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Fostering Science Literacy in Indonesia and its Impact: A Systematic Literature Review

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Abstract: Science literacy remains a central issue in education, encompassing not only conceptual understanding but also awareness of scientific processes, socio-scientific issues, and empirical reasoning. This study aims to analyze research findings on instructional approaches, learning models, and learning media that have been implemented to enhance students' scientific literacy in Indonesia. This study conducted a systematic literature review using the PRISMA protocol, covering identification, screening, eligibility, and inclusion. A total of 20 international articles indexed by Scopus and accredited by Sinta 1 or 2 were analyzed. The findings show that approaches such as STEM, project-based learning, interactive e-modules, and environment-based activities significantly improve science literacy. Instructional models like MURDER, IB-NOSA, JAS with Google Lens, and graphic organizers also have positive impacts. Moreover, digital tools—including flipbooks, virtual-reality games, and culturally contextual modules—further enhance comprehension. Assessment instruments such as SLiSIS and Lisa3D exhibit strong validity in measuring science literacy. These findings highlight the importance of integrating technology and contextual strategies to effectively foster students' scientific literacy.

Keywords: Fostering Science Literacy in Indonesia.

Introduction

The rapid advancement of science and technology in the 21st century has profoundly influenced various aspects of human life, particularly in the field of education. This global transformation requires students not only to master technological competencies but also to develop a deep understanding of scientific concepts that enable them to engage critically with real-world issues. Within this context, scientific literacy has emerged as a fundamental competency that determines students' ability to participate actively and responsibly in a science-driven society. The importance of scientific literacy has been widely recognized in international assessments such as the Programme for International Student Assessment (PISA), which measures students' capacity to apply scientific knowledge in everyday situations (Hutomo et al., 2022). As a core 21st-century skill, scientific literacy encompasses the ability to relate scientific ideas to real-life contexts, interpret and evaluate empirical data, and make informed, evidence-based decisions regarding issues such as environmental sustainability, human health, and technological innovation.

In parallel, thinking skills—including critical, creative, analytical, and reflective thinking—play a vital role in helping students address social, scientific, and practical challenges (Uslan et al., 2024; Nur Hasan et al., 2018). According to Yusuf (2023), the growing complexity of global educational demands requires the enhancement of digital and technological literacy, enabling learners to navigate, process, and evaluate information effectively in an increasingly digital world. The integration of scientific and digital literacy has become central to the Education 4.0 paradigm, which emphasizes the fusion of digital technologies with learning processes to foster independent and adaptive learners. Strengthening these literacies is essential for improving the

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overall quality of education, promoting meaningful learning experiences, and preparing students to become competent individuals equipped with critical, creative, communicative, and problem-solving abilities (Widiyatmoko, 2023).

Globally, many countries have recognized the strategic importance of developing students' scientific literacy as part of educational reform. For instance, in Chile, scientific literacy is considered a national educational priority and is integrated into curriculum design and teacher professional development (Bórquez-Sánchez, 2024). Similarly, Lebanon has positioned scientific literacy at the center of its educational transformation, responding to low national performance in PISA assessments (Baltikian, 2024). In Indonesia, however, efforts to cultivate scientific literacy still face numerous challenges, including the persistence of ineffective teaching models, an overreliance on rote memorization, and the limited implementation of assessment models resembling PISA (Hudha et al., 2023; Rosnelli & Ristiana, 2023). Additional contributing factors such as school location, socioeconomic disparities, gender differences, and the overall quality of science education from primary to tertiary levels further exacerbate these challenges (Haetami et al., 2023). Therefore, there is a growing need for the development and implementation of innovative instructional strategies that can effectively enhance students' scientific literacy and higher-order thinking skills in alignment with the demands of modern education. Therefore, this study aims to synthesize and analyze research findings on instructional approaches, learning models, and learning media that have been implemented to enhance students' scientific literacy in Indonesia through a systematic literature review following the PRISMA protocol.

Materials And Methods

Study area

This study employs a systematic literature review guided by the PRISMA methodology, which ensures a structured and rigorous approach to data retrieval. The PRISMA framework consists of four key phases: identification, screening, eligibility assessment, and inclusion of relevant literature (Moher et al., 2009). Literature reviews serve to synthesize existing findings and provide a comprehensive understanding of previous research outcomes (Amruddin et al., 2022).

