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Enhancing Digital Literacy of Pre-Service Science Teachers in Indonesia Through Real Science Mask with QR Code Integrated E-Module

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ABSTRACT: Technology development in the digital era has encouraged the birth of virtual learning media that allow students to access science materials digitally. However, physical media is still needed to attract attention and increase student engagement. This study developed a Real Science Mask with a QR Code integrated with an e-module as an innovative hybrid learning media. The artistic mask is used for role-playing in learning, while the QR Code provides access to an interactive e-module. Using e-modules also supports environmentally friendly education programs by reducing paper use. This study aims to evaluate this media's effectiveness in improving prospective science teachers' digital literacy. The case-based learning method was applied to the Basic Biology II course in the Science Education Study Program at Semarang State University in the 2024–2025 academic year. The sample was divided into experimental and control classes. The instrument used to measure digital literacy has been validated, and data analysis was carried out quantitatively. The results showed that the experimental class's N-gain was 0.77 (high) and the control class's was 0.24 (low). The results of the Independent Sample T-Test statistical test showed a significance value of 0.000 <0.05, which means there is a significant difference between the two groups.

KEYWORDS: digital literacy, pre-service science teacher, RSM

I. INTRODUCTION

Indonesia entered the Industrial Revolution 5.0, a continuation phase of the Industrial Revolution 4.0. This revolution emphasizes harmonious collaboration between humans and intelligent technology, such as artificial intelligence (AI) and collaborative robots (cobots). Different from the previous era, which focused on automation and efficiency (Engelbrecht, Yitmen, and Almusaed 2024). Revolution 5.0 places humans at the center of innovation to create a more personal, ethical, and sustainable system. In this era, technology is designed to strengthen creativity and human values, not replace the role of humans. Its characteristics include mass product customization, the application of environmentally friendly technology, and the integration of ethical values and social responsibility in every technological development (Muliani et al. 2021). The implementation of the Industrial Revolution 5.0 can be found in health, education, and manufacturing, where technology is used to support human decision-making and improve overall well-being. Although it brings many opportunities, this revolution faces challenges such as the digital divide, the need for new skills, and digital ethics issues (Anggraeni 2019). Overall, the Industrial Revolution 5.0 is here to create a balance between technological progress and the interests of humanity and the environment. An era that prioritizes intelligence from technology to help ease human work. Technological sophistication can also be utilized in the world of education, namely in terms of utilizing learning media that collaborate with cyber technology and media digitalization technology (Sudarsana et al. 2020). This can be seen from the many digital references presented in paperless form, for example, e-books, online journals, and several learning applications on laptops and smartphones. Efforts are being made to transition learning media from paper-based to digital, which is paperless, so that it is environmentally friendly. The use of digital media will reduce the consumption of paper as a print medium, so it will help reduce tree felling as a raw material for paper. In addition, the use of online-based learning resources makes it easier for students to be able to carry out learning anywhere and anytime (Ulukhanov and Khusayinova 2024).

Continuous technological changes in the world of education require the digitalization of education (Schmidt and Tang 2020; Prokopenko 2021). This requires human resources who are able to access technology in learning. Indonesia must improve its readiness to face the Industrial Revolution 5.0 in terms of human resources (HR) and infrastructure in order to compete with other countries. A dynamic learning culture means that learning is not limited to one field of expertise, and learning can be done anywhere and anytime. College graduates will later be required to be able to master various fields of science and be flexible in developing independence in seeking and finding knowledge. To seek and find knowledge in the current era of the Industrial Revolution 5.0, good digital literacy skills are needed (Petrusevich 2020; Griban, Griban, and Korotun 2019; Nadrljanski, Nadrljanski, and

Pavlinović 2022). Digital literacy is an individual's interest, attitude, and ability to use digital technology and communication tools to access, manage, integrate, analyze, and evaluate information, build new knowledge, and create and communicate with others to participate effectively in society (Silamut and Petsangsri 2020).

Digital literacy is an individual's ability, attitude, and skills to use digital technology to access, manage, analyze, and create information ethically, responsibly, and participate effectively in society (Peng and Yu 2022). Digital literacy is also defined as the ability of a person to understand and utilize information from a wide range of sources in various formats accessed via gadgets (Giovanni and Komariah 2019). Digital literacy is used to sort through various information, interpret messages, and communicate effectively with others (Restianty 2018).

