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Electronic Physics Teaching Materials with a STEM Approach to Improve Students' Science Literacy

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Abstract

Despite the importance of scientific literacy, the scarcity of teaching materials to foster this skill has led students to demonstrate low levels of it. The study aims to assess the feasibility of using electronic teaching materials with a STEM approach to increase students' scientific literacy. The specific objectives of this study are to describe the practicality and effectiveness of electronic teaching materials with the STEM approach to increase students' scientific literacy. This uses a quasi-experimental one-group pretest-posttest design with 37 students in class XI at a Senior High School in Banjarmasin. Data collection techniques used student response questionnaires and scientific literacy learning outcomes tests. The data were analyzed by reviewing the average questionnaire response score and the n-gain score on the learning outcomes test. The results of the study show: (1) electronic teaching materials with the STEM approach are classified as effective because the scientific literacy n-gain value is in the moderate criteria; (2) electronic teaching materials with a STEM approach include practical, student responses in practical criteria. Obtained from the results of student responses in the practical criteria. Thus, the electronic teaching materials developed are effective and can be used by teachers as an alternative to improve students' scientific literacy. The results of this study imply that electronic teaching materials based on the STEM approach are effective and practical alternatives for improving students' scientific literacy. It is recommended that teachers start integrating STEM-based teaching materials into the learning process, and that further researchers test their effectiveness across different levels and subjects.

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INTRODUCTION

Literacy is one of the abilities that students must have in the 21st century (Aina & Hariyono, 2023; Asnidar et al., 2024; Saputra et al., 2023a; Setiawan et al., 2023; Siswanto et al., 2023; Triwibowo et al., 2021). One of the important objectives of education is to equip students with scientific literacy skills (Fakhriyah et al., 2019; Kusumawati et al., 2019; Wahyu et al., 2020; Yamtinah et al., 2019). Educators are expected to develop students' literacy to address the challenges of the industrial revolution era 4.0 (Latifah & Siti Hasanah, 2021; Sumanik et al., 2021). Literacy skills play a very important role in the success of the younger generation (Irianto & Febrianti, 2017; Narut & Supardi, 2019).

Young people with good literacy skills will easily understand verbal and written information. Science literacy education is expected to form people who are literate in science and technology so that they are able to face the challenges of the 21st century (Dewantara et al., 2024, 2025; Hanfstingl et al., 2024; Hartini et al., 2024; Pratiwi et al., 2019; Pujiati, 2019; Saroughi & Cheema, 2023; Vogelzang et al., 2020). Science literacy is the ability to understand science concepts and processes, and to use science to solve everyday problems. It is divided into four dimensions: the science process (competence), science content (knowledge), science attitudes, and the context of science applications.

The results of initial observations at a school in South Kalimantan, Indonesia, shared via Google Forms, showed that students' science literacy skills remained low. Fifty percent (50%) of learners are still unable to explain scientific phenomena, 63.64% of learners are still unable to design and evaluate scientific investigations, and 76.14% of learners are still unable to interpret data and provide scientific evidence. This is reinforced by the results of a researcher interview with a physics teacher at SMA Negeri 4 Banjarmasin, who reported that, after the COVID-19 pandemic, science literacy in the learning process has not been properly applied in physics learning. During the pandemic, teachers used a direct, teacher-centered learning model, providing material only through learning videos in WhatsApp groups, accompanied by assignments, so that students were only recipients of information from the teacher.

The absence of electronic teaching materials that specifically support training students in dynamic fluid materials. This is in line with the results of Sutrisna (2021), who found that students still have low science literacy skills. The lack of student interest in reading, evaluation tools that have not focused on improving science literacy, and teachers' limited understanding of science literacy are factors that contribute to students' low science literacy. In addition, there are factors related to the ongoing educational process, including the applied education system, selection of models, approaches, and learning strategies; selection of learning resources that do not include complete science literacy; student learning styles; learning facilities; and infrastructure. Therefore, there is a need for innovation in the learning process to improve students' science literacy (Kristiani et al., 2022; Sholihah et al., 2023; Sutiani et al., 2021).

