JIPI (Jurnal IPA dan Pembelajaran IPA) 9(2), p.342-356, (2025)
p_ISSN: 2614-0500 e_ISSN: 2620-553X
https://jurnal.usk.ac.id/JIPI/index https://doi.org/10.24815/jipi.v9i2.44946

Opportunities and Challenges in Enhancing Students' Science Literacy

Siti Aqilah[1,3], Indarini Dwi Pursitasari[1*], Irvan Permana[1], Didit Ardianto[1], Indriyani Rachman[2]

[1]Department of Science Education, Postgraduate School, Universitas Pakuan, Bogor, Indonesia.
[2]Graduate Programs in Environmental Systems, Graduate School of Environmental Engineering, The University of Kitakyushu, Kitakyushu, Japan.
[3]SMP Rimba Teruna, Bogor, Indonesia.

*Corresponding author's email: indarini.dp@unpak.ac.id.

Article History:
Received date: March 5 2025
Received in revised from: May 10 2025
Accepted date: May 15 2025
Available online: June 3 2025

Citation:
Aqilah, S., Pursitasari, I.D., Permana, I., Ardianto, D., Rachman, I. 2025. Opportunities and challenges in enhancing students' science literacy. *JIPI (Jurnal IPA dan Pembelajaran IPA)*, 9(2):352-356.

Abstract. Science literacy is a skill that students need to have to face the challenges of the 21st century. One aspect that can improve science literacy is the use of teaching materials. The purpose of the study was to analyze the opportunities and challenges of improving students' science literacy using teaching materials. The research method used was a systematic literature review with a preferred reporting items for systematic reviews and meta-analysis (PRISMA) flowchart. The results showed that opportunities to improve science literacy are done through various ways including the use of teaching materials, in-depth review of books, and the use of technology. However, learning that involves science activities is still few and more conceptual. In addition, the teaching materials used only contain subject matter and examples of problems and solutions, without encouraging students to find learning concepts. The conclusion obtained is that teaching materials that can be used to improve science literacy include comics, multimedia, books, e-modules, worksheets, and mobile-based learning media.
Keywords: 21st century, learning, science literacy, teaching material

Introduction

Basic literacy is one of the main components of 21st-century skills in addition to competence and character quality. The fundamental literacy skills that should be acquired include reading and writing, numeracy, scientific, information and communication technology, financial, as well as cultural and civic. Science literacy is a very important literacy in making decisions about life and human interaction with nature. In the 21st century, science literacy is essential for developing high-quality human resources and acquiring dependable knowledge and technology, enabling individuals to compete effectively in the global era (Hartono et al., 2023; Suryanti et al., 2021).

Science learning must be oriented towards science literacy and make science literacy one of the outputs that must be achieved in science education (Husniyyah et al., 2023). Aspects of science literacy include the ability to identify and assess methods of inquiry that contribute to scientific knowledge; and the ability to compile, analyze; and understand quantitative data and scientific information (Sarini et al., 2024). The science literacy of students internationally can be known through the results of assessments conducted by the Program for International Student Assessment (PISA) periodically.

PISA assesses the key reading, math, and science competencies of 15-year-old students around the world every three years (Hanfstingl et al., 2024). In addition to the proficiency test, questionnaires for students, principals, and teachers were administered. Science literacy is necessary for everyday decision-making and it is also often applied by non-scientists (Kelp et al., 2023). About 34% of students in Indonesia achieved Level 2 or higher in science (OECD average: 76%) (OECD, 2023). At the very least, students should be able to identify accurate explanations of familiar scientific phenomena and apply this understanding to determine, in basic cases, whether a conclusion is logically supported by the given data (OECD, 2023).

In relation to science literacy, there are several factors that can affect students, both individual and social factors as well as internal and external (Ismeini et al., 2024). Individual factors that influence students' science literacy include background, interest, and learning intensity (Sholikah & Pertiwi, 2021). While social factors include family such as educational background and parental guidance and schools ranging from teaching, facilities, and infrastructure (Setiawan et al., 2023). The external factors that influence are the learning environment so various learning strategies and methods need to be applied to improve students' science literacy (Ahied et al., 2020).

Scientific literacy refers to students' ability to comprehend, communicate, and apply scientific skills to solve real-world problems (Nuraini et al., 2023). Students who have science literacy are able to face the challenges faced today or in the future. One aspect that can improve science literacy is the use of teaching materials. The reliance of both students and teachers can be addressed simultaneously by providing contextually appropriate teaching materials, using language that students can easily understand, enabling them to independently grasp the material they are learning (Nisa et al., 2023).

The learning resources used in instruction do not effectively support the development of science literacy, and the way the material is presented in the book does not align with the student's level of comprehension (Avikasari et al., 2018). The effectiveness of the learning process depends greatly on the quality of teaching materials. Teaching materials are the most important component in the learning process to explain the subject matter. Using teaching materials designed to align with learning objectives encourages students to become active learners, as they can review the content beforehand and prepare for class (Sapulette, 2022; Subagja et al., 2022). This is the prior knowledge that needs to be possessed to build new knowledge so that learning becomes more meaningful.