The objective of this review is to analyze and describe existing literature concerning the implementation of instructional approaches, learning models, and educational media aimed at enhancing students' scientific literacy, particularly at the middle school level. The detailed stages of the review process are illustrated in Figure 1.

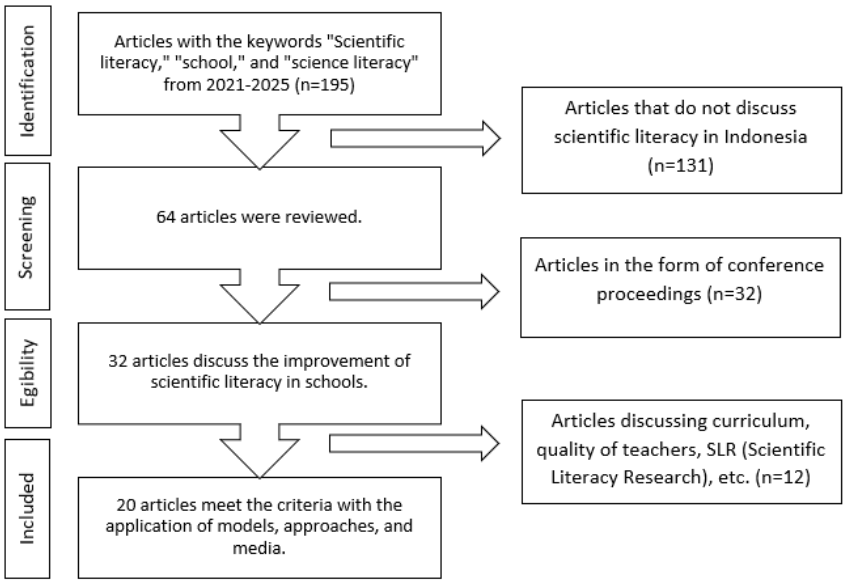

Figure 1 PRISMA Flowchart.

Procedures

The data sources for this study comprised peer-reviewed journal articles, books, and research reports relevant to the topic. Literature was retrieved from online academic databases, including Scopus and Sinta (accredited at Sinta 1 and Sinta 2 levels). The literature search employed keywords such as "school," "scientific literacy," "science literacy," and their combinations. Selection criteria included a focus on school-based instructional practices related to scientific literacy enhancement and publications from the past five years.

Data analysis

Data analysis was conducted inductively through thorough reading and examination of the selected literature. Key themes, recurring patterns, and significant findings were identified across sources. The analysis involved tabulating and categorizing data, followed by the synthesis of concepts related to the implementation of teaching methods and media, as well as their effects on students' scientific literacy. The research questions guiding this systematic review are as follows:

Q1 : What was the geographical setting of the study aimed at improving scientific literacy, and in which province was the research conducted?

Q2 : What were the educational characteristics and academic levels of the participants involved in the study on scientific literacy enhancement?

Q3 : What research design and methodological framework were employed to investigate improvements in scientific literacy?

Q4 : Which instructional strategies, pedagogical models, or educational media were implemented to support the development of scientific literacy?

Results And Discussion

This study synthesizes findings on instructional approaches, learning models, and media through a systematic literature review following the PRISMA protocol, which includes the phases of identification, screening, eligibility, and inclusion. The data collection and selection process yielded 20 relevant studies published within the last five years, focusing on efforts to enhance scientific literacy.

Sources were obtained through database searches in Scopus and Sinta (accredited at Sinta 1 and Sinta 2 levels), using predetermined keywords related to scientific literacy and school-based learning. A total of 20 journal articles met the inclusion criteria. The findings are presented and discussed in relation to the research questions guiding this review.

Geographical Context of the Study

The analysis of the selected articles indicates that efforts to enhance students' scientific literacy have been documented across eleven provinces in Indonesia over the past five years. These provinces include Bali (Tegeh et al., 2021), Bengkulu (Winarni et al., 2022), West Java (Chairunnisa et al., 2021), Central Java (Minsih et al., 2023; Widiyatmoko et al., 2023; Suwandi et al., 2023; Hutomo et al., 2022; Poernomo et al., 2021; Susongko et al., 2021, 2024), East Java (Sulistina & Hasanah, 2024), West Kalimantan (Ananda et al., 2024), South Kalimantan (Hartini et al., 2024), East Nusa Tenggara (Uslan et al., 2024), West Sumatra (Safrizal et al., 2022; Fitria et al., 2023), North Sumatra (Fatmawati et al., 2023; Anas & Hasibuan, 2023; Simamora et al., 2022), and Yogyakarta (Lestari et al., 2024).