The selection of teaching materials and the appropriate learning model can develop science literacy skills and improve student learning outcomes (Deta et al., 2021; Fautin et al., 2020; Mahjatia et al., 2020). The STEM approach refers to four areas of knowledge: science, technology, engineering, and mathematics (Hsieh et al., 2022; Ijirana et al., 2022; Reffiane et al., 2020; Simatupang & Purnama, 2019). Educators need to integrate these four areas to address learning problems in everyday life (Davidi et al., 2021). The STEM approach has a positive impact on students academically, affectively, and psychomotorically, where if schools implement STEM for a long time, students will get maximum learning outcomes (Fadlina & Ritonga, 2021; Hasanah et al., 2021; Mardhiyatirrahmah et al., 2020; Niam & Asikin, 2021; Pérez Torres et al., 2023; Sholihah et al., 2023). Research by Banila et al. (2021) shows that students' science literacy skills have an average score of 85.50, with good performance in the application of STEM approaches. Learning that applies a STEM approach can improve students' science literacy (Hurley et al., 2024; Romine et al., 2023; Schreiter et al., 2024; Syahmani et al., 2021, 2025; Wang et al., 2024; Widyawati et al., 2024). The science literacy ability of students can experience significant improvements through the existence of STEM-based worksheets (Chen et al., 2024; Hartini et al., 2019; Marosi et al., 2024; Purwaningsing et al., 2020; Saputra et al., 2023b; Sung & Huang, 2024; Utami et al., 2020). There are activities on environmental issues that help students develop science literacy skills.

Electronic teaching materials that apply a STEM approach to improve students' science literacy are one of the efforts to overcome the above problems (Sari, 2020; Taylor, 2016). Researchers are interested in developing dynamic fluid electronic teaching materials that can make it easier for students to understand the material and improve science literacy using a STEM approach (Ardianti et al., 2019; Fikri et al., 2019; Syafei et al., 2020). The research generally aims to describe the feasibility of electronic teaching materials that apply STEM approaches to improve students' science literacy. The specific objectives of the study are 1) to describe the effectiveness of electronic teaching materials that apply the STEM approach to improve students' science literacy and 2) to describe the practicality of electronic teaching materials that apply the STEM approach to improve students' science literacy.

METHODS

This study used a quasi-experimental one-group pretest-posttest design. As seen in Table 1, it compares learning outcomes before and after the use of electronic teaching materials on fluid dynamics material to improve students' scientific literacy.

Table 1 One-group pre-test post-test design

Pre-test	Treatment	Post-test
O1	X	O2

The sampling technique is cluster random sampling. The test subjects in this study were 37 grade XI MIPA 3 students at SMA Negeri 4 Banjarmasin for the 2022/2023 academic year. This study utilized two main research instruments: (1) a science literacy learning outcomes test to measure the effectiveness of the STEM-based electronic teaching materials and (2) a student response questionnaire to assess the practicality of the materials. The learning outcomes test was administered as a pre-test and post-test, consisting of 7 descriptive questions designed to measure cognitive levels C2 (understanding), C3 (applying), C4 (analyzing), and C5 (evaluating), based on Bloom's taxonomy. The test covered three subtopics in fluid dynamics: the principle of continuity, Bernoulli's law, and its applications in real-life contexts. The validity of the learning outcomes test was evaluated in terms of four aspects: topic relevance, question construction, language clarity, and alignment with science literacy indicators. The validation results indicated that the test met the "good" criteria and demonstrated a relatively high degree of reliability. Therefore, all test items were deemed appropriate for assessing the targeted aspects of students' science literacy. In addition, the student response questionnaire was used to evaluate the practicality of the STEM-based electronic teaching materials. This questionnaire was validated by experts and received a "very good" rating, indicating its suitability for use in this study.

Data were obtained through science literacy learning outcomes test instruments to assess the effectiveness of the teaching materials, and through student response questionnaires to assess the practicality of the teaching materials. The learning outcome test instrument was administered as a pre-test and post-test, consisting of 7 descriptive questions at cognitive levels C2 (understanding), C3 (applying), C4 (analyzing), and C5 (evaluating). There are three sub-topics in the fluid dynamics material: the principle of continuity, Bernoulli's law, and its application. The results of the validation test for the overall science literacy learning outcome test instrument covering the topics of construction, language, and science literacy met the criteria and showed a fairly high degree of reliability. Then it can be concluded that all the questions made are declared good and can be used to assess several aspects of expected science literacy. Student response questionnaires for the practicality of teaching materials have also been validated in the very good category.