Given the increasing importance of science literacy in modern education, particularly in fostering critical thinking and decision-making skills, the development of effective teaching materials has become crucial (Osborne & Allchin, 2024). Although various teaching resources are available, many still focus on content delivery rather than concept exploration and active engagement. Moreover, most materials do not integrate components of science literacy such as inquiry skills, contextual relevance, or the connection between science and society (Kusumaningtyas et al., 2025; Virtič, 2022). Previous studies have examined isolated interventions, but a comprehensive synthesis of teaching materials and their potential to enhance science literacy remains limited. Therefore, this study aims to systematically analyze both the opportunities and challenges associated with using diverse teaching materials to improve students' science literacy. This research offers a novel contribution by providing an integrated overview through a systematic literature review approach based on the preferred reporting items for systematic reviews and meta-analysis (PRISMA) protocol, focusing specifically on the alignment of teaching resources with science literacy competencies.

Methods

This research uses the systematic literature review (SLR) method. This SLR uses the PRISMA flowcharts in determining the selection of articles based on the stated research questions. (Mohd & Mahmud, 2024). The stages carried out in the systematic literature review are as follows search strategy, selection criteria, study selection, and data analysis.

Online search engines were used to search for relevant sources to find opportunities and challenges to improve science literacy in students. Some of the online search engines used were ERIC, scopus, google scholar, and science direct. Finding suitable articles was done by using keywords in online search engines. The selection criteria were determined at an early stage before obtaining the required material. Different keywords were selected and are presented in Table 1.

Table 1. Keywords used.

No	Keywords 1	Keywords 2	Keywords 3	Number of articles
1	Science	Literacy	Learning	155
2	Science	Literacy	Analysis	165
3	Science	Literacy	Students	141
4	Science	Literacy	Teaching Material	200

Next, the criteria for selecting articles that were included and excluded were carried out to ensure that the data obtained was valid. Table 2 shows the criteria for articles included and excluded.

Table 2. Reference criteria.

Criteria	Included	Excluded
Year of publication	Published in 2020 to 2024	Published before 2020
Language	English	Other than English
Reference type	Review of articles and journals	Books, theses, proceedings
Research scope	Education	Other than education

Another criterion is that the article must have open access. Articles published in the last four years, and articles published before 2020 are excluded. Articles submitted are articles published by internationally indexed journals on scopus, copernicus, or E-SCI (Thomson Reuters). The PRISMA model was used to select the literature obtained with the stages of identification, screening, eligibility, and inclusion. The four stages are charted in Figure 1.

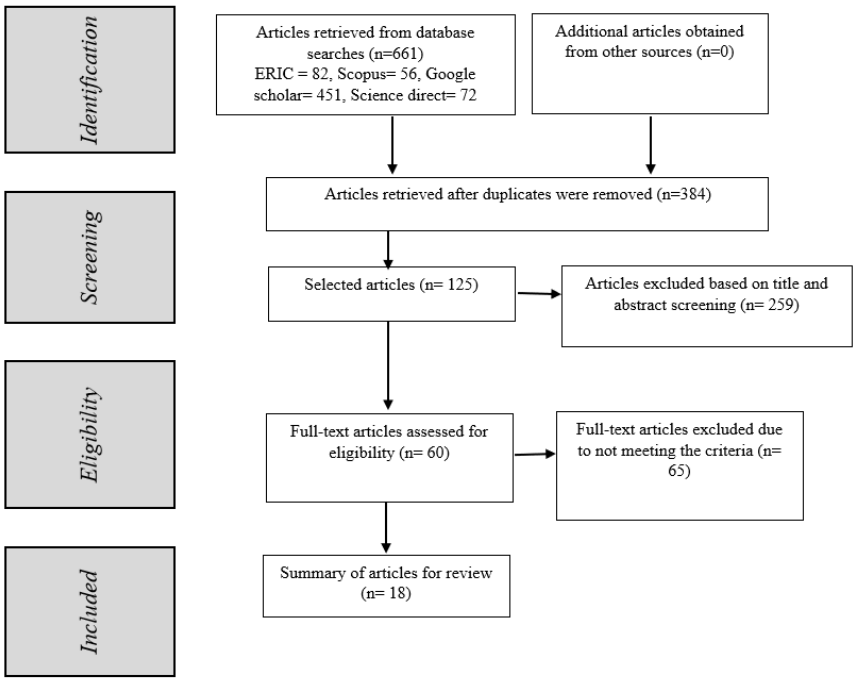

Figure 1. PRISMA protocol (Zakeri et al., 2022).

Based on Figure 1, at the identification stage, articles are sourced from search engines. There are no additional articles from sources other than search engines. In the screening stage, the same article is deleted. Next, articles are selected based on the title and abstract of the article. Articles that pass the selection then enter the eligibility stage. At the eligibility stage, articles are assessed for eligibility based on the specified criteria. At the included stage, 18 articles were found to be suitable for review. The article quality assessment rubric is presented in Table 3.

