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Research trends in the development of learning models oriented to increasing scientific literacy: A systematic literature review

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ABSTRACT

This study aims to identify and analyze publications on the use of learning models, learning approaches, or learning programs in Science Education oriented towards enhancing scientific literacy based on research journal articles over the last five years from 2019 to 2024. A systematic literature review method was employed, guided by the PRISMA flowchart. Data were obtained from 456 national and international articles through Mendeley. After screening, 15 articles were found to meet the criteria as samples. Our findings indicate that integrated science education using a variety of models, approaches, or programs significantly improves students' scientific literacy. This study delineates effective educational strategies, impacting the pedagogical domain by offering insights into learning models that can foster scientific literacy. Future research should investigate the integration of inquiry-based collaborative learning with team-based projects to innovate and enhance educational outcomes.

Tren penelitian pengembangan model pembelajaran dalam meningkatkan literasi sains: Sebuah tinjauan literatur sistematis

Keywords:

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ABSTRACT

Penelitian ini bertujuan untuk mengidentifikasi dan menganalisis publikasi tentang penggunaan model pembelajaran, pendekatan pembelajaran atau program pembelajaran dalam pembelajaran Ilmu Pengetahuan Alam yang berorientasi pada peningkatan literasi sains berdasarkan artikel jurnal penelitian dalam 5 tahun terakhir dari tahun 2019 hingga 2024. Metode tinjauan literatur sistematis digunakan dengan panduan diagram PRISMA. Data diperoleh dari 456 artikel nasional dan internasional melalui Mendeley. Setelah penyaringan, ditemukan 15 artikel yang memenuhi kriteria sebagai sampel. Temuan kami menunjukkan bahwa pendidikan sains terpadu yang menggunakan beragam model, pendekatan, atau program secara signifikan meningkatkan literasi sains siswa. Studi ini menjelaskan strategi pendidikan yang efektif, memberikan dampak pada domain pedagogi dengan menawarkan wawasan tentang model pembelajaran yang dapat mendorong literasi sains. Penelitian di masa depan harus menyelidiki pengintegrasian pembelajaran kolaboratif berbasis inkuiri dengan proyek berbasis tim untuk berinovasi dan meningkatkan hasil pendidikan.

1. INTRODUCTION

In the 21st Century, the world of work requires every individual to have various skills. The world of work requires individuals who are creative, innovative, critical, initiative, independent, able to lead, work together in teams, literate, communicate effectively, and able to make decisions and solve problems [1]. Trilling & Fadel also revealed that 21st Century skills consist of three main types of skills, namely: (1) life and career skills, (2) learning and innovation skills, and (3) information media and technology skills. Scientific literacy is one of the skills demanded in the 21st Century. Scientific literacy is becoming increasingly important as modern society becomes increasingly dependent on science and technology. However, scientific knowledge is still limited among the general public, and scientific information is often incorrectly believed to be true [1], [2]. The PISA (Program for International Student Assessment) results show that scientific literacy is still a problem in many countries [3], [4]. The 2022 PISA results announced on December 5, 2023, showed a decrease in Indonesia's PISA scores compared to Indonesia's PISA scores in 2018 and 2015. Indonesia only scored 359 in reading, 366 in mathematics, and 383 in science. This score has decreased compared to Indonesia's PISA scores in the two previous PISA tests in 2018 and 2015. This decrease in scores was caused by learning loss due to the COVID-19 pandemic, which occurred from early 2020 to mid-2022 [5]. The 2018 PISA results show that for scientific literacy, the average score of Indonesian students reached 389, with an international average score of 489 [6]. Indonesia's PISA score in 2018 also decreased compared to the results of the 2015 PISA test, which showed a scientific literacy achievement of 403. The scientific literacy score in PISA 2015 was the highest score ever achieved by Indonesian students.

The decline in Indonesia's PISA scores in the two latest PISA test results is quite worrying. When compared with the average international score, Indonesia has quite a distance. Even Indonesia's PISA scores in the two most recent PISA tests failed to reach a score above 400 for the three aspects measured in PISA. If we look at the start of the PISA test in 2000 until the last PISA test in 2022, the PISA score for the scientific literacy aspect of Indonesian students was only once above 400, namely in 2015. The rest of the time, Indonesia's science score was below 400, far from the OECD international average score, which is close to 500. This result is undoubtedly enough to illustrate that the scientific literacy abilities of Indonesian students are still low. The results of other scientific literacy research in Indonesia were conducted by the Ministry of Education and Culture in 2018. The research was conducted using a survey method among students throughout Indonesia, with 10,587 respondents from 34 provinces. The results of the research show that the scientific literacy of Indonesian students is still relatively low; namely, only 2.6% of students have achieved a high level of scientific literacy, 42.8% of students are at a medium level of scientific literacy, and 54.6% of students are at a medium level of scientific literacy low level of scientific literacy. These results show that many students in Indonesia have inadequate science skills and knowledge [6].

