



Enhancing contextual scientific literacy through the integration of STEM in biology education in the society 5.0 era: A literature review

Intan Sari, Rastra Juliean Putra Akhmadi *, Sahtia Dewi Puspitasari, Sahara Juliana Jihan Kausar, Shella Ananda

Department of Biology Education, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Banjarmasin, South Kalimantan, Indonesia, 70123

*Corresponding Author Email: rastra.jpa@gmail.com

Abstract. The low level of science literacy among Indonesian students, as reflected in PISA scores below the OECD average, indicates a gap between educational goals and biology teaching practices that still focus on memorization and textbooks. The integration of the STEM (Science, Technology, Engineering, and Mathematics) approach offers a solution by linking scientific concepts to real-life contexts. This study used a systematic literature review method of ten national articles published in the last six years obtained through Google Scholar. The results show an increasing trend in publications, particularly in 2021, indicating growing attention to this topic. The main findings show that project-based approaches (STEAM-PJBL), interactive digital media such as flipbooks, and STEM-based E-LKPD are effective in improving science literacy and encouraging more participatory and reflective learning. Overall, the integration of STEM in biology learning has a positive impact on strengthening contextual science literacy that is relevant to the demands of the 21st century and the Society 5.0 era.

Abstrak. Rendahnya literasi sains siswa Indonesia, yang tercermin dari skor PISA di bawah rata-rata OECD, menunjukkan adanya kesenjangan antara tujuan pendidikan dan praktik pembelajaran biologi yang masih berfokus pada hafalan dan teks. Integrasi pendekatan STEM (Science, Technology, Engineering, and Mathematics) menawarkan solusi dengan mengaitkan konsep sains pada konteks kehidupan nyata. Penelitian ini menggunakan metode tinjauan literatur sistematis terhadap sepuluh artikel nasional terbitan enam tahun terakhir yang diperoleh melalui Google Scholar. Hasil menunjukkan tren peningkatan publikasi, khususnya pada 2021, menandakan meningkatnya perhatian terhadap topik ini. Temuan utama menunjukkan bahwa pendekatan berbasis proyek (STEAM-PJBL), media digital interaktif seperti flipbook, dan E-LKPD berbasis STEM efektif meningkatkan literasi sains serta mendorong pembelajaran yang lebih partisipatif dan reflektif. Secara keseluruhan, integrasi STEM dalam pembelajaran biologi berdampak positif dalam memperkuat literasi sains kontekstual yang relevan dengan tuntutan abad ke-21 dan era Society 5.0.

Received date: 31/07/2025
Accepted date: 17/08/2025
Published date: 14/10/2025

Keywords: scientific literacy; biology learning; STEM approach; contextual; society 5.0

Introduction

The transformation of the Society 5.0 era, which emphasizes the harmonization between advanced technology and human life, encourages the world of education to prepare a generation that is not only adaptive to technological developments but also possesses applicable scientific thinking skills. Science literacy plays a crucial role in this context as a foundation for students to critically and creatively address the complexity of global and local problems. However, the real conditions in the Indonesian education system show a gap between the expected ideal competencies and the actual achievements of students. The PISA 2022 report confirms that the science literacy score of Indonesian students is at 396, far below the OECD average of 489 (De Bortoli et al., 2023). Based on research Srigati (2020) Biology learning that has not optimally adopted project-based and STEM approaches still shows a significant gap between students' conceptual understanding and their ability to apply science knowledge to real-life contexts. This gap not only reflects the weak internalization of concepts but also indicates a systemic failure in developing 21st-century skills, particularly in terms of critical thinking, problem solving, and applicative skills. These conditions create structural barriers in the biology learning process that should be rich in contextual, experiential, and interdisciplinary approaches. Furthermore, Srigati emphasized that the information and application of the integration of the STEM approach to support contextual science literacy is still relatively limited, generally local, and has not touched various educational units evenly. To date, no studies have been found that comprehensively review the application of this model in a broader scope.