Table 3. Quality assessment rubric.

No	Criteria	Assessment Weight			
		4 (Exceeds Standard)	3 (Meets Standard)	2 (Almost Meets Standard)	1 (Does not meet)
1	Purpose and objectives	Clearly articulated problem, purpose, and rationale, and questions.	Fully articulated.	Well articulated.	Not clearly articulated.
2	Literature review	Critically examine the situation in the field. Make interesting connections with previous research. Synthesize and evaluate ideas and offer new perspectives.	Discuss what has and has not been done. Connecting with previous research. Define key vocabulary and synthesize and evaluate ideas.	Minimally discusses what has and has not been done. Makes connections with previous research but lacks cross-literature synthesis. Minimal evaluation of ideas	None.
3	Theoretical or conceptual framework	Clearly articulated and described in detail. The framework is aligned with the research objectives.	Articulated and aligned with research objectives.	Implied or described in terms that are unclear or not fit for purpose.	Incomplete.
4	Participants	Detailed description and population, sample, and sampling are present.	A relatively detailed explanation of the population, sample, and procedures.	Basic description of the sample and procedure.	Incomplete.
5	Methods	The instruments and their administration are	Instruments and administration	The instrument is described, but	Incomplete.

No	Criteria	Assessment Weight			
		4 (Exceeds Standard)	3 (Meets Standard)	2 (Almost Meets Standard)	1 (Does not meet)
		thoroughly described, with validity and reliability evidence provided, and potential biases taken into account.	described. Evidence of validity or reliability. Potential bias considered.	evidence of validity or reliability is incomplete, and certain research practices may be questionable.	
6	Results and Conclusion	Detailed results. Excellent use of data displays. The discussion clearly links findings to previous research. Suggests future research directions. Conclusions clearly answer the problem or question.	Complete results. Adequate use of data displays. Discussion relates findings to previous work. The conclusion addresses the problem or question.	Basic results. Inadequate use of data. The discussion fails to link findings to previous research. The conclusion summarizes the findings.	Incomplete.

The data reviewed was obtained through the thematic analysis method and used to analyze the data. This method is a suitable method for sorting qualitative data, which can be very helpful in research. Articles were analyzed based on the research questions to derive research themes. The research questions were (1) what are the opportunities and challenges in improving students' science literacy? and (2) what are the teaching materials that can be used to improve students' science literacy?

Results and Discussion

The articles analyzed are articles published in the range of 2020-2024 as many as 18 articles. All articles are in English and the research was conducted in Indonesia, Canada, and the United States. The research methods of the articles analyzed were qualitative, quantitative, and research and development (R&D). A summary of the results of the article review is in Table 4. Based on Table 4, the R&D method is the most widely used in improving science literacy. Increasing science literacy is done by using various teaching materials given to students.

The effectiveness of the teaching materials used is carried out by validation as well as tests so that the improvement of students' science literacy can be seen. Integration of teaching materials with various approaches is also carried out such as integrating teaching materials with ethnoscience, and science, technology, engineering, arts and mathemathics (STEAM), science, technology, and society (STS), to distance learning. The findings show various positive impacts of improving science literacy such as an increase in understanding and positive attitudes towards science, better understanding of complex scientific problems, generating high interest, encouraging students to engage with science as a body of knowledge, a way of investigating, and a way of thinking, thus increasing understanding of science.

Table 4. Result of article review.

No	Title	Author (year)	Methods	Findings
1	*Science*-literacy-based teaching materials training management model: improving the professional competence of Middle School Teachers	(Ismeini et al., 2024)	R&D Thiagarajan Four-D (4-D) development model	The model significantly affected the improvement of student's grades in the classroom, indicated by tcount 3.263 exceeding t-table 2.042, suggesting that the training model is suitable for use by teachers at SMP N 11 Medan.