Data on the effectiveness of electronic teaching materials are obtained from the results of science literacy tests, in the form of pre-test and post-test scores, which are calculated using the N-gain formula (Hake, 1998), as shown in Table 2.

Table 2 Learners' science literacy n-gain criteria

No.	Score $\langle g \rangle$	Classification
1	$\langle g \rangle > 0.70$	High
2	$0.30 \leq \langle g \rangle \geq 0.70$	Medium
3	$\langle g \rangle < 0.30$	Low

The reliability of teaching materials is calculated using the Alpha Cronbach equation, which is then adjusted according to Arikunto's (2016) criteria.

Table 3 Practical criteria for electronic teaching materials

No.	Score Range	Criterion
1	$\bar{x} > 3.4$	Very Good
2	$2.8 < \bar{x} \leq 3.4$	Good
3	$2.2 < \bar{x} \leq 2.8$	Enough
4	$1.6 < \bar{x} \leq 2.2$	Less Good
5	$\bar{x} \leq 1.6$	Bad

Widoyoko (2016)

RESULTS AND DISCUSSION

Electronic teaching materials with a STEM approach to improve students' science literacy are the result of development in this research. Teaching materials are tested to support learning activities in students in XI MIPA 3 SMA Negeri 4 Banjarmasin, and are adjusted to the characteristics of dynamic fluid materials. Dynamic fluid material electronic teaching materials consist of cover (Figure 1a), concept maps, keywords, STEM columns, subchapter titles, material descriptions, practice questions, advanced exercises, student worksheets (Figure 1b), science literacy tests, summaries, glossaries, indexes, and bibliographies.

(a) (b)

Figure 1 (a) Display of subchapter covers and headings and (b) Worksheet display

Learning outcomes tests are divided into two, namely pre-test and post-test. The test consists of 5 questions, and the effectiveness of electronic teaching materials is calculated by using several indicators of science literacy, with the average N-gain. The results of the analysis of students' scientific literacy are shown in Table 4.

Table 4 Results of science literacy analysis of students

Average Pre-test	Average post-test	N gain	Category
5.08	66.89	0.52	Medium

Table 4 shows that students' pre-test scores are very poor, indicating that their science literacy is still low, while their post-test scores have improved to good. An n-gain score in the medium range indicates that electronic teaching materials are effective for learning.

The practicality of electronic teaching materials with a STEM approach to dynamic fluid materials to improve science literacy is evident from the student questionnaire completed by 37 grade XI MIPA 3 students at SMA Negeri 4 Banjarmasin. A student response questionnaire is a questionnaire that collects students' opinions on electronic teaching materials, developed and administered at the end of the meeting via questionnaire instrument sheets.

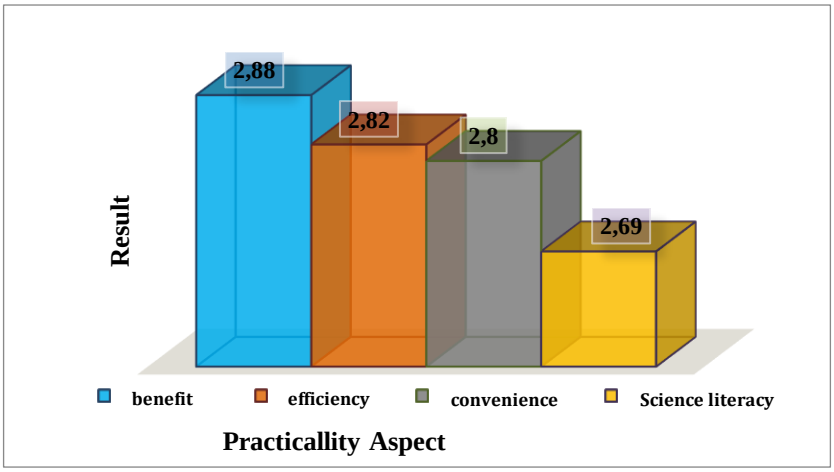

Figure 2 Graphic of practical results of electronic teaching materials

Based on Figure 2 the average practicality of electronic teaching materials that apply the STEM approach to increase students' science literacy is 2.80, in the good category, and the reliability is 0.77, in the high category. This phenomenon shows that, from the perspective of users or respondents, the product or program being studied is perceived as very useful and efficient. However, its contribution to increasing scientific literacy remains relatively low.