The factors that cause students' low scientific literacy are closely related to the learning models applied in the educational process. Learning models that do not support active interaction, concept exploration, and the development of critical thinking skills tend to exacerbate scientific literacy problems. In contrast, learning models that encourage active student involvement in investigating natural phenomena, conducting experiments, and discussing scientific concepts will be more effective in increasing their scientific literacy [7].

Implementing student-centered learning models like project-based, problem-based, or cooperative learning can help students build a deep understanding of science concepts. These models encourage students to be active in their learning, asking questions, seeking answers, and communicating their understanding to others. This can help students develop strong science literacy skills, including comprehension of science texts, the ability to interpret data, and critical thinking skills [7], [8].

In addition, using technology in learning models can also help improve students' scientific literacy by providing access to interactive learning resources and tools that can increase their understanding of science concepts more visually and practically. By implementing appropriate and effective learning models, schools can play an essential role in improving students' scientific literacy and preparing them to face future science and technology challenges [9].

Indonesia, as one of the developing countries in the world, has significant challenges in improving students' scientific literacy skills. Good scientific literacy skills are necessary for students in the current era, which is increasingly filled with technological advances and scientific innovation. However, in reality, students' scientific literacy abilities in Indonesia are still low. According to a study conducted by Rahman, The scientific literacy ability of high school students in Indonesia only reaches an average of 44.5. This research also shows that students' scientific literacy abilities are influenced by several factors, such as curriculum, teaching methods, and learning environment [10]. Scientific literacy skills are also influenced by the educational institution where students study [11].

The most fundamental thing in students' mastery of scientific literacy is understanding the basic concepts of science itself. A deep understanding of the scientific method, basic theories in various science fields, and the principles underlying knowledge are fundamental in all aspects of scientific literacy. This helps students understand the world around them, explore scientific questions, and participate in science learning more effectively. Understanding basic concepts also helps students better recognize and evaluate scientific information, enabling them to become informed consumers in a society increasingly dominated by scientific knowledge [12].

Even though various efforts have been made to increase students' scientific literacy, several limitations still hinder success. Limited resources, such as limited laboratory facilities, dense curricula, and varying teaching quality, can hinder the development of effective scientific literacy. The lack of support from family and community, ineffective evaluations, and cultural and language challenges also complicate these efforts. To overcome these limitations, collaborative efforts are needed from various stakeholders in education to provide a supportive and relevant learning environment for students to develop solid and relevant scientific literacy in an increasingly complex future [7].

The results achieved from scientific literacy-oriented learning do show an increase in students' scientific literacy abilities, but these results are only local, so they do not have a massive impact on increasing the scientific literacy of Indonesian students as a whole. For this reason, a learning model specifically designed to improve scientific literacy skills is needed, and it can be applied to every science lesson oriented toward scientific literacy. So, to design the learning model in question, a literature review is needed regarding suitable learning models/approaches/programs in increasing students' scientific literacy as a basis for developing new innovative learning models.

Various efforts have been made to increase scientific literacy, such as implementing the discovery learning model [13], use of interactive multimedia [14]–[16], inquiry-based learning [17], use of guided inquiry-based teaching materials [18], Use of integrated particle dynamics module, traditional game based e-learning [19], guided inquiry learning

[20], [21], use of STEM-based virtual laboratories [22], inquiry learning [23], use of socio scientific issue based learning materials [24], application of the level of inquiry model [25], application project-based learning [26], using problem-based learning based on e-modules or e-worksheets [27], [28]. However, there has yet to be any research that examines the trend in research development on learning models. Based on the above, systematic and structured efforts are required to enhance scientific literacy.

This study aims to analyze and synthesize various effective learning models for improving science literacy. It examines the efforts that have been explicitly made regarding models, approaches, media, teaching materials, and/or learning programs used to enhance students' science literacy. Recognizing the need to develop learning programs with the best potential for improving science literacy is crucial. Therefore, this study brings new findings in the form of valuable information for researchers as a basis for designing innovative learning programs/models tailored explicitly for learning oriented towards enhancing students' science literacy.