No	Title	Author (year)	Methods	Findings
2	"*Fin*-tastic fish science": using a comic book to disseminate and enhance science literacy	(Wayne et al., 2024)	Quantitative	The "Fin-tastic Fish Science" comic book effectively increased science literacy and engagement among students, showing learning gains comparable to those achieved through traditional journal articles.
3	*Beyond* a textbook: a captivating popular nonfiction book on virology for enhancing science literacy	(Stadtländer, 2023)	Qualitative	Popular books can significantly improve science literacy by making scientific information more accessible and engaging for students, leading to increased understanding and positive attitudes toward science.
4	Development of science literacy-based teaching materials on soil formation process and soil building components	(Nisa et al., 2023)	R&D model 4D	The scientific literacy-based teaching materials on soil formation processes and soil components were validated as highly reliable, earning a validity score of 3.70, demonstrating their appropriateness for educational use. The materials also proved practical, scoring 70.85%, and effective, with an n-gain of 0.91, classifying them as highly effective. These results confirm their suitability for classroom implementation.
5	Learning science through argumentative synthesis writing and deliberative dialogues: a comprehensive and effective methodology in secondary education	(Casado-Ledesma et al., 2023)	Quasi-experimental pre-post study	Instructional practices have no direct effect on content learning, there is an indirect effect of explicit instruction on socio-scientific content learning, mediated by improved quality of argumentative synthesis writing, suggesting that improving students' writing skills may facilitate better understanding of complex scientific issues.
6	The potential of using mobile-based interactive multimedia to improve scientific literacy	(Pratama et al., 2023)	Qualitative	The use of mobile-based interactive multimedia in learning has significant potential to improve students' scientific literacy, as it not only generates high interest among students but also provides many benefits that facilitate students' understanding of the learning material.
7	STEAM-based science student worksheets to improve elementary school students' scientific literacy	(Afrijal et al., 2023)	R&D ADDIE development model	The developed Steam-based student worksheets are valid, practical, and effective in improving elementary school students' science literacy skills.
8	Exploration of integrated science-physics textbooks based on science literacy indicators: a case study in Kendari City Indonesia	(Fayanto et al., 2023)	Quantitative descriptive	Neither textbook fully addresses all aspects of scientific literacy, particularly the relationship between science, technology, and society.

No	Title	Author (year)	Methods	Findings
9	Mobile learning media based on STS to improve science literacy for v grade SD students	(Nugroho et al., 2022)	R&D model ADDIE	The development of STS based mobile learning media is essential for grade five primary school students, as it enhances their scientific literacy skills and is aligned with 21st century learning approaches. The media was found to be highly feasible and practical, receiving high validity scores from material and media experts, as well as positive feedback from teachers and students.
10	The implementation of teaching material based on stem in fluid for biology student	(Wulandari et al., 2022)	R&D	The implementation of this teaching material resulted in a significant increase in scientific literacy among students, as evidenced by an N gain of 0.48, and positive feedback from student response tests that confirmed its suitability as a learning resource.
11	Student needs analysis of the scientific literacy oriented interactive multimedia on living cells matter	(Subagja et al., 2022)	Qualitative descriptive	There is a clear need for the development of interactive multimedia-based teaching materials that incorporate scientific literacy, particularly in the context of living cell material, to improve students' understanding and skills in science.
12	Analysis of students' scientific literacy skill in terms of gender using science teaching materials discovery model assisted by PhET simulation	(Bahtiar et al., 2022)	Experimental method	Female students demonstrated higher scientific literacy skills (80) compared to male students (77.95), indicating gender differences in scientific understanding and performance in the context of the teaching materials used.
13	The development of electronic module based on scientific literacy on colloidal topic	(Silaban et al., 2022)	R&D 4D model	The electronic module based on scientific literacy for the topic of colloids was validated as 'very feasible' by the material expert, with a score of 91.75%, and the media expert, a score of 89%, indicating the high quality and suitability of the teaching materials for grade XI SMA/MA students.
14	The effectiveness of wetland environment static fluid e-module to train learners' science literacy	(Mahardika et al., 2022)	R&D ADDIE model	The e-module designed for static fluid materials in wetland environments effectively enhances students' scientific literacy, as demonstrated by the high n-gain in their science literacy test results.
15	The effect of ethnoscience-themed picture books embedded within context based	(Yuliana et al., 2021)	Quasi-experimental design	The findings suggest that integrating ethnoscience-themed materials into context-based learning can provide an alternative approach for educators and

No	Title	Author (year)	Methods	Findings
	learning on students' scientific literacy			curriculum developers to improve students' scientific literacy.
16	Enhancing science literacy and communication among the next generation of scientists in an online learning environment	(Fitzpatrick et al., 2021)	R&D	This e-module is designed to enhance critical thinking, scientific literacy, and communication skills, which are essential for students, particularly international students who encounter additional challenges.
17	Improving students scientific literacy through distance learning with augmented reality-based multimedia amid the covid-19 pandemic	(Ahied et al., 2020)	Quantitative descriptive, using pre-test and post-test approaches	Students' scientific literacy improved significantly through distance learning utilizing augmented reality-based multimedia, though the extent of improvement varied across classes (A, B, and C). The average N-gain scores were 0.31 for class A, 0.38 for Class B, and 0.22 for class C, reflecting differences in students' understanding and knowledge acquisition.
18	How to develop teaching material to promote student's scientific literacy through blended learning at Junior High School?	(Pursitasari et al., 2020)	R&D ADDIE model	The developed teaching materials, which incorporate scientific literacy components, have been validated as effective and categorized as excellent in promoting students' scientific literacy. The materials include various activities that encourage students to engage with science as a body of knowledge, a way of investigating, and a way of thinking, thereby enhancing their understanding of the earth's atmosphere and its relevance to life.

