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Developing and Evaluating Digital Learning Integration to Improve Students' Digital Literacy in High School Biology

Vonny Martha*[1], Ahmad Romadhoni[2], Ika Priantari[3]
[1,2,3] Universitas Muhammadiyah Jember, Indonesia

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Abstract (11 pt)

The rapid advancement of information technology requires students to develop strong digital literacy, particularly in subjects like Biology that increasingly utilize digital media. This study aims to develop and evaluate a digital learning integration model designed to improve high school students' digital literacy in Biology learning. Using a Research and Development (R&D) approach, the model was created and tested on 142 eleventh-grade students at SMAN Pakusari. Data collection involved a validated digital literacy questionnaire, Biology comprehension tests, and classroom observations. Results showed that the digital learning integration model was successfully implemented and well-received by both students and teachers. Statistical analysis revealed a significant improvement in students' digital literacy, with an average score of 77%, and 95% of students classified as highly proficient. In addition, students demonstrated enhanced understanding of Biology concepts following the intervention. These findings indicate that integrating digital learning effectively enhances digital literacy while simultaneously improving subject matter comprehension. The study recommends adopting this model as an innovative approach in Biology education to equip students with essential digital skills and better prepare them for the demands of the digital era.

Corresponding Author: Vonny Martha
Email: vonimarta3@gmail.com

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1. INTRODUCTION

The development of information and communication technology has brought significant changes in various aspects of life, including education. Digital literacy has become an essential competence that learners must possess to adapt and competen in today's digital era (Lim & Tan-Chia, 2022; Nopitasari et al., 2023). Digital literacy not only involves technical skills in using digital devices but also critical abilities to evaluate, manage, and produce information ethically and effectively (Alsowat, 2022). In Indonesia, the government

has responded to this need by introducing the Independent Curriculum (*Kurikulum Merdeka*), which emphasizes competency-based, student-centered learning and the optimal use of digital technology (Edgel et al., 2021; Supriyadi, 2022).

The Independent Curriculum is an educational innovation that emerged amid the challenges of the Covid-19 pandemic, where online learning became the main mode of instruction (Frison, 2023). This curriculum emphasizes learning focused on essential material and core competencies, including the development of strong digital literacy and numeracy skills (Nopitasari et al., 2023). Through project-based and contextual learning approaches, the Independent Curriculum provides opportunities for students to actively explore current issues, enhance character building, and develop the profile of Pancasila Students who have integrity and adaptability to changes (Fatqurhohman, 2025; Hannigan et al., 2022).

Although digital literacy is increasingly gaining attention, research on the development and evaluation of digital technology integration in Biology learning at the senior high school level remains relatively limited (Sukma et al., 2024). Most previous studies focus on digital literacy in general without directly linking it to specific subjects such as Biology, which has unique characteristics and requires mastery of concepts as well as the application of technology for experiments and simulations (Amin et al., 2023; Rosyadi et al., 2022). Therefore, there is a significant gap in the literature regarding how integrated digital learning can specifically support the improvement of both digital literacy and conceptual understanding in high school Biology (Hafiza et al., 2022).

Furthermore, challenges in implementing digital learning technology are often found in the field, such as limited infrastructure, low students' digital literacy skills, and insufficient teacher readiness to use technology effectively (Fatqurhohman & Huda, 2025; Yusuf et al., 2022). These factors become major obstacles in realizing innovative and interactive Biology learning that prepares students for the demands of the 21st century (Cahya et al., 2023; Khotimah & Mangkurat, 2022). Hence, research is needed that not only develops digital learning models but also comprehensively evaluates their implementation in Biology instruction.

This study aims to develop and evaluate the integration of digital learning in Biology subjects at the senior high school level to improve students' digital literacy skills. Mastery of digital literacy will not only help students access and understand learning materials more effectively but also equip them with critical, creative, and collaborative thinking skills that are highly needed in the digital era (Hafiza et al., 2022; Sukma et al., 2024). This research is also expected to provide strategic recommendations for teachers and policymakers to optimize the use of digital technology in classrooms, making the learning process more effective and relevant to contemporary needs.

Theoretically, integrating digital technology in Biology learning not only enriches learning resources but also enables more contextual and project-based learning, potentially increasing students' motivation and learning outcomes (Santi, 2023; Sariam & Harahap, 2022). Moreover, digital learning supports the development of science literacy, defined as the ability to understand and apply scientific concepts in daily life, contributing to sustainable advancement in science and technology (Sirih et al., 2019). Therefore,

developing a learning model that combines digital literacy and Biology content is a strategic step in addressing educational challenges in the 21st century (Maharani & Irsadi, 2023; Rosyadi et al., 2022).

This research is relevant because there is still a lack of student understanding regarding the optimal use of digital technology for Biology learning. Additionally, literature specifically addressing the evaluation of digital learning integration in enhancing students' digital literacy in the context of high school Biology remains scarce. Thus, this study fills this gap and offers important contributions to the development of adaptive and technology-responsive education.