Contribution to the literature

This research contributes to filling existing research gaps, specifically:

- This study provides valuable insights into effective learning models for enhancing students' science literacy.
- It encourages innovation in learning approaches and curriculum development.
- This research can be a starting point for further science education and literacy studies.

2. METHOD

This research used a qualitative approach with a systematic literature review method using the PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis) technique. The following PRISMA diagram depicts the article selection process presented in Figure 1.

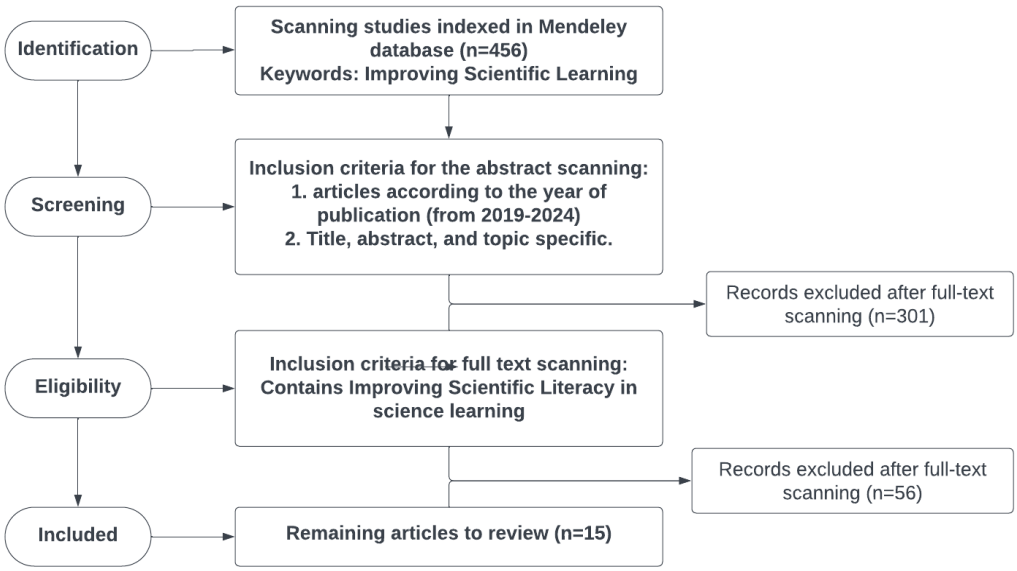

Figure 1. PRISMA diagram describing the article selection process

The research process was carried out to identify and analyze relevant research [29]. The results were used to answer research questions and provide guidance for future research. This technique consists of four stages: identification, screening, eligibility, and inclusion. The initial stage is identification, namely searching for articles using the Mendeley application based on the keyword "Improving scientific literacy" with an article limit of 2019-2024. In the initial search using Mendeley 456, articles that matched the keywords were obtained. Then, a filtering stage was carried out where all articles were filtered using criteria according to the year limit, suitability of the title, abstract, and topics related to the specified keywords. The third stage was checking the suitability of the article content by the research questions and summarizing it in a data mapping table to make it more effective in the analysis stage. In the eligibility stage, 301 articles were obtained that met the research criteria so they could proceed to the inclusion stage. The activities carried out at the inclusion stage were reviewing, analyzing the contents of the articles, and making a summary (synthesis) of the review results to describe findings related to science learning models, approaches, or programs represented by 15 articles.

3. RESULTS AND DISCUSSION

Systematic studies in various publications provide an overview of the close relationship between the use of learning models and scientific literacy skills with the various research designs carried out. The literature review focuses on two things: the efforts made in learning to increase scientific literacy and the results of the efforts made.

Learning with a learning model is a practical approach to achieving optimal learning outcomes. Various learning models, such as cooperative learning, project-based learning, and problem-based learning, allow students to actively participate in the learning process [30].

The cooperative learning model prioritizes cooperation and collaboration between students. Students can help each other, share knowledge, and develop social skills through teamwork. This model also increases active participation in learning because students are directly involved in group discussions, share ideas, and achieve mutual understanding [31].

Project-based learning engages students in real-world activities that are relevant to real-world contexts. Students learn concepts and skills by completing projects demanding problem-solving, analysis, and creativity. In this model, students learn meaningfully and connect to everyday life, increasing their motivation and understanding [32].