The widespread and free use of information technology must still take into account norms, ethics, and culture (Suherdi 2021). Digital literacy can be an indicator for training the abilities, competencies, and ICT (Information and Communication Technology) skills needed to adapt to the technological era (Naila, Ridlwan, and Haq 2021). Digital literacy, when applied in various contexts, both in schools, families, and communities, is also considered capable of driving the progress of society in the 21st century (Sujana and Rachmatin 2019).

Measurement of digital literacy is explained in Digital Literacy Across the Curriculum, which consists of 8 components of digital literacy, namely: Functional Skill and Beyond, Creativity, Collaboration, Communication, The Ability to find and select Information, Critical Thinking and Evaluation, Cultural and Social Understanding, and E-Safety (Hague and Payton 2022). The dimensions and indicators of digital literacy are presented in Table 1.

Table 1. Dimensions and Indicators of Digital Literacy Measurement (Hague and Payton 2022)

Dimensions	Indicator
Functional Skill and Beyond	ICT Skills Ability
Creativity	1. Product creation or output in various formats and models by utilizing digital technology 2. Creative and imaginative thinking skills, including planning, weaving content, exploring ideas, and controlling the creative process
Collaboration	1. Ability to participate in digital space 2. Able to explain and negotiate ideas with others in the group
Communication	1. Able to communicate through digital media 2. Ability to understand and comprehend the audience
The Ability to Find and Select Information	Ability to search and select information
Critical Thinking and Evaluation	Able to contribute, analyze, and sharpen critical thinking when dealing with information
Cultural and Social Understanding	In line with the context of social and cultural understanding
E-safety	Ensuring security when users explore, create, collaborate with digital technology

Literacy is not just reading or writing, but digital literacy is the knowledge and skills to use digital media, communication tools, or networks to find, evaluate, use, create information, and utilize it in a healthy, wise, intelligent, careful, precise, and legally compliant manner in order to foster communication and interaction in everyday life (Mauludin and Cahyani 2018; Farias-Gaytan, Aguaded, and Ramirez-Montoya 2022). In Indonesia, there has not been much research that examines digital literacy (Mujtahid et al., 2021). Previous research has focused more on information, media, and ICT literacy in particular community groups in several regions of Indonesia (Luthfia et al. 2021; Naila, Ridlwan, and Haq 2021). Digital literacy competencies are useful for dealing with information from various digital sources that continue to develop along with the development of information and communication technology as a result of the media convergence phenomenon. (A'yuni 2015; Syah, Darmawan, and Purnawan 2019; Fatchan, Soekamto, and Yuniarti 2015).

Science learning provides various learning experiences to understand scientific concepts and processes that are developed through analytical, inductive, and deductive thinking skills to solve problems related to events that occur in the natural environment (Russell and Martin 2023). The concept of natural science is based on observations of phenomena that occur in living things and their environment; some things that are observed cannot be seen with the naked eye during learning (Luft et al. 2022). Real Science Mask with QR Code integrated e-module is a learning media in the form of a mask containing unique images of science material that is connected to the e-module with the help of a unique code in the form of a QR Code. The use of a Real Science Mask with a QR Code integrated e-module is expected to facilitate learning activities to concretize a science concept that is still abstract and

cannot be observed directly. Its use connected to the e-module can provide unlimited access in the learning process, so that learning can be done anywhere and anytime without having to carry large paper books. Based on the background that has been described, the purpose of this study is to analyze the effectiveness of the use of Real Science Mask with QR Code integrated E-module learning media to improve the digital literacy of prospective science teacher students.

Research on the development of science learning media, both those based on digital technology, has been widely carried out previously. Utami & Asri Hardini (2021) has developed Digital Literacy Learning Media Based on Educational Games. Panjaitan et al., (2020) has researched Animation Digital Learning Media. Mulyaningsih & Saraswati (2017) Developing Digital Learning Media Books With Kvisoft Flipbook Maker. Printina (2017) has developed Exelsa Moodle Digital Learning Resources and Toondo Comics. Riwanto & Wulandari (2019) have developed Digital Comic media (Cartoon Story Maker). These studies are still focused on the application of digital learning media only and have not yet collaborated with an interesting work of art such as Real Science Mask. In its development, researchers adopted the importance of an interesting and innovative art media that can be mass-produced and can be used by students as a learning medium. Real Science Mask with QR Code integrated e-module requires good digital literacy skills in facing the Industrial Revolution 5.0 in the field of education. The results of research that takes the theme of digital literacy have been carried out by several researchers, including research on increasing digital literacy that can be done using the Technology-Embedded Scientific Inquiry Learning Model. (Nurhcayo 2016). In addition, research uses the Science Technology Society learning model to determine its influence on science learning outcomes in terms of digital literacy (Jayanti, Aryana, and Gunamantha 2017). Science literacy can be trained using Schoology-based e-learning (Pratama, Hartini, and Misbah 2019). The use of website-based learning media can also improve students' digital literacy skills in physics learning (Rahayu, Mayasari, and Huriawati 2019; Ramdani, Syukur, and Restu 2024). The research conducted also utilizes IT (technology)-based learning media. The learning media used is a Real Science Mask with a QR Code integrated with an e-module, in the form of a mask containing unique images of science material connected to the e-module. Real Science Mask with QR Code integrated with e-module as a learning media, specifically designed to improve the digital literacy of science students, has been validated by experts, and its readability has been tested. Therefore, research is needed on the use of engaging and effective learning media, such as Real Science Mask with QR Code integrated with an e-module, to improve the digital literacy of prospective science teacher students. This research was conducted in an effort to meet these needs.