Opportunity to improve students' science literacy

An in-depth analysis of scientific literacy in integrated science textbooks has not yet been conducted (Fayanto et al., 2023). Thoroughly assessing the quality of textbooks used in schools and available on the market is essential before they are implemented in the classroom. Teachers should evaluate their textbooks to enhance the quality of education and learning, particularly in scientific literacy. One effective approach to improving education is the use of well-designed teaching materials. The use of appropriate teaching materials in science teaching is one of the strategies that help students in developing science literacy (Bahtiar et al., 2022). Previous research findings indicate that students' scientific literacy, particularly in Indonesia, remains relatively low (Pratama et al., 2023). Therefore, there is potential for using interactive multimedia to improve students' science literacy.

One effective way that can be used to teach science literacy skills to students is by utilizing digital technology (Nugroho et al., 2022). The utilization of interactive multimedia based on mobile devices in learning has great potential to improve students' scientific literacy. This is due to its ability to attract students' interest significantly while providing various advantages that support students' understanding of learning materials (Pratama et al., 2023).

The Challenge of Improving Students' Science Literacy

Science literacy plays an important role in catalyzing science learning in the 21st century. Research shows that it is difficult to connect science to everyday life and focus more on completing the syllabus rather than implementing the right teaching approaches (Yuliana et al., 2021). In addition, many science textbooks only emphasize basic knowledge without integrating science, technology, and society. Some of the factors that cause low student science literacy include learning activities that involve science activities are still relatively few and more focused on concepts, ma the teaching materials used only contain subject matter and examples of problems along with their solutions, without encouraging students to find learning concepts and solve problems faced (Mahardika et al., 2022).

Science literacy requires an understanding of scientific concepts and theories, as well as knowledge of common procedures and practices related to scientific research and scientific progress (Silaban et al., 2022). Many students have difficulties in learning science which will cause misconceptions and misunderstandings. One of the challenges faced is implementing fun and effective learning and developing science literacy (Ahied et al., 2020).

The key finding from the observations is that, during science lessons, students tend to memorize the material rather than understand, analyze, or evaluate the information presented by the teacher throughout the learning process (Nugroho et al., 2022). Furthermore, it was observed that teachers seldom incorporate scientific investigation activities, such as practical experiments and hands-on exercises, into the learning process. The data obtained shows that in classroom learning, there are always students who do not understand the learning material, especially in science or math lessons (Afrijal et al., 2023). Sometimes, the suggestions given by students seem complex, and students still find it difficult to find the substance of the material being studied.

Teaching Materials Used to Improve Students' Science Literacy

Teaching materials that currently exist vary from printed teaching materials to digital forms. Teaching materials that have been designed according to learning needs direct students to become active learners. Students can read or study the material contained in the teaching material before attending class. The available learning time is no longer used by the teacher to explain the material at length but is more focused on discussion and discussion of certain material that has not been understood by students (Sapulette, 2022). The types of teaching materials used in improving science literacy in the articles analyzed are presented in Figure 2.

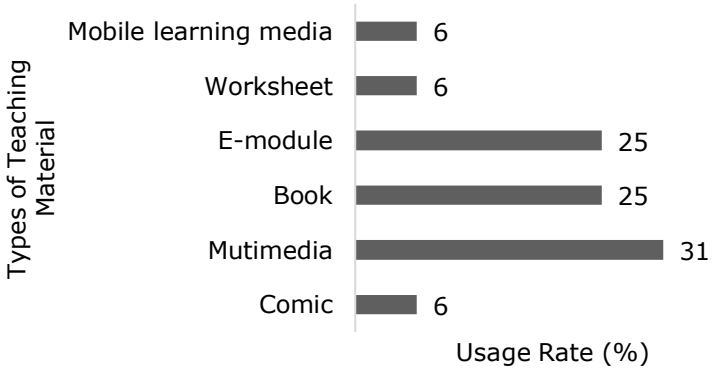

Figure 2. Teaching materials used to improve science literacy

Based on Figure 2, the most widely used teaching material to improve students' science literacy is multimedia. This is because multimedia contributes significantly to the effectiveness of the teaching and learning process as well as the delivery of messages and content, thus helping students to improve their understanding and thinking skills (Shofawati et al., 2023; Arlim et al., 2023). The smallest percentage of teaching materials used are comics, worksheets, and mobile learning media. This is because making a comic is more difficult than drawing a single illustration (Lamminpää et al., 2023). Meanwhile, worksheets have not functioned optimally in helping students find concepts (Mahyuny et al., 2022). The use and development of mobile learning media in science learning have been lacking (Pratama et al., 2023).

Several factors influence the mastery of scientific literacy, including the teaching materials used by teachers to develop learning concepts. Teaching materials that stimulate students' curiosity about a subject can foster their enthusiasm for problem-solving (Pursitasari et al., 2020). The teaching materials presented by teachers can enhance science process skills, which are a key component of scientific literacy competencies. High-quality science teaching materials should incorporate elements of scientific literacy, including science as a body of knowledge, science as a method of inquiry, science as a way of thinking, and the relationship between science, technology, and society (Pursitasari et al., 2020).