Problem-based learning emphasizes students' abilities to identify, analyze, and solve problems in a learning context. Students are invited to develop deep understanding by facing complex situations or challenges. Through this learning, students can develop critical thinking, creativity, and problem-solving skills that are important in real life [33].

Effective learning models can help improve students' scientific literacy by providing learning experiences that are student-centered, interactive, and relevant to their daily lives. One learning model that is often used is problem-based learning, where students are given complex problems or challenges that they must solve using their scientific knowledge. Through problem-based learning, students learn to identify questions, collect and analyze data, and formulate solutions supported by scientific evidence. This model encourages students to be active in their learning process and helps them develop critical thinking, problem-solving, and scientific communication skills [34].

In addition, inquiry-based learning is an effective learning model for increasing students' scientific literacy. In inquiry-based learning, students can ask questions, gather evidence, and investigate science concepts through active exploration and discovery. This model encourages students to carry out observations, experiments, and in-depth

discussions about natural phenomena, thereby deepening their understanding of scientific concepts. By providing opportunities for students to actively participate in their learning process through problem-based learning or inquiry-based learning, these models can significantly increase students' scientific literacy, preparing them to become critical thinkers and skilled in applying scientific concepts in everyday life.

Through this learning model, students are empowered as the main actors in learning. They actively understand, develop skills, and apply knowledge in relevant contexts. Thus, learning with learning models can improve learning quality and directly impact student learning outcomes [35].

Based on the literature review, several learning models/approaches/programs were used, as shown in Table 1.

Table 1. The use of learning models/approaches/programs

No	Source	Model/approach/learning program used
1	Rini et al., 2021 [36]	Question
2	Wulandari & Solihin, 2019 [37]	Inquiry
3	Atmojo et al, 2019 [38]	Ethnoscience-based learning model
4	Suparya et al., 2022 [39]	Contextual
5	Ichsan et al., 2022 [40]	TPACK based problem-based learning
6	Masithah et al., 2022 [41]	Inquiry
7	Milanto et al, 2023[42]	Contextual learning with a guided inquiry approach.
8	Valladares, 2021 [43]	Conceptual change theory and socio-cultural theory as potential learning models or approaches
9	Dewi et al., 2019 [44]	Ethnoscience-Based Learning Model
10	Zetterqvist & Bach, 2023 [45]	Development and validation of PISA-inspired assessment instruments
11	Rissanen et al., 2023 [46]	The InSciTE (Interdisciplinary Science Threshold Experience) program is designed to help new students face the challenges of transitioning from high school to a large research university, especially in the Faculty of Science.
12	Washburn et al., 2023 [47]	The learning model involves discussing scientific articles that have been annotated in the laboratory component
13	Ergashovich et al., 2023 [48]	Integration of information communication technology and pedagogical technology
14	Holincheck et al., 2022 [49]	Hybrid Model (Lecture and collaborative inquiry)
15	Bangun et al., 2022 [50]	Blended project-based learning

In the research presented in Table 1, various models, approaches, and learning programs are used to increase students' scientific literacy. One commonly used approach is inquiry, which engages students in active exploration, observation, and gathering scientific evidence to build conceptual understanding [36], [37], [41]. The Ethnoscience-Based Learning Model is also applied to integrate local cultural elements into science learning to increase students' understanding of the science context [44].

Apart from that, several studies also apply the problem-based learning approach and collaborative learning. TPACK-based problem-based learning combines the application of problem-based learning with content knowledge of technology, pedagogy, and science to create a practical learning experience [40]. Collaborative learning engages students in online citizen science projects, which can improve their knowledge, understanding, and skills in interpreting and analyzing scientific data [51].

Applying various learning models and approaches can be relevant and valuable in current conditions. In the rapidly developing technology and information era, integrating information communication technology and pedagogical technology is becoming increasingly important in developing scientific literacy. In addition, with global challenges

such as climate change, disease outbreaks, and environmental problems, increasing scientific literacy is the key to understanding and overcoming these problems. Therefore, these studies make an essential contribution to developing learning strategies that are relevant to current conditions and have the potential to prepare students with the scientific literacy needed for the future.

The results of scientific literacy conditions after taking action using the treatment carried out by researchers are shown in Table 2.