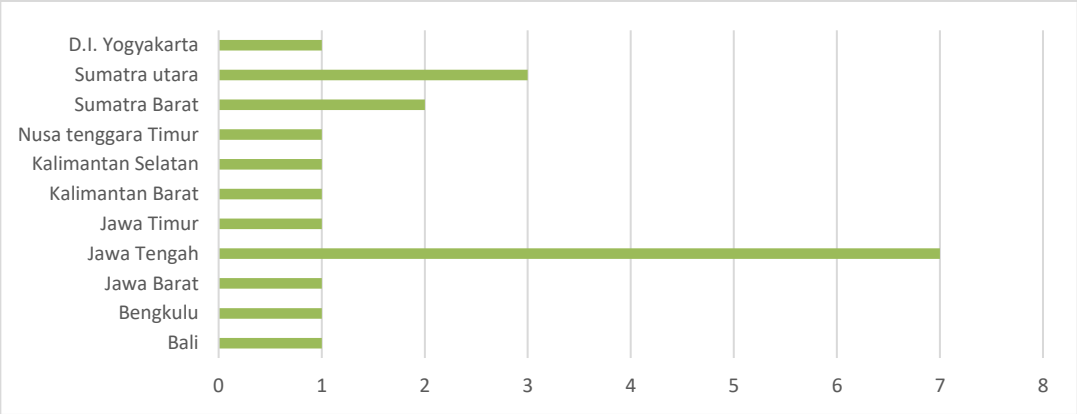

Figure 2 Province of Origin.

The data reveal that Central Java and North Sumatra are the provinces with the highest number of studies focusing on the improvement of students' scientific literacy. This finding is consistent with Anggraeni (2023), who reported that research related to the development of higher-order thinking skills—particularly critical thinking—is more prevalent in the Java and Sumatra regions. Similarly, Wahono and Chang (2019) noted that the western part of Indonesia, especially Java, demonstrates greater engagement in science-based instructional approaches, such as STEM, to enhance scientific literacy.

This trend may be attributed to more equitable access to educational resources, professional development for teachers, and infrastructure supporting inquiry-based learning in these regions. Consequently, there is a pressing need for policy initiatives and research support to be extended to other regions of Indonesia. Such efforts are essential to promote equitable development of scientific literacy across all educational levels and geographic areas in the country.

Educational Level of the Target Population

The selected articles were also analyzed based on the educational levels of the research subjects. For the purpose of this study, educational levels were categorized into four groups: elementary school, middle school, high school, and higher education. The analysis shows that eight studies focused on enhancing scientific literacy at the elementary school level (Tegeh et al., 2021; Winarni et al., 2022; Minsih et al., 2023; Uslan et al., 2024; Safrizal et al., 2022; Fitria et al., 2023; Anas & Hasibuan, 2023; Fatmawati et al., 2023). At the middle school level, four studies were identified (Widiyatmoko et al., 2023; Hutomo et al., 2022; Simamora et al., 2022; Lestari et al., 2024). Another eight studies targeted high school students (Chairunnisa et al., 2021; Suwandi et al., 2023; Poernomo et al., 2021; Susongko et al., 2021, 2024; Sulistina & Hasanah, 2024; Hartini et al., 2024; Ananda et al., 2024).

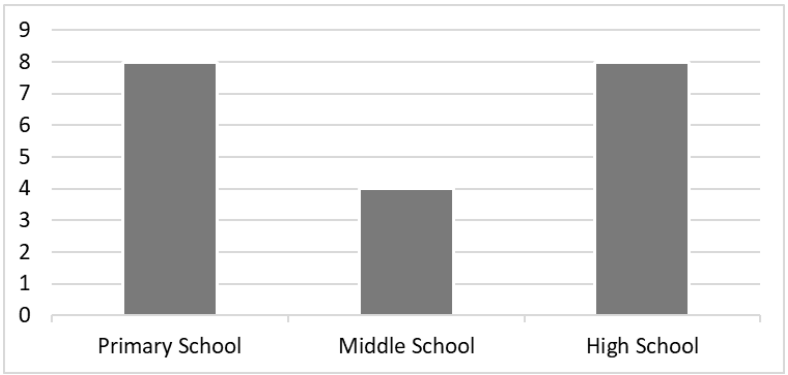

Figure 3 Subject Research.