2. METHOD

This study employed a quantitative descriptive method to analyze students' digital literacy skills in Biology learning at SMAN Pakusari. The research was conducted from March 11 to March 24, 2025, at SMAN Pakusari. The population consisted of all tenth-grade students at SMAN Pakusari. The sample comprised students from classes X, totaling 142 students, selected through random sampling to ensure representativeness.

Data were collected based on students' learning experiences during several Biology lessons focused on the topic of Genetics. Each lesson lasted for two sessions of 40 minutes in a face-to-face learning format. During the learning process, students were encouraged to use search engines as part of their strategy to find relevant information and answer questions in the student worksheets (LKPD).

Data collection was carried out using an online digital literacy questionnaire distributed via Google Forms. The questionnaire consisted of 17 statements designed to measure students' digital literacy skills, particularly in using search engines within the context of Biology learning on genetics. The collected data were then analyzed descriptively and interpreted according to the study's objectives.

The questionnaire instrument was adapted from the digital literacy framework proposed by Gilster (1997), which includes four main dimensions: Internet searching, Hypertextual navigation, Content evaluation, and Knowledge assembly. The digital literacy questionnaire was validated and consisted of 17 statements deemed valid for use. Responses were measured using a 5-point Likert scale to assess the degree of agreement, enabling quantitative capture of variations in digital literacy skills.

The following is the instrument grid of the digital literacy questionnaire used in this study (Table 1).

Table 1. Pronunciation Scoring Rubric

No	Indicator	Number of questions
1	Internet Searching	5
2	Hypertextual Navigation	4
3	Content Evaluation	4
4	Knowledge Assembly	4
	Total	17

In this study, data were collected by administering a questionnaire to students who had undergone the treatment. The questionnaire employed a five-point Likert scale, ranging from Strongly Agree to Strongly Disagree. Each student's response, whether to positive or negative statements, was scored according to the Likert scale as outlined in Table 2.

Table 2. Likert Scale Score

Answers	Score	
	Positif	Negatif
Strongly Agree	4	1
Agree	3	2
Disagree	2	3
Strongly Disagree	1	4

3. RESULTS AND DISCUSSION

3.1. Results

This study aimed to assess the digital literacy skills of tenth-grade students at SMAN Pakusari in the context of biology learning, particularly focusing on their ability to utilize search engines for genetic material. Data were analyzed based on four indicators of digital literacy: internet searching, hypertextual navigation, content evaluation, and knowledge assembly. The results showed that students exhibited a high level of proficiency in all four indicators. The percentage scores for each indicator are presented in Table 1.

Table 3. Digital Literacy Ability Level

No	Indicator	Percentage	Category
1.	Internet Searching	77,2 %	Very good
2.	Hypertextual Navigation	77 %	Very good
3.	Content Evaluation	77 %	Very good
4.	Knowledge Assembly	77 %	Very good
Total		77 %	Very good

The average digital literacy score across all indicators was 77%, which falls into the "Very Good" category. This suggests that students possess adequate skills to effectively search for information on the internet, navigate hypertext links, critically evaluate digital content, and synthesize knowledge from various online sources. The high scores in the internet searching indicator (77.2%) reflect students' capability to efficiently locate relevant information using search engines, which is crucial for independent learning and problem-solving in biology. Similarly, their proficiency in hypertextual navigation (77%) indicates that students can successfully follow links and navigate through interconnected digital content, facilitating deeper exploration of genetic topics. Content evaluation, with a score of 77%, reveals that students are able to critically assess the credibility and relevance of the information they find online, an essential skill to distinguish valid scientific information from misinformation. Furthermore, the knowledge assembly score (77%) indicates students'

ability to integrate and organize the information they gather into a coherent understanding, supporting higher-order thinking skills necessary for mastering biological concepts.

These findings align with previous studies emphasizing the importance of digital literacy as a fundamental competence in 21st-century education (Gilster, 1997; Iman, 2022). The results also underscore the successful integration of digital tools within the biology curriculum at SMAN Pakusari, especially the use of search engines during guided learning activities. However, despite the overall positive results, it is important to consider that there is still room for improvement. Continuous efforts are needed to further enhance students' critical digital literacy skills, particularly in complex content evaluation and knowledge synthesis, to prepare them for increasingly digitalized academic and professional environments.

Table 4. Percentage of Digital Literacy Categories

No	Category	Percentage
1.	Very Good	95 %
2.	Quite Good	5 %

Based on the data presented in Table 4, it can be concluded that the majority of tenth-grade students at SMAN Pakusari demonstrate a very high level of digital literacy. Specifically, 95% of the students fall into the "*Very Good*" category, while only a small portion, about 5%, are categorized as "*Quite Good*". This indicates that most students have a strong understanding of and competence in effectively utilizing digital technologies. Further analysis of the four digital literacy competency aspects, internet searching, hypertextual navigation, content evaluation, and knowledge assembly, revealed that students have an overall average digital literacy score of 77%, which is classified as "*Very Good*".