Table 2. Condition of students' scientific literacy after learning

No	Source	Research result
1	Rini et al., 2021 [36]	The research results show that the scientific literacy abilities of PGSD FKIP UMT students are in the "sufficient" category. In each indicator of scientific literacy ability, PGSD students show the "low" category as the indicator of explaining scientific phenomena and the "sufficient" category as the indicator of identifying scientific questions or problems and using scientific evidence. Therefore, it can be concluded that the research results show that the scientific literacy skills of PGSD FKIP UMT students still need to be improved.
2	Wulandari & Solihin, 2019 [37]	The average achievement of scientific literacy skills in knowledge is 66.45%. The achievement category tends to be good, indicating that students' mastery of the knowledge aspects of scientific literacy skills in heat material is good
3	Atmojo et al, 2019 [38]	The research results show that science learning integrated with ethnoscience can increase students' scientific literacy with an increased score of 0.81, which is included in the high category. The average score of students' scientific character in science learning integrated with ethnoscience is also in the high category, where the average score of scientific character in each aspect at each meeting is > 70%. In addition, there was a significant increase in scientific literacy in the experimental class compared to the control class, which shows the effectiveness of the learning approach used
4	Suparya et al., 2022 [39]	The article states that Indonesian students' scientific literacy (LS) results are still relatively low, as can be seen from the 2011 and 2015 TIMSS results. In these two tests, the percentage of Indonesian students who achieved high and advanced levels of scientific literacy is still very low, namely only 3-6%.
5	Ichsan et al., 2022 [40]	The TPACK-based problem-based learning model significantly influences students' scientific literacy abilities in high school science material, with an average of 70 and an effect size (ES) of 0.42. Therefore, the TPACK-based problem-based learning model effectively applies to science material.
6	Masithah et al., 2022 [41]	The research results show that inquiry-based science teaching materials effectively increase students' scientific literacy. Therefore, it can be concluded that the use of inquiry-based science teaching materials can help improve students' scientific literacy
7	Milanto et al., 2023 [42]	The research results showed that students' scientific literacy abilities were already in a relatively good category before taking part in the lesson. However, after following contextual learning with a guided inquiry approach, there was an increase in students' scientific literacy abilities. Evaluation based on pretest and post-test scores shows an increase in the n-gain value of 0.64 or 64%. Thus, it can be concluded that contextual learning combined with a guided inquiry approach effectively improves students' scientific literacy skills.
8	Valladares, 2021 [43]	Active and participatory learning approach: Actively involving students in the science learning process, such as conducting experiments, observations, and group discussions. This helps students understand science concepts more deeply and develop critical thinking skills.
9	Dewi et al., 2019 [44]	Ethnoscience-Based Learning Model: This model integrates local cultural elements in science learning to improve students' understanding of science content, competencies, context, and attitudes
10	Zetterqvist & Bach, 2023 [45]	This research aims to measure students' epistemic knowledge in the context of scientific literacy. By using the assessment instruments developed, this research

		can provide a better understanding of students' understanding of epistemic knowledge in the context of scientific literacy.
11	Rissanen et al., 2023 [46]	The research results showed that students in the InSciTE program had stronger scientific literacy skills than the control group. This shows that the InSciTE program can effectively increase students' scientific literacy.
12	Washburn et al., 2023 [47]	The results show a significant increase in students' scientific literacy scores at the end of the semester. Even though there was no significant interaction between the teacher and the pretest-posttest difference, there was a significant increase in student scores at the end of the semester. This shows that this learning model is effective in improving students' scientific literacy skills
13	Ergashovich et al., 2023 [48]	The integration of information communication technology and pedagogical technology enhances the formation of natural science literacy in students by providing visual representations, facilitating active learning, and incorporating international assessment studies to develop critical thinking and scientific interpretation skills.
14	Holincheck et al., 2022 [49]	The results of treatment with the hybrid learning model used in this research show an increase in students' ability to evaluate trust in digital scientific information. This can be seen from the test results of the average difference between the pretest and post-test in the categories of publisher reputation, author competence, author objectivity, and overall trust in digital scientific articles 12. Thus, this hybrid learning model can be an alternative for improving students' ability to evaluate trust in digital scientific information.
15	Bangun et al., 2023 [50]	The research results show that applying blended project-based learning effectively improves higher education students' scientific literacy skills. After implementing this learning model, significant improvements were found in various aspects of scientific literacy skills. This shows that a blended project-based learning approach can positively contribute to developing scientific literacy skills.