The data presented in Figure 3 indicate that efforts to enhance scientific literacy were most frequently implemented at the elementary and high school levels. This trend underscores the importance of fostering scientific understanding from an early age to enable students to think logically, comprehend scientific concepts, and connect learning to real-world contexts. At the elementary level, scientific literacy is typically developed through simple, engaging activities such as observation and basic experimentation.

In contrast, at the middle school level, instructional efforts tend to emphasize problem-solving skills, critical thinking, and the application of the scientific method. International studies have highlighted the essential role of scientific literacy in equipping students to address contemporary global challenges, including environmental issues, technological advancements, and evidence-based decision-making (OECD, 2017; Bybee, 2013). Holbrook and Rannikmae (2009) further contend that scientific literacy encompasses not only content knowledge but also scientific reasoning and appropriate attitudes toward societal issues. Therefore, strengthening scientific literacy across primary and secondary education is a critical step in preparing future generations to navigate the complexities of the modern world.

Research Design and Methodological Framework

The data presented in Figure 3 highlights the efforts of researchers to improve scientific literacy in schools. Quantitative research with a quasi-experimental design is the most commonly used method for enhancing scientific literacy in schools.

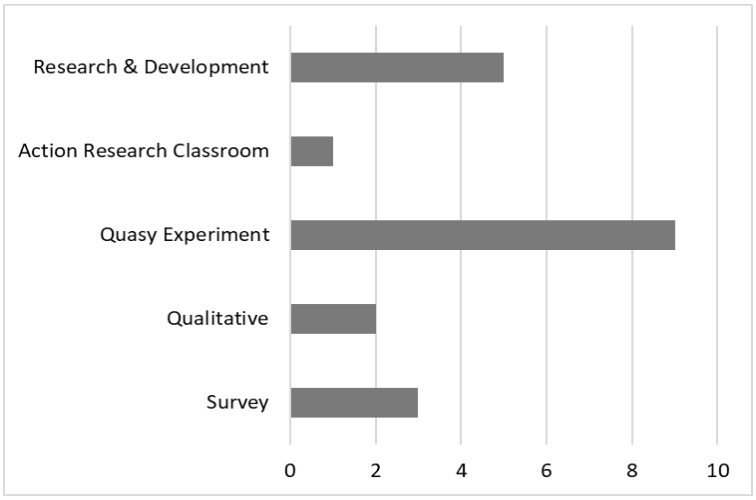

Figure 4 Type of Research.

Quasi-experimental designs were employed to examine the effects of learning models and media on scientific literacy in the classroom (Tegeh et al., 2021; Winarni et al., 2022; Suwandi et al., 2023). Qualitative research was used to assess school programs, facilities, and students' perceptions of scientific literacy (Minsih et al., 2025; Safrizal et al., 2022). Classroom action research aimed at improving scientific literacy was also conducted in schools (Fatmawati et al., 2023). Research and development (R&D) studies focused on developing teaching materials and models (Hutomo et al., 2022; Poernomo et al., 2021). Susongko et al. (2024) used descriptive surveys with a quantitative approach to validate instruments measuring students' scientific literacy.

Instructional Approaches, Pedagogical Models, and Learning Media

Based on the results of the article analysis, the research findings are presented in Table 1. Various efforts to improve science literacy were explored, and the results were diverse. The studies used sample sizes ranging from 20 to 310 participants.

Table 1 Data related to research results.

