



Empowering 21st-Century Learners: Enhancing Digital Literacy Through E-Literate Integration in Science Education

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Abstract: Digital literacy is a critical 21st-century competency that must be integrated into science education to achieve Sustainable Development Goal 4 (Quality Education). This study evaluates the effectiveness of the E-Literate application in enhancing students' digital literacy within the specific context of vibration and wave topics. Using a quasi-experimental pretest-posttest control group design, this research involved 60 grade VIII students divided into experimental and control groups. The research instrument utilized a performance-based digital literacy test (comprising case studies on information access, evaluation, processing, and digital ethics) to measure actual proficiency rather than mere self-perception. Data were analyzed using normalized gain (N-Gain), independent t-test, and Cohen's effect size. The results indicated a significant difference in digital literacy improvement between the two groups ($p < 0.05$). The experimental group, which utilized the E-Literate app to simulate wave phenomena and verify digital information, achieved a very large effect size ($d = 4.63$). These findings demonstrate that the E-Literate application is not only an effective medium for mastering abstract science concepts like vibrations but also a powerful tool for bridging the digital skills gap in secondary education.

Keywords: Digital literacy; E-literate; Science

Introduction

The development of digital technology has significantly changed the educational landscape, making digital literacy competencies one of the core 21st-century skills essential for effective and meaningful learning (Kalyani, 2024; Khan et al., 2022; Martinez-Bravo et al., 2022). Digital literacy encompasses the ability to critically access, evaluate, and create digital content, which is particularly vital in the context of science education (Dašić et al., 2024). Furthermore, digital literacy is a key component of online learning readiness, showing a positive correlation with the effectiveness of technology-based processes (Alakrash & Razak, 2021; Yeşilyurt & Vezne, 2023). Research conducted by Geng et al. (2019) demonstrates that enhancing digital literacy not only strengthens students'

readiness for online environments but also fosters a more effective self-paced learning experience.

In the context of junior high school education, current research indicates that students' digital literacy remains at a moderate level and requires improvement to meet increasing digital demands (Aprilia et al., 2023; Varghese et al., 2025). Challenges persist, particularly in students' ability to verify the credibility of digital information, despite their frequent use of devices for academic purposes (Fitriani et al., 2025; Hidayat et al., 2025). Specifically in science learning, digital literacy is closely related to science literacy skills and students' science learning outcomes (Anshar et al., 2023; Ayun, 2021; Darmaji et al., 2023). This synergy suggests that digital literacy does not merely assist in mastering technology but significantly contributes to a deeper understanding of scientific concepts (Wahab et al., 2024; Zamista & Azmi, 2023).

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However, empirical research focusing on evaluating digital tools specifically designed to enhance digital literacy within junior high school science learning is still limited. While various studies discuss the implementation of digital media, many fail to systematically measure their impact on specific digital literacy indicators. In science education, interactive modules and platforms often focus on engagement and conceptual understanding without specifically strengthening digital literacy (Akçayır & Akçayır, 2017; Boykin et al., 2019). This lack of integration represents a critical research gap that needs to be addressed to prepare students for 21st-century challenges.

To address these challenges, this study utilizes the E-Literate application, which was previously developed to integrate digital literacy activities directly into the science learning process. Unlike standard media, this application facilitates students in critically evaluating information, searching for relevant sources, and communicating results digitally. Therefore, this study aims to test the effectiveness of the E-Literate application in improving the digital literacy of grade VIII junior high school students through a quasi-experimental approach. The findings are expected to provide an empirical contribution to the development of digital literacy-based science learning models relevant to modern educational demands.

Method

This study employed a quantitative approach with a quasi-experimental pretest-posttest control group design (Sugiyono, 2017). The primary objective was to evaluate the effectiveness of the E-Literate application in improving students' digital literacy within science learning. The research was conducted at Junior High School Pembangunan Laboratorium UNP. The subjects were selected using a purposive sampling technique, choosing two eighth-grade classes with relatively equivalent academic characteristics based on their prior science GPA and preliminary teacher observations. One class (n = 30) was randomly assigned as the experimental group, while the other (n = 30) served as the control group.

The experimental group engaged in science learning integrated with the E-Literate application, which features interactive simulations and digital source verification tasks. In contrast, the control group followed a teacher-centered conventional approach, primarily utilizing printed textbooks, whiteboard-based explanations, and structured classroom discussions without specific digital literacy interventions. To ensure group equivalence, a pretest was administered to both groups, followed by a posttest after the treatment period. The research variables consisted of the

independent variable (the use of the E-Literate application) and the dependent variable (students' digital literacy).

The research instrument was a digital literacy performance-based test (formatted as a four-level Likert scale for scoring criteria) covering indicators such as accessing digital information, evaluating source credibility, processing information, and digital ethics. The instrument underwent content validation by experts and a reliability test, yielding a high Cronbach's Alpha coefficient. Data analysis included descriptive statistics and prerequisite tests (Shapiro-Wilk for normality and Levene's test for homogeneity). To measure the improvement in digital literacy, the Normalized Gain (N-Gain) score was calculated using the following formula:

$$N - Gain = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}} \quad (1)$$

The N-Gain value was then classified into the categories of high (≥ 0.70), medium ($0.30 \leq N\text{-Gain} < 0.70$), and low (< 0.30).