Several national studies indicate that biology learning in secondary schools often focuses on textual content and memorizing concepts, rather than problem-solving or exploring students' real-life experiences. This condition indicates that the learning process is still limited to one-way information transfer without providing space for students to explore the relationship between Biology concepts and the daily phenomena they face. This finding is also supported by Abdi et al. (2023), which highlights how the dominance of conventional methods has resulted in low achievement of 21st-century skills in biology learning, alongside a lack of material relevance to real-world applications. Similarly, Srigati (2020) Shows that text-based approaches are insufficient in building contextual science literacy, and project-STEM-based approaches are more effective in fostering conceptual understanding and critical thinking skills. In responding to these needs, the STEM-based learning approach (Science, Technology, Engineering, and Mathematics) offers an innovative and transformative solution, especially in the context of 21st-century education. This approach not only emphasizes integrative mastery of concepts across disciplines but also encourages the development of higher-order thinking skills (HOTS), creativity, and strong science literacy through contextual and meaningful learning experiences. Andaresta & Nadia (2021) stated that the application of the STEAM approach, as a derivative of STEM, can improve the quality of biology learning by facilitating students to think critically, creatively, and reflectively in dealing with contemporary issues in the Society 5.0 era. Therefore, the urgency of this research lies in the importance of learning strategies that are adaptive and responsive to the times, so that students not only master conceptual knowledge, but are also able to apply it functionally and solutively in real life. This research focuses on assessing the potential of the STEM approach as a strategic alternative in learning biology that is contextual, relevant, and effective to support the development of 21st-century competencies.

Based on the study of Andaresta & Nadia (2021), learning biology in schools is still dominated by a teacher-centered approach that makes students tend to be passive and less actively involved in the learning process. As a result, the learning process has not fully formed 21st-century skills optimally. The tendency towards one-way learning, which emphasizes only cognitive aspects, leads to a lack of development in essential skills such as critical thinking, collaboration, communication, and problem-solving, all of which should form the foundation of modern learning. Some studies have shown that learning models that do not involve active student participation and do not relate the material to everyday life tend to fail to foster technological literacy and adaptive abilities to global dynamics. Putra & Maheswara (2024) stated that learning that is not applicable and contextualized hinders the development of 21st-century skills. Similarly, Astuti et al. (2023) asserted that the absence of STEM integration in biology learning can limit creativity and problem-solving in real contexts. Kamal et al. (2024) emphasized that learning that does not integrate real contexts in the process will only produce passive learners who are less prepared to face the challenges of the digital era. Thus, the integration of the STEM approach in biology learning becomes increasingly relevant, considering that this approach not only strengthens academic aspects but also shapes the character of resilient, collaborative, and visionary learners. This is crucial for preparing a generation that can contribute actively and responsibly to addressing the complexity of global challenges in the era of Society 5.0.

To address these challenges, the STEM (Science, Technology, Engineering, and Mathematics) approach has been widely adopted as a learning strategy to enhance students' science literacy and creativity. Various research results have provided empirical evidence of the effectiveness of this approach in improving learning outcomes and student engagement in the learning process. Putra & Maheswara (2024) showed that STEM integration in Biology subjects contributed significantly to the improvement of students' understanding and active participation. Meanwhile, a study conducted by Sabila et al. (2023) recorded an average increase in learning outcomes with n-Gain reaching 94.81% on

the application of STEM-based e-LKPD in biotechnology materials, showing its effectiveness in strengthening cognitive aspects. In addition, Hadi et al. (2024) revealed that STEM-based learning is also able to foster students' critical and creative thinking skills through challenging and project-based activities. However, most of these studies are still focused on academic achievement and have not explicitly included the contextual and socio-cultural dimensions of learners. The challenges of the 21st century and the era of Society 5.0 require students not only to understand science concepts, but also to be able to relate them to local and global issues and offer solutions that are relevant, sustainable, and oriented towards solving real problems in their environment. Therefore, the integration of a contextualized STEM approach is an urgent need in designing biology learning that is more meaningful and transformative.

The STEM approach in biology learning has been proven effective in improving students' science literacy and creativity (Astuti et al., 2023). The integration of science, technology, engineering, and mathematics encourages active engagement and strengthens students' thinking skills. The application to junior high school students resulted in a significant increase in science literacy scores, especially in the generating, planning, and producing indicators, which indicate understanding of concepts and the ability to solve real problems. In line with that, Banila et al. (2021) Research has found that STEM-based blended learning can also enhance science literacy skills, particularly in pandemic situations, by training students to identify scientific issues, explain data-based phenomena, and draw critical conclusions. They also added that the STEAM approach, which incorporates the arts, contributes to developing critical and creative thinking through design-based projects and social-ecological contexts. The findings from these two studies reinforce the importance of learning biology that is not only academic, but also contextual, applicable, and relevant to the needs of the 21st century and the demands of the Society 5.0 era.