Author(s)	Year	Research Findings
I. M. Tegeh, I. G. Astawan, I. K. Sudiana, M. G. R. Kristiantari	2021	A significant effect of the Murder learning model supported by Metacognitive Scaffolding on students' scientific literacy and numeracy skills.
Friska Chairunnisa, Yuyun Maryuningsih, Djohar Maknun	2021	The use of e-modules in biology learning improves students' scientific literacy. Students showed enthusiasm for e-modules due to their interactive.
JB Poernomo, Qisthi Fariyani, Widy Lestari	2021	This study produced 14 valid science literacy questions. The results showed that most students exhibited low levels of higher-order thinking skills.
P. Susongko, Y. Arfiani, M. Kusuma	2021	The analysis revealed that some questions in the SLiSIS test had varying levels of difficulty for different student groups.
Endang Widi Winarni, Mageswary Karpudewan, Bhakti Karyadi, Gumono Gumono	2022	The results indicated that Project-Based Learning (PjBL) and STEM significantly impacted science literacy and environmental awareness across three indicators. Additionally, the diorama project allowed students to investigate environmental conservation methods, applying science and technology.
Safrizal, Sudarmono, Resti Yulia	2022	Science literacy development was achieved through academic culture, learning media, open-ended questions, and a reward and punishment system at the Adiwiyata school.
Bagus Addin Hutomo, Sigit Saptono, Bambang Subali	2022	This study showed that STEM-based e-modules effectively improve students' science literacy skills, encompassing science processes, contexts, and content.
Aprido B. Simamora, I Gusti Made Sanjaya, Wahono Widodo	2022	The BRADeR model is considered highly valid according to experts in the field of Science Education.
Y. Fitria, N. A. Alwi, R. Eliasni, Chandra, A. Kharisma	2023	Significant differences were found between students' learning outcomes before and after using the science literacy-based graphic organizer learning model. The N-gain for Experiment Group 2 was high category, and for Experiment Group 1 was medium category
Fatmawati, Yusrizal, Ali Mustadi, Yunus Abidin	2023	Students' science literacy improved when taught using the environmental utilization method, with average scores of 79 in Cycle I and 84 in Cycle II.
Nirwana Anas, Ahmad Tarmizi Hasibuan	2023	Based on the conducted research, it was concluded that the Digital Flipbook media was effective in enhancing elementary school students' science literacy.
Roisyah Ashshaddiqah Suwandi, Suciati Suciati, Suranto Suranto	2023	Game-based learning using Virtual Reality (VR) significantly increased students' STEM literacy, covering science, technology, engineering, and mathematics, particularly on energy-related topics.
A. Widiyatmoko, R. Nugrahani, A. Yanitama, M. S. Darmawan	2023	The study revealed that STEM literacy for eighth-grade students showing significant differences between control and experimental groups.
Uslan, N. Abdullah, M. K. W. Imami, U. Aiman	2024	The research demonstrated that the use of Local Knowledge-Based Modules (LKBM) in plant organ topics effectively enhanced science literacy and students' thinking skills.
P. Susongko, N. B. A. Wahab, Y. Arfiani, M. Kusuma	2024	This study resulted in a standardized instrument, the Lisa3D Test, which met all validity criteria for measuring the scientific literacy of high school students in science programs. The instrument was implemented online through the website www.lisatest.id.
Oktavia Sulistina, Samudra Mutiara Hasanah	2024	The research findings showed that socio-scientific issues (SSI) content had a significant positive effect on students' science literacy, especially regarding chemical structure topics.
Dea Putri Ananda, Mahwar Qurbaniah, Hanum Mukti Rahayu	2024	The implementation of the JAS model assisted by Google Lens effectively improved students' science literacy on the topic of Plantae.
Hartini S., Khairiyah N., Wati M., Dewantara D., Zainuddin Z., Ismail I., Saehena S., Rahman N. F. A.	2024	Students' science literacy increased significantly as demonstrated by statistical tests between pretest and posttest results. The improvements occurred particularly in explaining scientific phenomena, interpreting scientific data or evidence, and evaluating and designing scientific investigations.
Diah Puji Lestari, Paidi Paidi, Suwarjo Suwarjo	2024	All groups experienced significant improvements in science literacy. The effectiveness of the IB-NOSA Model: Effect size 0.79, gain score 0.49 (medium); more effective than guided inquiry (0.76) and discovery learning (0.71).
Minsih Minsih, Imam Mujahid,	2025	Integrated cultural literacy in science education through science concepts

Author(s)	Year	Research Findings
Amirul Mukminin, Helzi Helzi		contextualized with local wisdom and traditional knowledge strengthens cultural identity and student engagement.