By using teaching materials designed to meet learning needs, students are encouraged to become active learners, as they can review and study the content before attending class (Sapulette, 2022). As a result, when discussing the material in class, students already possess adequate information and knowledge. This allows teachers to spend less time on lengthy explanations and instead focus on discussions and clarifying concepts that students may not yet fully understand. The essence of making teaching materials is to facilitate the learning process (Subagja et al., 2022). One way to facilitate the learning process is by using interactive multimedia.

The use of interactive multimedia can help improve science literacy because it makes science material more interesting and easy to understand. Interactive multimedia can present scientific information in various formats, such as images, videos, animations, and simulations (Pratama et al., 2023). This makes science concepts more visual and facilitates understanding of complex concepts. The use of augmented reality as interactive multimedia can improve students' science literacy (Ahied et al., 2020).

Science literacy contained in the module is one of the factors determining the effectiveness of the module. Science literacy can improve student learning outcomes or achievements because it becomes the core of learning by integrating science literacy materials and indicators (Mahardika et al., 2022). In addition to printed modules, electronic modules are currently being developed by leveraging technology. These electronic modules are designed to address existing challenges and aim to mitigate students' lack of interest in science subjects by producing science literacy-based teaching materials that facilitate learning, both collaboratively and independently (Silaban et al., 2022). In addition to electronic modules, another type of instructional material that utilizes technology is mobile-based learning media.

Mobile-based learning media are interactive and contextual tools equipped with engaging features that facilitate students' understanding of learning materials. These media can be utilized in school settings to enhance students' science literacy skills (Nugroho et al., 2022). One example of learning media used to enhance students' science literacy is PhET Colorado. Computer simulations have been proven to be significantly more effective compared to traditional instructional designs. (Banda & Nzabahimana, 2023). Classroom learning often relies on the use of textbooks.

The textbooks used by students should contain content that stimulates critical thinking, as this can capture their attention at the beginning of the learning process

(Fayanto et al., 2023). The quality of textbooks also influences the level of science literacy (Yuliana et al., 2021). In addition to textbooks, comics can be utilized to enhance science literacy. Comics can visually depict abstract scientific topics, making them a valuable medium for educational purposes and literacy improvement (Wayne et al., 2024). Another approach to enhancing science literacy is through the use of student worksheets.

An effective STEAM-based student worksheet for improving students' science literacy skills should incorporate elements of STEAM contextually, based on phenomena or activities within the students' local environment (Afrijal et al., 2023). These elements need to be integrated comprehensively with the indicators of science literacy. A STEAM-based student worksheet product that is practically effective for improving science literacy skills ensures that all learning activities can be conducted efficiently within the allocated time frame.

Conclusion

Opportunities for improving science literacy can be pursued through various methods, including the use of science literacy-based teaching materials, an in-depth review of science literacy-based textbooks, and the utilization of technology. Challenges in enhancing science literacy include difficulties in connecting science to everyday life and an overemphasis on completing subject matter rather than applying appropriate teaching approaches. Additionally, science-related activities in learning are still limited and primarily focused on concepts, while the teaching materials used typically consist only of subject content and example problems with their solutions. These materials do not encourage students to discover learning concepts or solve problems independently. Teaching materials that can be utilized to enhance science literacy include comics, multimedia, books, e-modules, worksheets, and mobile-based learning media.

References

Afrijal, Yulianti, D., Rohman, F., & Sunyono. 2023. STEAM-based science student worksheets to improve elementary school students' scientific literacy. *Thinking Skills and Creativity Journal*, 6(2):94–105. https://doi.org/10.23887/tscj.v6i2.67152

Ahied, M., Muharrami, L.K., Fikriyah, A., & Rosidi, I. 2020. Improving students' scientific literacy through distance learning with augmented reality-based multimedia amid the covid-19 pandemic. *Jurnal Pendidikan IPA Indonesia*, 9(4):499–511. https://doi.org/10.15294/jpii.v9i4.26123

Arlim, M., Afrizon, R., Hufri, H., Dewi, W.S., & Sundari, P.D. 2023. Need analysis of interactive multimedia based on scientific literacy in physics learning. *Physics Learning and Education*, 1(2):91–99. https://doi.org/10.24036/ple.v1i2.36

Avikasari, A., Rukayah, R., & Indriayu, M. 2018. The influence of science literacy-based teaching material towards science achievement. *International Journal of Evaluation and Research in Education (IJERE)*, 7(3):182-187. https://doi.org/10.11591/ijere.v7i3.14033

Bahtiar, Ibrahim, & Maimun. 2022. Analysis of students' scientific literacy skill in terms of gender using science teaching materials discovery model assisted by phet simulation. *Jurnal Pendidikan IPA Indonesia*, 11(3):371–386. https://doi.org/10.15294/jpii.v11i3.37279

Banda, H.J., & Nzabahimana, J. 2023. The impact of physics education technology (phet) interactive simulation-based learning on motivation and academic achievement among malawian physics students. *Journal of Science Education and Technology*, 32(1):127–141. https://doi.org/10.1007/s10956-022-10010-3