II. METHODS

This research uses an experimental method to test the corelation between variables influencing treatment in controlled conditions (Creswell 2011; Sugiyono 2013). The research used this method to select two randomly selected classes as samples. This study tested two classes: the experimental class that implemented problem-based learning with RSM media with QR Code integrated with E-module, and the control class as a comparison that implemented inquiry-based learning with virtual animation methods. Learning was carried out in several stages, namely: (1) orientation; (2) practice, namely each class applied the intended method; (3) experiment, namely the experimental class used virtual experiments and the control class used discovery; and (4) evaluation through tests. The aspects observed during learning were digital literacy skills, which were tested through tests. The test questions were made based on the digital literacy assessment indicators put forward by Hague & Payton (2022) which includes (1) being able to create products or outputs in various formats and models by utilizing digital technology; (2) being able to think creatively and imaginatively, including planning, weaving content, exploring ideas, and controlling the creative process; (3) being able to participate in digital space; (4) being able to explain and negotiate ideas with others; (5) being able to communicate through digital media; (6) being able to understand and comprehend the audience; (7) being able to search for and select information; (8) being able to contribute, analyze and sharpen critical thinking when dealing with information; (9) in line with the context of social and cultural understanding; (10) being able to guarantee security when users explore, create, collaborate with digital technology. This study uses a True Experimental Design with the Pretest-Posttest Control Group Design type.

According to Creswell (2011) in this type of research design, there are two groups that are selected randomly and then given a pretest to determine the initial state of student abilities between the experimental class and the control class. The subjects of this study were students of the UNNES Science Education Study Program who took the Basic Biology II course. The research sample was selected using simple random sampling, which is a sampling technique that ignores the strata in the population (Datey and Kuthe 2015; Sugiyono 2013). The data collected includes aspects of digital literacy skills. Data collection techniques include: (1) initial surveys on the population to determine samples in both classes; (b) implementation of learning in control and experimental classes; (c) data collection by collecting digital literacy skill scores using tests that meet digital literacy indicators. Before the study was conducted, a homogeneity test was conducted with homogeneous results, meaning that the data had the same or relatively similar variance between the experimental and control classes.

III.RESULTS AND DISCUSSION

Digital literacy skills were measured through two tests in each class, namely the initial test and the final test. The data obtained were then tested for normality, and the results showed that the data were normally distributed. Furthermore, to determine the average difference between the two classes, the N-gain test and t-test were carried out using SPSS version 23. The N-Gain results for the average of both classes are presented in Table 2.

Table 2. The Results of N-gain's Pretest and Posttest

Class	Mean		Gain Score	Criteria
	Pretest	Posttest		
Experiment	63,44	91,68	0,77	High
Control	62,56	71,68	0,24	Low

Based on Table 2, the experimental class's N-gain was 0.77 (high) and the control class's was 0.24 (low). Higher increases in the experimental class occurred due to the use of RSM media with QR Code integrated with the E-module. This reversed the control class, which employed an animation learning video. The results of the study showed that the use of Real Science Mask with QR Code media integrated with e-modules significantly improved the digital literacy skills of prospective science teacher students. This was evidenced by an increase in the average value of the experimental class of 87.86 compared to the control class, which only reached 73.86. In addition, the results of the N-Gain test showed a high increase in the experimental class (0.77) and a low increase in the control class (0.24). This difference indicates that the learning media used in the experimental class provided a more meaningful learning experience and encouraged active student involvement in accessing, evaluating, and producing digital information.

