital literacy and explanation skills, which is attributed to the different types of learning media used. Augmented Reality (AR) learning media had a significant impact on enhancing students' digital literacy and explanation skills. This is reflected in the differences in average post-test scores, as well as the range of scores from the post-test follow-up analysis, which are presented in Table 3.

Table 2. ANCOVA Test Results

Source	Type III Sum of Squares	df	F	Sig.
Corrected Model	2629.518[a]	2	1314.759	0.001
Intercept	5895.062	1	5895.062	0.001
Pretest (covariat)	1916.801	1	1916.801	0.001
Class	515.371	1	515.371	0.001
Error	1685.441	70	24.078	
Total	456596.000	73		
Corected Total	4314.959	72		

a. R Squared = 0,145 (Adjusted R Squared = 0,120)

Table 3. Post Hoc Test Results

Kelas	Average	Std. Error (SE)	95% Average Accuracy	
			Lowest	Highest
Eksperimen	81.569[a]	0.843	79.887	83.251
Control	76.222[a]	0.787	74.652	77.792

The significant findings from the ANCOVA test were further examined through post hoc tests to identify the specific differences in students' digital literacy and explanation skills. The experimental class using AR Media achieved higher average scores for digital literacy and explanation skills compared to the control class, which did not use AR Media. The average score for the experimental class was 81.57, while the control class had an average score of 76.22.

AR Media, based on Assembler Edu, offers advantages over traditional printed modules in enhancing students' digital literacy (Nielsen et al., 2016). The use of AR media in the experimental group resulted in a more significant improvement in digital literacy compared to the control class.

Augmented Reality is particularly useful for visualizing the shapes of viruses, such as HIV, Influenza, bacteriophage, and others. Since viruses cannot be directly observed, their representation through AR technology provides students with a realistic view of their structures. This visualization helps students better understand the characteristics and structures of various viruses, allowing them to differentiate between the features of different viral types.

Augmented Reality (AR) can enhance digital literacy and explanation skills. Several characteristics of AR that empower the improvement of digital literacy and explanation include:

1.1. Augmented Reality (AR) media plays a crucial role in connecting content and context in learning materials (Kamarainen et al., 2018). It assists students in evaluating information and providing explanations related to the topics or problems being studied. AR acts as a bridge, enabling students to visualize the relationship between the content of the lesson and its real-world context (Fonseca et al., 2014). This enhances their understanding and helps contextualize the material, making the learning experience more meaningful and interactive.

1.2. Augmented Reality (AR) media supports student reasoning and the investigation of phenomena, which are essential for developing strong explanation skills (Kyza & Georgiou, 2019). Reasoning and investigation play a critical role in students' ability to explain concepts effectively. AR media provides students with interactive visualizations that aid in their reasoning processes, allowing them to explore and understand the material more deeply (Syawaludin et al., 2019). By engaging with these visualizations, students can investigate complex concepts and phenomena, enhancing their explanatory abilities.

1.3. Augmented Reality (AR) facilitates the collection of data from hard-to-reach information, making it easier for students to access and interact with complex concepts (Georgiou & Kyza, 2021). The data obtained through AR can be used as evidence to support logical reasoning, helping students build explanations and find solutions to problems encountered during the learning process. This ability to visualize and engage with otherwise inaccessible or abstract information enhances students' understanding and problem-solving skills.

1.4. Augmented Reality (AR) assists in demonstrations during teacher or student explanations, providing a more effective and clear presentation of concepts (Chen et al., 2017). Compared to other media, including 3D formats, AR can depict demonstrations with greater clarity (Radu, 2014). hese demonstrations enhance students' understanding of processes and phenomena (Enfield, 2013), enabling them to more effectively access, manage, evaluate, and describe the results. By visualizing complex concepts, AR helps students grasp difficult material, improving their overall comprehension and explanatory skills.

1.5. Augmented Reality (AR) allows students to engage in authentic learning by providing real-world contexts and experiences (Chin & Wang, 2021). AR media is designed using authentic sources, enabling students to identify reliable information sources and apply techniques for gathering and retrieving data. This approach fosters a deeper understanding of the subject matter, encouraging students to interact with real-world scenarios and hone their research and critical thinking skills in an immersive learning environment.

One of the key applications of technology in creating interactive learning media based on the real environment is Augmented Reality (AR). According to Bowers (Nazilah & Ramdhan, 2021), AR is a technology that merges virtual objects (2D or 3D) with the real world by projecting these objects digitally in real-time. An example of an application that utilizes AR technology is Assemblr Edu, which enhances learning experiences by integrating digital content with real-world environments.

Assemblr Edu is an application designed to create interactive and engaging three-dimensional (3D) and Augmented Reality (AR) content by combining various available objects. This platform is suitable for use by teachers, educators, developers, and learners. It includes tools that allow users to manage, store, and share the content they create, fostering collaboration among educators. Additionally, Assemblr Edu enables the evaluation of learners' performance by incorporating questions or quizzes into the AR content, making it a versatile tool for both teaching and assessment (Chairudin et al., 2023).

Based on the explanation above, it can be concluded that the use of Augmented Reality (AR) media in teaching the topic of viruses and their roles significantly enhances students' digital literacy and explanation skills. This conclusion is supported by previous research (Aygina et al., 2023), which found a positive relationship between the application of augmented reality and attitudes toward digital learning. The role of AR-based interactive multimedia can also be seen in promoting critical

thinking. AR-based multimedia helps students locate and analyze data or information that deepens their understanding of the material, such as the structure of the Earth and rocks, thereby supporting the development of their critical thinking skills (Chang & Hwang, 2018; Mustaqim & Kurniawan, 2017; Sirakaya & Alscancak, 2018; Yuliono et al., 2018).

The results of this study align with previous research focused on enhancing critical thinking skills. Textbooks incorporating augmented reality technology on the digestive system concept have been shown to improve high school students' ability to analyze problems related to digestion (Amir. Isnawati, 2017; Nur, 2015). Similarly, AR-based interactive learning media has also been found to enhance problem-solving skills in high school students studying chemical bonding (Nur, 2015). Augmented Reality media has been shown to stimulate critical thinking by encouraging students to analyze and reason through problems (Mustaqim, 2016).

AR technology aids in understanding the spatial relationships between components. A study by (Deshpande & Kim, 2018) found that the use of AR improves the ability to solve spatial problems, which is particularly useful in technical tasks like object assembly. By presenting 3D objects in real-time through AR cameras, students can better engage with and solve complex problems. Furthermore, AR-based interactive multimedia can facilitate interactive learning by providing immediate feedback in the form of ideas, arguments, data interpretation, explanations, and problem-solving outcomes, particularly in topics like the Earth's structure and rocks.

The use of Augmented Reality (AR) media on the topic of Viruses and Their Roles has proven effective in enhancing students' digital literacy and explanation skills, as demonstrated by the ANCOVA test results with a significance value of 0.001. The experimental class, which used AR media, achieved an average post-test score of 81.57, while the control class, which did not use AR media, had an average post-test score of 76.22. This indicates that AR media had a significant positive impact on students' learning outcomes in terms of digital literacy and explanatory abilities.

CONCLUSION

The results indicate that the development of augmented reality (AR) learning media holds significant potential for improving students' digital literacy and explanation skills compared to traditional PowerPoint-based learning media. AR media has been shown to significantly enhance students' digital literacy and explanatory abilities, providing a more interactive and engaging learning experience that fosters better understanding and skill development.

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