The studies reviewed from 2021 to 2025 indicate a consistent and increasing emphasis on improving students' scientific literacy in Indonesia through a range of instructional models, media, and assessment tools. Efforts to enhance scientific literacy in Indonesia have involved the introduction of a revised curriculum and efforts to improve teachers' understanding and pedagogical practices.

Project-based learning (PjBL) has been shown to enhance scientific literacy in subjects such as physics, chemistry, biology, epidemiology, and environmental science, promoting skills like reading, writing, and calculation. PjBL, when combined with a STEM approach, encourages active student participation and fosters the development of literacy, critical thinking, competencies, and attitudes (Winarni et al., 2022). A study by Adriyawati et al. (2020) demonstrated that PjBL with a STEAM approach significantly improved students' scientific literacy on topics related to alternative energy, sparking curiosity and enabling students to conduct basic scientific investigations. A significant effect of the Murder learning model supported by Metacognitive Scaffolding on students' scientific literacy and numeracy skills (Tegeh et al., 2021).

Integrating socio-scientific issues (SSI) into science education has been identified as an effective strategy for enhancing scientific literacy. SSI-based learning supports the development of scientific literacy, as evidenced by Haetami et al. (2023). In a study by Sulistina and Hasanah (2024), the combination of SSI and Augmented Reality (AR) improved students' understanding of chemical bonding by relating it to real-world phenomena. Similarly, research by Bosser (2024) highlighted that SSI-based learning encourages students to explore scientific facts, engage in experiments, and adopt evidence-based reasoning.

Digital and scientific literacy are fundamental in today's educational landscape, as emphasized by Yusuf et al. (2023). Given the rapid pace of technological advancements, students must develop the skills to filter, analyze, and utilize information effectively. Widiyatmoko (2023) stressed that Virtual Reality Game-Based Learning (VRGBL), along with interactive technologies such as Virtual Reality (Suwandi et al., 2023), Google Lens (Ananda et al., 2024), and digital flipbooks (Anas & Hasibuan, 2023), have been instrumental in improving both technology and scientific literacy. These tools assist students in understanding scientific phenomena and their relationships with technology. Additionally, validated assessment tools like the SLiSIS and Lisa3D tests (Susongko et al., 2021, 2024) have been developed to accurately assess literacy levels. While some technical limitations have been identified in e-modules (Chairunnisa et al., 2021), the majority of interventions have shown measurable improvements in students' literacy skills, particularly in areas such as scientific phenomenon comprehension, data interpretation, and higher-order thinking.

STEM-based learning has been demonstrated to be effective in enhancing students' understanding of scientific concepts. Hutomo (2022) found that STEM-based e-modules on matter pressure are a viable approach in science education. Gertner et al. (2021) observed that combining STEM with e-portfolios enhances engagement and understanding in biology. Moreover, STEM-based learning, supported by Mobile Augmented Reality (MAR), has been shown to improve both cognitive and procedural achievements (Wahyu et al., 2020). Environmental-based methods (Fatmawati et al., 2023) have also been proven to significantly enhance science literacy.

Local Knowledge-Based Modules (LKBM) offer a way to contextualize learning and engage students by integrating local wisdom and traditional knowledge into the science curriculum. These modules have been found to improve both scientific literacy and critical thinking skills (Uslan et al., 2024). By incorporating cultural literacy into science education, students gain a deeper connection to the material, strengthening both their

cultural identity and engagement in the learning process (Minsih et al., 2025). Rosnelli and Ristiana (2023) recommended training teachers to enhance literacy and numeracy through activities that promote systematic reasoning, research, and the application of ICT to deepen knowledge, attitudes, and skills.

Conclusions

This study examines various teaching approaches to enhance students' scientific literacy, focusing on the impact of methods and media. The findings indicate that project-based learning (PjBL) with STEM and STEAM approaches, socio-scientific issues (SSI)-based learning, and the use of digital technologies such as Virtual Reality (VR) and Augmented Reality (AR) effectively improve scientific literacy. These methods enhance understanding, investigative skills, and foster positive attitudes toward science. Moreover, the integration of local knowledge-based media (LKBM) and contextual learning resources supports critical thinking and content comprehension. In conclusion, combining active teaching methods and technology is a valuable strategy for advancing scientific literacy and should be widely adopted to enhance science education in Indonesia.

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Conflict of Interest: The authors declare that there are no conflicts of interest concerning the publication of this article.

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