This high level of competence is particularly attributed to their critical information processing skills. The students at SMAN Pakusari not only demonstrate proficiency in locating diverse and relevant sources of information but also exhibit advanced skills in critically evaluating and synthesizing the data they find online. They show the ability to assess the validity and credibility of digital content rigorously rather than relying solely on the top search results. This analytical approach includes actively cross-checking and comparing information from multiple perspectives.

Such habits of thorough verification have become an integral part of their learning process, enabling them to build deep and comprehensive understanding of the biological concepts studied, especially in genetics. These competencies equip students to confidently navigate the dynamic and rapidly evolving digital landscape in education. In summary, the findings underscore that the students' strong digital literacy skills support their effective engagement with digital tools in the biology learning context. This readiness is crucial for meeting the demands of 21st-century learning environments and preparing students for future academic and professional challenges in a technology-driven world.

3.2. Discussion

Literacy, broadly defined as an individual's ability to communicate effectively through reading, speaking, listening, and writing, varies according to the purpose and context of its

use. Its role is fundamental for human survival, enabling individuals to solve problems, analyze information, and comprehend messages critically (Nurhasanah et al., 2019; Rosyadi et al., 2022). Despite its importance, literacy, particularly reading interest, remains low in several regions, including Indonesia, which highlights the urgency of addressing literacy development comprehensively.

In the modern era, digital literacy has emerged as a crucial competency, especially in education. Digital literacy empowers students to access a vast array of information quickly and efficiently, regardless of time and location. Moreover, it supports learners who face challenges by enhancing learning quality and efficiency through digital media (Huang et al., 2023). Internet usage, a key component of digital literacy, involves not just data retrieval but also the ability to critically process and evaluate information found online.

The application of interactive multimedia technology in biology education, as observed in previous studies, significantly enhances student engagement, knowledge acquisition, and scientific process skills (Alsowat, 2022; De Vega & Rahayu, 2023). Digital technology thus presents a promising solution to make biology learning more interactive and collaborative. By integrating digital tools, educators can foster active participation, deeper conceptual understanding, and the development of essential skills such as collaboration and digital literacy, which are vital in adapting to the rapidly evolving technological landscape (Indah et al., 2022; Sukma et al., 2024).

However, digital media also introduces challenges, notably the spread of misinformation or "*hoaxes*" on social media platforms. Youth, who are among the highest users of digital media (Fatqurhohman & Huda, 2025; Hafizah, 2023), are particularly vulnerable to such misinformation due to their relatively limited critical information processing skills. To mitigate this risk, developing students' critical thinking abilities is essential, enabling them to discern factual information from falsehoods and to use digital media responsibly (Caneva & Pulfrey, 2023; Heryani et al., 2022).

The digital literacy excellence observed at SMAN Pakusari is attributable to a well-integrated curriculum and supportive infrastructure. The school's approach includes embedding technology use ethically and effectively into various subjects, supported by reliable internet access and computer facilities. Regular teacher training and extracurricular activities, such as programming and graphic design clubs, further nurture students' digital competencies through practical applications, fostering creativity and critical digital engagement.

The high digital literacy rating aligns with findings by (Edgel et al., 2021; Kim & Ryoo, 2023), who noted that structured guidance and systematic use of hyperlinks in learning resources support students' internet searching and online content evaluation skills. Routine practice in seeking, processing, analyzing, and interpreting information, both in face-to-face and online learning environments, enhances students' critical and creative thinking abilities (Kugler & Kárpáti, 2023; Molin & Godhe, 2020). Furthermore, integrating digital technology into biology education creates a more engaging and relevant learning environment for digital-native students, promoting not only conceptual understanding but also collaboration and digital literacy (Alfia et al., 2021). Overall, this study confirms that digital literacy is indispensable in modern education, particularly in scientific disciplines like

biology. The integration of digital tools and critical information skills prepares students not only to thrive academically but also to navigate the complexities of an increasingly digital society effectively.

4. CONCLUSION

This study demonstrates the essential role of both traditional and digital literacy in enhancing biology education at SMAN Pakusari. The results indicate that tenth-grade students possess a high level of digital literacy, with an average score of 77% across competencies such as effective internet searching, hypertext navigation, content evaluation, and knowledge assembly. These skills are vital for supporting the goals of the Merdeka curriculum and fostering active learning.

The use of interactive multimedia and digital tools contributes significantly to student engagement and deepens understanding of biological concepts while also encouraging collaboration and critical thinking. Despite these strengths, the persistence of misinformation challenges highlights the need to further develop students' critical thinking and media literacy skills.

The school's success in promoting digital literacy is supported by a well-structured curriculum, adequate technological resources, and enriching extracurricular programs that encourage responsible and proficient use of digital media. In summary, strengthening both traditional and digital literacies equips students to effectively navigate the complexities of the digital age. This research offers important implications for curriculum development and teaching practices aimed at preparing students for lifelong learning and meaningful participation in an increasingly digital society.

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