Casado-Ledesma, L., Cuevas, I., & Martín, E. 2023. Learning science through argumentative synthesis writing and deliberative dialogues: a comprehensive and effective methodology in secondary education. *Reading and Writing*, 36(4):965-996. https://doi.org/10.1007/s11145-021-10191-0

Fayanto, S., Sulthoni, S., Wedi, A., Takda, A., & Fadilah, M. 2023. Exploration of integrated science-physics textbooks based on science literacy indicators: a case study in kendari city indonesia. *Anatolian Journal of Education*, 8(1):159–172. https://doi.org/10.29333/aje.2023.8111a

Fitzpatrick, A., Andreopoulos, S., & Freedman, L. 2021. Enhancing science literacy and communication among the next generation of scientists in an online learning environment. *Biochemistry and Molecular Biology Education*, 49(6):856–858. https://doi.org/10.1002/bmb.21584

Hanfstingl, B., Gnambs, T., Porsch, R., & Jude, N. 2024. Exploring the association between non-specialised science teacher rates and student science literacy: an analysis of PISA data across 18 nations. *International Journal of Science Education*, 46(9):874–892. https://doi.org/10.1080/09500693.2023.2262729

Hartono, A., Djulia, E., Hasruddin, & Jayanti, U.N.A.D. 2023. Biology students' science literacy level on genetic concepts. *Jurnal Pendidikan IPA Indonesia*, 12(1):146–152. https://doi.org/10.15294/jpii.v12i1.39941

Husniyyah, A.A., Erman, E., Purnomo, T., & Budiyanto, M. 2023. Scientific literacy improvement using socio-scientific issues learning. *IJORER : International Journal of Recent Educational Research*, 4(4):447–456. https://doi.org/10.46245/ijorer.v4i4.303

Ismeini, R., Rahman, A., & Mudjisusatyo, Y. 2024. Science-literacy-based teaching materials training management model: improving the professional competence of middle school teachers. *Randwick International of Education and Linguistics Science Journal*, 5(1):159–171. https://doi.org/10.47175/rielsj.v5i1.915

Kelp, N.C., McCartney, M., Sarvary, M.A., Shaffer, J.F., & Wolyniak, M.J. 2023. Developing science literacy in students and society: theory, research, and practice. *Journal of Microbiology & Biology Education*, 24(2):1-4. https://doi.org/10.1128/jmbe.00058-23

Kusumaningtyas, D.I., Suprapto, N., & Suryanti. 2025. Fostering science literacy: a comprehensive systematic review of learning models. *Multidisciplinary Reviews*, 8(9):1-12. https://doi.org/10.31893/multirev.2025292

Lamminpää, J., Vesterinen, V.M., & Puutio, K. 2023. Draw-a-science-comic: exploring children's conceptions by drawing a comic about science. *Research in Science and*

Technological Education, 41(1):39–60. https://doi.org/10.1080/02635143.2020.1839405

Mahardika, A.I., Arifuddin, M., Saputra, N.A.B., & Hayati, M. 2022. The effectiveness of wetland environment static fluid e-module to train learners' science literacy. *Cypriot Journal of Educational Sciences*, 17(12):4556–4569. https://doi.org/10.18844/cjes.v17i12.8190

Mahyuny, S.R., Nursamsu, N., Hasruddin, H., & Muslim, M. 2022. Development of students worksheet learning tools made by ethnoscience based on science literacy. *Jurnal Penelitian Pendidikan IPA*, 8(4):2294–2301. https://doi.org/10.29303/jppipa.v8i4.1949

Mohd, N.M.Z., & Mahmud, S.N.D. 2024. Empowering scientific literacy of science teachers: systematic literature review (SLR). *International Journal of Academic Research in Progressive Education and Development*, 13(1):676-697. https://doi.org/10.6007/ijarped/v13-i1/20434

Nisa, H., Putri, R.F., & Hafizah, E. 2023. Development of science literacy-based teaching materials on soil formation process and soil building components. *Journal of World Science*, 2(7):957–966. https://doi.org/10.58344/jws.v2i7.338

Nugroho, H.S., Supriyadi, & Haryani, S. 2022. Mobile learning media based on science, technology, and society (STS) to improve science literacy for v grade SD students. *International Journal of Research and Review*, 9(4):180–188. https://doi.org/10.52403/ijrr.20220423

Nuraini, N., Asri, I.H., & Fajri, N. 2023. Development of project based learning with steam approach model integrated science literacy in improving student learning outcomes. *Jurnal Penelitian Pendidikan IPA*, 9(4):1632–1640. https://doi.org/10.29303/jppipa.v9i4.2987

OECD. 2023. PISA 2022 Results Factsheets Indonesia. OECD (Organisation for Economic Co-Operation and Development), 1–9. https://www.oecd.org/en/publications/pisa-2022-results-volume-i-and-ii-country-notes_ed6fbcc5-en/indonesia_c2e1ae0e-en.html