Based on these interpretations, it can be concluded that students' low science literacy is caused by biology learning that is not context-based and does not emphasize the connection between scientific concepts and everyday life. The STEM approach is a relevant alternative because it encourages cross-disciplinary exploration and authentic problem-based learning. Although several previous studies have demonstrated the effectiveness of the STEM approach in enhancing concept understanding, the emphasis on developing contextualized science literacy rooted in local issues has been underrepresented. Therefore, this study aims to examine the integration of the STEM approach in biology learning to build contextual science literacy that not only fits the needs of 21st-century learning, but also responds to the challenges and complexities of the Society 5.0 era.

To achieve these objectives, this research focused on three main questions, namely: (1) What are the research trends related to the integration of the STEM approach in biology learning in the last five years, especially in the context of strengthening contextual science literacy in the era of Society 5.0? (2) What are the main findings of the literature review regarding the effectiveness of the STEM approach in improving students' understanding of complex and contextual Biology concepts? and (3) What is the scientific impact of the application of the STEM approach on the development of contextual and meaningful biology learning strategies, and their implications for improving students' science literacy in the 21st century? These three questions became the basis for a systematic literature review process, which is expected to provide a comprehensive picture of the direction, effectiveness, and contribution of the STEM approach in shaping biology learning that is more contextual, relevant, and adaptive to the demands of the times.

Research Methods

This research method employs a literature review approach to analyze and integrate previous research results relevant to the topic of contextual science literacy and the application of the STEM approach in biology learning. The data sources used come from national scientific journal articles that have been published from 2019 to 2024 and can be accessed through the Google Scholar database. The research procedure began with a literature search using keywords such as "contextual science literacy", "biology learning", "STEM approach", and "Society 5.0", then continued with the article selection process based on the inclusion and exclusion criteria listed in Table 1. From the initial search results, 2,300 documents were found. Still, after going through the quality and relevance screening process, 10 articles were obtained that were considered most suitable for the focus and objectives of this study. The data collection technique involved extracting key information from each article, focusing on empirical findings, learning implementation strategies, and their impact on strengthening science literacy. The data analysis technique used is descriptive analysis, which aims to interpret the pattern of findings and identify the space for scientific renewal in the development of STEM-based learning models that are contextual and adaptive to the challenges of the Society 5.0 era.

A brief description of the type, number, and distribution of articles used in this study has been presented in Table 1. However, to provide a more thorough understanding of the systematic process of searching and selecting literature, this study also visualizes the search flow in the form of a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram. This figure outlines the main stages, beginning with the initial identification of articles via the

Google Scholar search engine using predetermined keywords. It then involves filtering based on publication year, topic suitability, and information completeness, ultimately yielding relevant articles worthy of further analysis.

Table 1 Inclusion and Exclusion Criteria

No	Inclusion criteria	Exclusion criteria
1.	Electronic database search using Google Scholar	Electronic database search did not use Google Scholar
2.	Publication in the last 7 years	Articles more than 7 years old
3.	Original article	Review article
4.	Articles in English and Bahasa Indonesia	Publication not in English or Indonesian
5.	Full access article (full text available)	Articles not open access or not available in full text
6.	Field of study: Biology Education	Field of study outside Biology Education
7.	Search based on data by the theme discussed	Not by the research theme

The PRISMA diagram not only clarifies the number of articles screened out at each stage, but also explicitly shows the reasons for exclusion of some articles, for example, because they were not relevant, not available in full-text, or did not meet the methodological criteria. This process is important to ensure the validity and credibility of the results of the literature synthesis, as well as to provide transparency into the systematic way of working used in this study. Therefore, the following figure serves as an important complement in understanding how this literature review is organized logically, structured, and based on systematic review principles that can be academically accounted for.