The relationship between the research results phenomenon and the data reflects that although the product or innovation being studied has met practical aspects such as benefits and efficiency, its impact on increasing scientific understanding or knowledge (scientific literacy) is not optimal. This could be caused by an approach to delivering material that does not emphasize the scientific concept in depth, or by users who are not yet accustomed to linking product use to scientific principles. Therefore, further development should focus on enhancing the product's educational elements, thereby increasing scientific literacy while also improving its benefits and efficiency of use.

The effectiveness of electronic teaching materials that apply the STEM approach to improve students' science literacy, developed by researchers, is evident in pre- and post-test results on science literacy learning outcomes. Table 5 shows the average pre-test and post-test scores of students. It is known that post-test students experience increased learning after using electronic teaching materials in classroom instruction. The pre-test results show that, in general, students have not been able to answer questions on dynamic fluids that assess science literacy. This is because the learning resources or teaching materials used in STEM-integrated schools that contain indicators of science literacy are still few, and students are still not interested in reading them. Furthermore, the post-test results of students show that, in general, their value has increased, and they have begun to be able to solve problems involving dynamic fluids, demonstrating indicators of scientific literacy.

This is because the use of electronic teaching materials that apply a STEM approach can increase students' science literacy.

Overall, if the test results were tested using n-gain, an increase in the moderate category was obtained. The application of electronic teaching materials with a STEM approach has been effective in achieving the intended purpose of improving learners' science literacy. This is characterized by students' science literacy, which increases across each indicator. Effectiveness is one of the quality standards of education as measured by the achievement of predetermined goals.

The results of the practicality test were rated "good" and “quite good," with high reliability. This shows that electronic teaching materials that apply STEM approaches to improve students' science literacy are practically used in classroom instruction. Figure 4 shows the practicality of electronic teaching materials; the benefit aspect received the highest average score, while the science literacy aspect received the lowest score (Syofyan et al., 2019).

The benefit aspect receives the highest score, indicating that the developed teaching materials can help students learn physics. Students state that the teaching materials developed explain a concept that connects to everyday life, making learning more meaningful. This is in accordance with the meaningful learning indicators outlined by Fatimiyah et al. (2020).

The aspect of science literacy met the lowest criteria, earning a sufficient rating. The teaching materials developed help students gain new knowledge and understanding of the history of physics and its key figures, so that learning does not feel boring. Learners know that science and technology have a positive impact on everyday life, and learning models associated with science literacy make learning easier to understand. This is in accordance with Saputro (2021), who states that questionnaires are one of the instruments that can be used to explore views on the use of learning tools developed.

According to Mujizah et al. (2020), the developed teaching materials are practical and feasible if they facilitate teachers' learning activities. So researchers concluded that electronic teaching materials that apply a STEM approach to improve students' science literacy are practically used in learning activities.

CONCLUSION

Based on the results and discussion, it was concluded that the teaching materials for electronics with a STEM approach are feasible to be used in the learning process to improve students' science literacy. Electronic teaching materials developed with a STEM approach are classified as "engineers" based on student response questionnaires that are categorized as good. Similarly, the gain score is in the medium range, indicating it is effective and can be used by teachers as an alternative to improve students' science literacy.

However, this study has several limitations that need to be considered. The testing of STEM-based electronic teaching materials was conducted in only one class at one school, so it cannot represent a wider population. This condition limits the generalization of findings to different learning contexts. Therefore, further research is recommended to conduct larger-scale trials across multiple schools with diverse student characteristics. Thus, the effectiveness of these teaching materials can be tested more comprehensively and produce stronger findings as an alternative learning method in improving students' scientific literacy.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHOR CONTRIBUTIONS STATEMENT

All of the authors have contributed to the conceptualization, methodology, formal analysis, investigation, and writing this article.

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