This can happen because the Real Science Mask with QR Code learning media integrated with e-modules has the advantage of presenting interactive, multisensory, and contextual learning experiences, directly facilitating the improvement of students' digital literacy. Artistic masks function as concrete media that can be touched, seen, and used directly by students through role-playing activities. At the same time, QR Codes connect users with digital content in the form of interactive e-modules. This integration simultaneously stimulates cognitive, affective, and psychomotor involvement so that understanding of concepts becomes stronger and deeper.

E-modules connected to QR Codes allow students to access materials anytime and anywhere without being limited by time or place. This flexibility encourages independent learning and fosters the ability to search, select, and evaluate information digitally. Masks containing images of science materials are designed creatively and visually, which helps students visualize abstract concepts in science. This visualization increases students' interest and focus on the material while supporting critical and reflective thinking processes. Problem-based learning applied in experimental classes allows students to discuss, present ideas, and work together in teams. These activities strengthen aspects of digital literacy, such as communication, collaboration, and technological skills. Unlike passive animated videos in the control class, RSM media invites students to participate actively in the learning process. Interactive activities such as scanning QR codes, opening digital modules, and working on technology-based assignments encourage them to be more skilled in using and managing digital information. In other words, media that is designed to be interesting, relevant, and technology-based directly forms a learning environment that supports the development of digital literacy, especially in the context of science education, which often requires the concretization of abstract concepts.

The experimental class that used Real Science Mask not only integrated technological elements through QR Code but also combined it with aspects of art and physical involvement (role-playing), thus creating a fun, concrete, and contextual learning atmosphere. This media effectively facilitates access to learning without space and time limits to the demands of learning in the Industrial Revolution 5.0 era. Meanwhile, the control class that used the virtual animation learning method was less able to trigger an equivalent increase because it did not involve direct interaction or real learning experiences.

The significance of the difference between the two classes was revealed through an Independent Sample Test, which was used to determine the significance of the discrepancy. The Independent Sample Test results of the experimental and control classes' posttest were displayed in Table 3.

Table 3. The Independent Sample Test Results of the Experimental and Control Class' posttest

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	.912	.344	24.312	48	.000	52.72377	2.16868	48.36336	57.08418
	Equal variances not assumed			24.312	45.560	.000	52.72377	2.16868	48.35732	57.09022

The results of the Independent Sample T-Test statistical test showed a significance value of 0.000 <0.05, which means there is a significant difference between the two groups. This finding strengthens the idea that using innovative digital-based media combined with creative approaches such as Real Science Mask can effectively improve students' digital literacy competencies. The digital literacy in question includes technical skills in using information technology, the ability to search for and evaluate information, and aspects of communication, collaboration, and digital security, as measured by the Hague & Payton (2022) indicators. Overall, this study's results align with previous studies that emphasize the importance of technology-based learning media in supporting the development of 21st-century skills. However, innovation in the form of physical and digital media integration, as carried out in this study, provides a new contribution to the development of learning media that is not only adaptive to technology but also fun and pedagogically meaningful.

This result was obtained because the Real Science Mask with QR Code media integrated with the e-module was able to create an active, interactive, and meaningful learning experience. Students receive the material passively and are directly involved in the learning process through activities such as scanning QR Codes, accessing digital e-modules, and using masks as visual aids in role-playing. This process naturally trains students' digital skills, from technical skills in using devices and searching for and evaluating information to communicating and collaborating digitally. Case-based learning also encourages students to think critically and creatively in solving problems, according to the digital literacy indicators developed by Hague and Payton (2022). In addition, flexible access to materials through digital devices makes students accustomed to learning independently and increases their awareness of the importance of ethics and safety in using technology. Thus, this media's combination of creative approaches and digital technology effectively forms comprehensive digital literacy competencies in prospective science teacher students.

IV. CONCLUSION

The use of Real Science Mask with QR Code media integrated with e-modules has proven effective in improving the digital literacy of prospective science teacher students. This media can combine visual, interactive, and digital elements harmoniously, thus creating an active, enjoyable, and meaningful learning experience. The study showed a significant increase in the digital literacy skills of students who used this media compared to conventional animation-based learning methods. The digital literacy developed includes technical skills in using technology, the ability to evaluate and manage digital information, and aspects of communication, collaboration, and digital security. Thus, this innovative learning media can be a strategic alternative in facing education challenges in the Industrial Revolution 5.0 era, which demands mastery of technology and 21st-century skills.

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