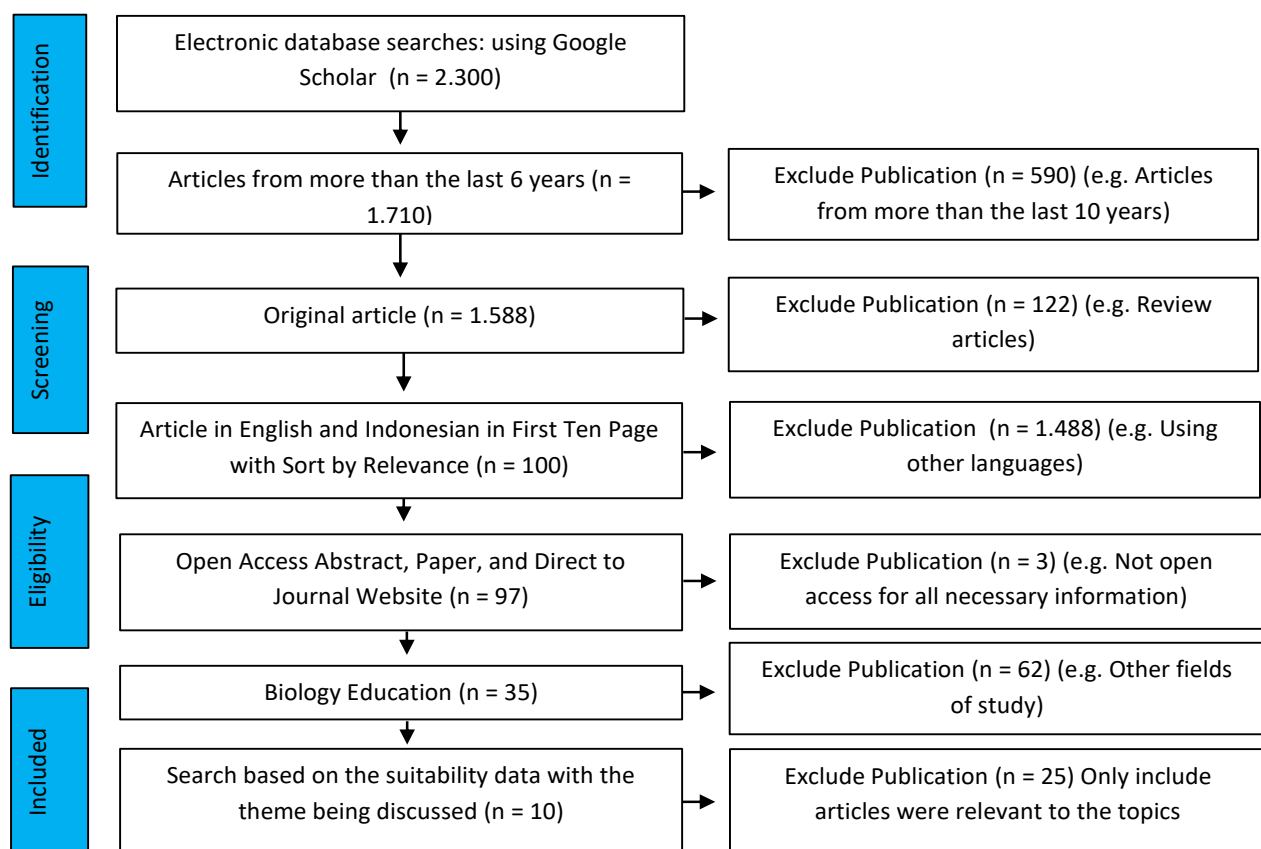


Figure 1 Article selection used in SLR using the Prisma model

Picture 1. Selection of articles used in the SLR using the PRISMA model used in this study. In the initial identification stage, 2,300 articles were found through the Google Scholar search engine using a combination of keywords such as "contextual science literacy", "biology learning", "STEM approach", and "Society 5.0". After removing duplicates and conducting initial screening based on titles and abstracts, the number of remaining articles shrank significantly. At the screening stage, articles were further screened based on the suitability of the topic, the scope of biology learning, and their relevance to the context of strengthening science literacy. Articles that did not explicitly include the STEM approach, were not relevant to the Indonesian context, or did not meet methodological standards

were eliminated. This process resulted in 35 articles entering the eligibility stage, which is a thorough review of the article content based on full-text availability, data completeness, and relevance to the focus of the research study.

From the 35 articles that entered the final stage, 10 main articles were selected that were considered the most representative and relevant for in-depth analysis. These 10 articles met all inclusion criteria and were used as the basis for synthesizing the literature, forming the theoretical basis, and developing the conceptual framework of the study. This selection process was designed to ensure the quality, reliability, and relevance of the results to the research objectives, while also ensuring transparency and replicability in future follow-up studies.