Osborne, J., & Allchin, D. 2024. Science literacy in the twenty-first century: informed trust and the competent outsider. *International Journal of Science Education*, 1–22. https://doi.org/10.1080/09500693.2024.2331980

Pratama, K.R., Yamtinah, S., & Roemintoyo. 2023. The potential of using mobile-based interactive multimedia to improve scientific literacy. *International Journal of Social Science and Human Research*, 6(2):916–919. https://doi.org/10.47191/ijsshr/v6-i2-20

Pursitasari, I.D., Ardianto, D., Kurniasih, S., & Hidayat, I. 2020. How to develop teaching material to promote student's scientific literacy through blended learning at junior high school? *Journal of Education and Practice*, 11(17):46–55. https://doi.org/10.7176/jep/11-17-05

Sapulette, V. 2022. Development of scientific-based indonesian teaching materials to train communication skills of physics education students FKIP Pattimura University Ambon. *International Journal of Social Science and Human Research*, 5(4):1352–1357. https://doi.org/10.47191/ijsshr/v5-i4-21

Sarini, P., Widodo, W., Sutoyo, S., & Suardana, I.N. 2024. Scientific literacy profile of prospective science teacher students. *IJORER : International Journal of Recent Educational Research*, 5(4):1026–1039. https://doi.org/10.46245/ijorer.v5i4.627

Setiawan, D., Ashari, R.B., Ansori, I., Fathurrahman, M., Kiptiyah, S.M., & Tyas, D.N. 2023. Actualization of science literacy in the freedom era of studying in the city of semarang. *Jurnal Penelitian Pendidikan IPA*, 9(9):7238–7248. https://doi.org/10.29303/jppipa.v9i9.4219

Shofawati, A., Widodo, W., & Sari, D.A.P. 2023. The use of multimedia interactive to improve students science literacy in the new normal era. *Jurnal Pijar Mipa*, 18(1):65–71. https://doi.org/10.29303/jpm.v18i1.3832

Sholikah, L., & Pertiwi, F.N. 2021. Analysis of science literacy ability of junior high school students based on programme for international student assessement (PISA). *Insecta: Integrative Science Education and Teaching Activity Journal*, 2(1):95–104. https://doi.org/10.21154/insecta.v2i1.2922

Silaban, R., Sitorus, M., Musa Panggabean, F.T., & Manullang, E. 2022. The development of electronic module based on scientific literacy on colloidal topic. *International Journal of Computer Applications Technology and Research*, 11(06):223–230. https://doi.org/10.7753/ijcatr1106.1007

Stadtländer, C.T.K. 2023. Beyond a textbook : a captivating popular non fiction book on virology for enhancing science literacy. *Journal of Microbiology & Biology Education*, 24(1):1-3. https://doi.org/10.1128/jmbe.00020-23

Subagja, S., Rubini, B., & Pursitasari, I.D. 2022. Student needs analysis of the scientific literacy oriented interactive multimedia on living cells matter. *International Journal of Biology Education Towards Sustainable Development*, 2(1):1–11. https://doi.org/10.53889/ijbetsd.v2i1.116

Suryanti, S., Widodo, W., & Yermiandhoko, Y. 2021. Gadget-based interactive multimedia on socio-scientific issues to improve elementary students' scientific literacy. *International Journal of Interactive Mobile Technologies*, 15(1):56–69. https://doi.org/10.3991/IJIM.V15I01.13675

Virtič, M.P. 2022. Teaching science & technology: components of scientific literacy and insight into the steps of research. *International Journal of Science Education*, 44(12):1916–1931. https://doi.org/10.1080/09500693.2022.2105414

Wayne, C.R., Kaller, M.D., Wischusen, W.E., & Maruska, K.P. 2024. "Fin-tastic fish science": using a comic book to disseminate and enhance science literacy. *Natural Sciences Education*, 53(1):1–10. https://doi.org/10.1002/nse2.20135

Wulandari, D., Roza, D., Pulungan, A.S.S., Rangkuti, M.A., Wisnu, W.B., Tanjung, Y.I., Ramadhani, I., & Hasim, R. 2022. The implementation of teaching material based

on stem in fluid for biology student. *International Journal of Research - Granthaalayah*, 10(2):61–70. https://doi.org/10.29121/granthaalayah.v10.i2.2022.4507

Yuliana, I., Cahyono, M.E., Widodo, W., & Irwanto, I. 2021. The effect of ethnoscience-themed picture books embedded within contextbased learning on students' scientific literacy. *Eurasian Journal of Educational Research*, 2021(92):317–334. https://doi.org/10.14689/ejer.2021.92.16

Zakeri, N.B.N., Hidayat, R., Sabri, N.A.B.M., Yaakub, N.B.F., Balachandran, K.S., & Azizan, N.B.I. 2022. Creative methods in STEM for secondary school students: systematic literature review. *Contemporary Mathematics and Science Education*, 4(1):1-9. https://doi.org/10.30935/conmaths/12601