Based on Table 2, research results show variations in students' scientific literacy abilities and the effectiveness of various learning models in improving them. For example, research by Rini [36] shows that the scientific literacy abilities of PGSD students are in the "sufficient" category, while the results of research by Wulandari & Solihin [37] show exemplary achievements in achieving the scientific literacy abilities of high school students. Several learning models, such as TPACK-based problem-based learning [40] and inquiry-based teaching materials [41], have been proven effective in increasing students' scientific literacy. However, there are also challenges, such as Indonesian students' low scientific literacy abilities [39] and limitations in developing students' scientific literacy in an epistemic context [45]. Nonetheless, research shows that certain programs, such as the InSciTE program [46] and hybrid learning models [49], effectively increase students' scientific literacy. Theoretically, differences in the results of these studies can be explained by the diversity in educational contexts, student characteristics, and research methods used in each study. Empirically, these studies provide concrete evidence of the effectiveness of various learning models and programs in improving students' scientific literacy, with several studies highlighting significant success in this regard. However, further research is still needed to understand the factors that influence students' scientific literacy and develop more effective learning strategies to increase it.

A systematic literature review study focused on improving scientific literacy has been previously conducted [52], where the focus was on a systematic review of the development of assessment tools to enhance scientific literacy. The aim was to provide an overview of the existing framework to guide the development of future scientific literacy instruments, highlighting the need for such instruments to assess and improve scientific literacy globally. However, existing systematic literature reviews only highlight aspects of measuring scientific literacy capabilities. Unlike previous studies, this research focuses

more on the context of learning models that can enhance scientific literacy. This study offers new insights or a deeper interpretation of how certain learning models contribute to learning outcomes. This could include a comparative analysis among models or assessing the long-term impact on scientific literacy.

Some relevant learning theories include Constructivism and Sociocultural Theory. Constructivism theory emphasizes the importance of students' knowledge construction through their interaction with learning materials. Learning models such as problem-based learning and inquiry-based learning reflect the principles of constructivism by encouraging students to actively explore, ask questions, and build their understanding of scientific concepts [53]–[55]. The research results show the effectiveness of these models in increasing students' scientific literacy through the constructivism approach. Sociocultural theory emphasizes the importance of social interactions and the environment in forming students' knowledge and understanding. Learning models that involve group work, discussion, and interaction between students and teachers, as mentioned in research results by Valladares [43], Dewi [44], and Ergashovich [48], are in line with the principles of Sociocultural Theory.

Apart from learning theories, there is the framework that helps teachers to plan and implement effective learning by considering the complex interactions between technology, pedagogy, and content TPACK [56]–[58]. TPACK combines knowledge of technology, education, and content (in this case, science) to support the development of effective learning models. Research results that highlight the effectiveness of technology-based learning models, as mentioned by Holincheck [49], show the relevance of TPACK theory in increasing students' scientific literacy through integrating technology in to learning.

Educators can create more effective strategies to enhance students' scientific literacy by integrating the principles of learning theories with empirical research. This connection between theory and practice is crucial for developing improved educational methods. Various learning models tailored to the educational context and students' needs can significantly boost scientific literacy. For instance, problem-based learning immerses students in real-world problem-solving, fostering critical thinking and collaborative skills while integrating scientific knowledge. Inquiry-based learning encourages students to actively explore and investigate, enhancing their inquiry skills and understanding of science. The Project-Based Model allows students to apply scientific knowledge in collaborative projects, linking science to real-life contexts. Flipped classrooms shift the traditional teaching model, enabling deeper engagement with science concepts during class through discussions and hands-on activities. Additionally, technology-based models leverage digital tools to provide dynamic and interactive learning experiences, supporting the development of scientific literacy. These models exemplify the diverse strategies educators can employ to cultivate a robust understanding of science among students.

In choosing an appropriate learning model, it is important to consider student characteristics, learning objectives, and available resources. Combining various learning models can also give students a more holistic and in-depth learning experience.

4. CONCLUSION

This study's findings affirm that scientific literacy can be enhanced by implementing various learning models, such as problem-based learning based on TPACK and inquiry-based learning approaches. The integration of technology and the use of local cultural contexts in education also make a significant contribution to students' understanding and scientific skills. The impact of this research is important for the development of science pedagogy, providing insights for educators to design effective learning strategies to

improve scientific literacy. Nonetheless, further research is needed to optimize the integration of these various learning approaches and explore their influence on scientific literacy in different educational contexts.

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AUTHOR CONTRIBUTION STATEMENT

SR contributed to conceptualization, design of methodology, data curation, manuscript writing, original draft and finishing. AS contributed to validation, supervision, and manuscript review. M and IK contributed to validating and supervising the project for this publication.

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