Results and Discussion

In the context of 21st-century education transformation, the integration of the STEM approach in biology learning increasingly occupies a strategic position as a response to the need for science literacy that is not only conceptual, but also contextual. The global trend towards the era of Society 5.0 demands a learning system that is adaptive, transdisciplinary, and oriented towards solving real problems. This makes STEM not just a teaching method, but a pedagogical approach that emphasizes the connection between science and the social-ecological life of learners. One reflection of this increasing urgency can be seen in how the topic of STEM integration in biology learning has significantly developed in the stream of academic studies over the past six years. This paper systematically traces the direction of this development by reviewing relevant literature to understand the extent to which this approach is utilized to strengthen contextual science literacy. The discussion begins by answering the first question, namely: "What are the dynamics of research related to the integration of STEM approaches in biology learning in the last six years, especially in the context of strengthening contextual science literacy in the era of Society 5.0?"

Analysis of publications from 2019 to 2024 shows that academic attention to STEM integration in biology learning has experienced a sharp growth. The increase in the number of documents from year to year indicates that this topic is increasingly considered important in designing learning that not only emphasizes understanding of concepts, but also the connection between science, technology, and real life. To provide an initial overview of the dynamics of these publications, a visualization of the number of documents over the last six years is presented in Figure 2.

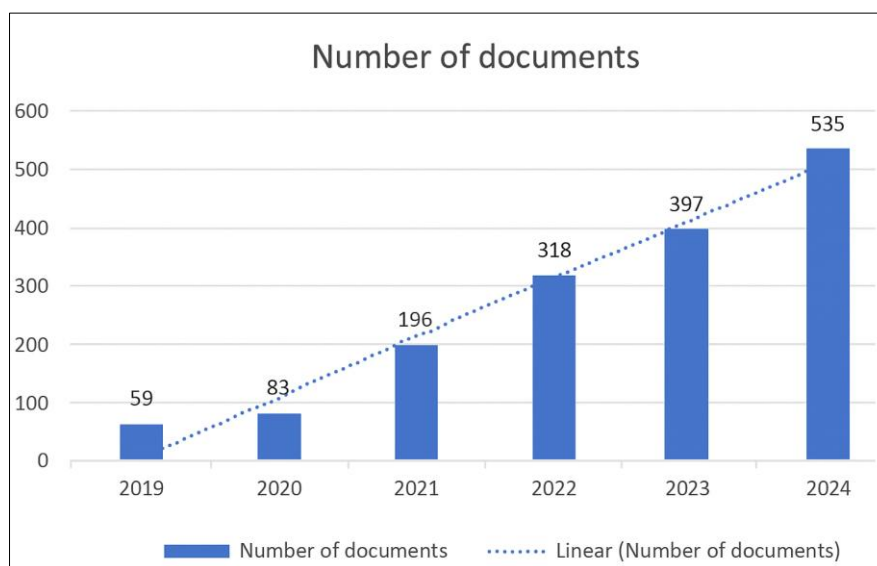


Figure 2 Graph of the number of research documents in the last six years

Figure 2 illustrates the dynamics of scientific publications addressing the integration of the STEM approach in biology learning from 2019 to 2024. The data shows a progressive and significant increase, starting from 59 publications in 2019 to reach the highest number of 535 publications in 2024. A sharp spike has been observed since 2021, accompanied by an increasing need for learning innovations that bridge the gap between mastering science concepts and applying them in real-life contexts. This shows that the STEM approach is starting to be seen as a relevant pedagogical strategy in responding to the demands of 21st-century education. This trend not only reflects an increase in academic activity but also indicates a paradigm shift in biology learning, from being centered on cognitive aspects to learning that is more contextual, interdisciplinary, and transformative.

Overall, this pattern reinforces the argument that the STEM approach continues to be a strategic field of study in education. Considering their quality, topical relevance, and contribution to strengthening contextual science literacy, ten key articles were selected as the main sources for the literature synthesis in this study (see Table 2).

Table 2 Details of Findings from Ten Articles Relevant to the Topic of STEM Approach