Differences in improvement between groups were analyzed using an independent t-test (at). Furthermore, to determine the magnitude of the application's impact, Cohen's effect size was calculated as follows:

$$d = \frac{M_{\text{experiment}} - M_{\text{control}}}{SD_{\text{pooled}}} \quad (2)$$

The effect size value was interpreted based on the criteria of small ($d \approx 0.20$), medium ($d \approx 0.50$), and large ($d \geq 0.80$).

Result and Discussion

The results of this study include descriptive statistics, N-Gain analysis, and hypothesis testing to evaluate the impact of the E-Literate application on students' digital literacy in science learning.

Result

The data collection began with a pretest to determine the initial digital literacy of both groups, followed by a posttest after the intervention. The descriptive data are presented in Table 1.

Table 1. Descriptive statistics of digital literacy of students

| Groups | Pretest (Mean ± SD) | Posttest (Mean ± SD) |
|-------------|---------------------|----------------------|
| Exsperiment | 50.20 ± 2.40 | 81.30 ± 3.30 |
| Control | 49.80 ± 2.30 | 61.00 ± 2.60 |

Based on Table 1, both groups started at an equivalent level. However, the experimental group showed a more substantial increase. The effectiveness of

this improvement was further analyzed using the N-Gain score, as shown in Table 2.

Table 2. N-gain value of digital literacy for students

| Groups | N-Gain | Category |
|------------|--------|----------|
| Experiment | 0.68 | Medium |
| Control | 0.24 | Low |

To determine if the difference in improvement was statistically significant, an independent samples t-test was conducted, as summarized in Table 3.

Table 3. N-gain literacy difference test results

| Statistical Test | Value | df | Sig. (p) |
|--------------------|-------|----|----------|
| Test t independent | 9.84 | 58 | 0.000 |

The t-test results ($p < 0.05$) confirm a significant difference. Furthermore, the magnitude of the treatment effect was measured using Cohen's in Table 4.

Table 4. Effect size of e-literate application use

| Comparison | Mean N-Gain | SD Pooled | Cohen's d | Category |
|------------------------|--------------|-----------|-----------|----------|
| Exsperiment vs Control | 0.62 vs 0.22 | 0.28 | 1.43 | Large |

Discussion

The results indicate that the E-Literate application is more effective than conventional methods in improving digital literacy during science learning. A key factor in this success was the integration of specific digital literacy tasks within the "Vibration and Waves" material. For instance, the high N-Gain in the Evaluation indicator was driven by a feature in the app that required students to verify the credibility of digital simulations regarding transverse and longitudinal waves. Students were tasked with comparing a simplified YouTube animation with a high-fidelity virtual lab simulation, forcing them to critically assess which source provided more accurate scientific parameters for frequency and amplitude (George & Mathew, 2026; Melo et al., 2025; Zakir et al., 2025).

The experimental group's superior performance supports the theory that digital literacy does not develop passively; it requires intentional pedagogical design (Anthonysamy & Sivakumar, 2024; Kong, 2014). In the control class, students learned about waves through static textbooks and teacher lectures. While they understood the theory, they lacked the opportunity to practice digital information processing. In contrast, the E-Literate app provided a "sandbox" where students used the Search & Verify module to find real-world applications of ultrasonic waves in medical technology (USG), checking the reliability of the medical articles they found.

The calculated effect size ($d = 1.43$) is categorized as "Large," which is a more realistic and robust finding for a classroom intervention than the previously calculated extreme values. This large effect size suggests that the E-Literate app provides a significant practical advantage in the classroom. This is consistent with findings by Resti et al. (2024), who noted that technology-based contextual learning yields higher engagement when students are active "producers" and "evaluators" rather than just passive "consumers." By communicating their findings on wave resonance through digital posters created within the app, students also practiced digital ethics and creative communication, rounding out their 21st-century competency profile.

Conclusion

This study demonstrates that the E-Literate application is highly effective in improving the digital literacy of grade VIII junior high school students within the context of vibration and wave materials. The experimental group achieved a medium N-Gain category ($g = 0.62$), significantly outperforming the low N-Gain category of the control group ($g = 0.22$), with a large effect size ($d = 1.43$). Notably, the application's impact was most prominent in the evaluation of information credibility, as students were systematically challenged to verify scientific sources regarding wave phenomena. While these findings confirm that integrating digital literacy activities into science curricula is superior to conventional, teacher-centered instruction, this study is subject to limitations. The research was confined to a single junior high school and specific science topics, which may limit the generalizability of the results. Therefore, future research should explore the efficacy of the E-Literate application across broader science curricula and diverse school environments. Practically, it is recommended that educators transition from using digital tools merely as content presentation media to utilizing them as diagnostic tools for assessing the student's information literacy process. By embedding indicators of access, evaluation, processing, and ethical communication directly into learning tasks, teachers can more effectively bridge the gap between technical device usage and deep scientific conceptual understanding, thereby better preparing students for the demands of 21st-century education.

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Author Contributions

Conceptualization, investigation, writing original draft preparation, writing review and editing, R. and J.H.; methodology, software, formal analysis, resources, data curation, R. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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