Code	Researcher (Year)	Problem	Method	Main findings
1.	Srigati, (2020)	Lack of exploration of 21st-century skills with Steam-PJBL	Quasi-experiment	Steam-PJBL improved the knowledge aspect of science literacy, especially in the use of scientific evidence.
2.	Andaresta & Nadia (2021)	Limited technology-based learning media to improve students' science literacy	R&D(4D Model)	A STEM-based e-book on ecosystem material was declared highly valid (98.92%) and highly practical (99.27%) to train students' science literacy.
3.	Abdi et al. (2023)	Lack of innovative digital media for science learning	R&D (ADDIE)	STEM-based digital flipbooks effectively improve students' science literacy (n-gain 0.64).
4.	Astuti et al. (2023)	Low science literacy and student creativity	Pre-experiment (pretest-posttest)	STEM significantly improved science literacy (n-gain 0.74) and creativity through contextual projects.
5.	Kamal et al. (2024)	Low science literacy and numeracy of students at the junior high school level	R&D (ADDIE model)	STEM-based digital worksheets effectively improve students' science literacy and numeracy through interactive and contextual learning.
6.	Putra & Maheswara (2024)	Weak understanding of science concepts and critical thinking	Quasi-experiment	STEM improved science literacy (score 58.4→78.6); learning is more contextual and meaningful.
7.	Kade et al. (2023)	Teachers do not understand the application of PjBL STEM thoroughly; the science literacy of junior high school students is low	Training & model implementation in MGMP	STEM-based PjBL builds teachers' confidence and shows great potential in improving junior high school students' science literacy in a contextualized manner
8.	Hadi et al. (2024)	Students are passive, less creative, and learning is monotonous	Quasi-experiment	STEAM was shown to significantly improve creativity, which is a crucial component in science literacy.
9.	Banila et al. (2021)	Low science literacy during the pandemic	Re-experience (one group)	STEM significantly improved all science literacy indicators (pretest score 72→, posttest 85.5).
10.	Sabila et al. (2023)	Conventional LKPD is not effective in improving literacy	R&D (4D model)	STEM-based E-LKPD is highly effective (N-Gain 94.81%) in improving science literacy through STEM syntax.

Based on an analysis of ten research articles, the application of the Science, Technology, Engineering, Arts/Mathematics (STEAM/STEM) approach in learning biology and natural science shows a significant effect in improving students' science literacy, creativity, and critical thinking skills. Most of the studies reviewed used quasi-experimental, research and development (R&D), and pre-experimental methods. This approach is focused on developing innovative e-learning media, such as digital flipbooks (Abdi et al., 2023) and STEM-based E-LKPD (Sabila et al., 2023), as well as implementing project-based learning models such as STEAM-PJBL (Srigati, 2020). The implementation of STEM/STEAM-based learning is generally effective in developing critical and creative thinking skills, as well as improving science literacy at the secondary education level. A study showed a significant increase in students' science literacy scores, from 58.4 to 78.6, after a STEM-based intervention (Putra & Maheswara, 2024). Similarly, there was an increase in n-gain of 0.74 (high category), as well as an increase in student creativity through project-based activities and scientific exploration (Astuti et al., 2023). Other findings also show that STEAM learning trains students to

think mathematically, logically, critically, and scientifically, which are high-level thinking skills relevant for the Society 5.0 era (Hadi et al., 2024).

These results are consistent with various national studies. STEM integration in science education contributes to the strengthening of conceptual understanding and active engagement of students in learning (Abdi et al., 2023). In addition, this approach encourages mastery of 21st-century skills, especially critical, collaborative, and creative thinking (Srigati, 2020; Kade et al., 2023). At the national level, STEAM implementation is considered important to prepare learners for the challenges of the Society 5.0 era. STEM-based education also makes an important contribution to developing innovative capabilities needed in the future (Putra & Maheswara, 2024). Although the learning methods and media used vary, such as development studies that emphasize the optimization of digital media (Abdi et al., 2023) and other studies that highlight the effectiveness of project-based learning models (Srigati, 2020). The findings of all these studies indicate complementary directions in achieving more optimal learning outcomes.

The development of the integration of STEM approaches in biology learning not only reflects methodological advances, but also indicates a change in the orientation of science education towards a more contextual and relevant approach to students' real lives. In various articles analyzed, it was found that STEM-based learning strategies actively encourage the connection between Biology concepts and social, ecological, and technological phenomena around students. This approach no longer places students as recipients of information, but as active subjects engaged in meaningful scientific exploration. Project-based learning models, interactive digital media, and real problem-solving-based assignments become the bridge between subject matter and life context, in line with the essence of contextual science literacy. The transformation of this approach is also evident in the changing role of teachers who shift to facilitators and learning partners. Teachers encourage students to construct knowledge through the process of scientific inquiry, testing ideas, and utilizing relevant technology. Through multidisciplinary integration of science, technology, engineering, and mathematics, students are encouraged to interpret biology concepts in various applied perspectives. This approach encourages learning that is more flexible and adaptive to the challenges of learning in the digital era, as well as creating a participatory and process-oriented learning atmosphere.

STEM-based learning significantly strengthens higher-order thinking skills. All articles analyzed emphasize the influence of STEM on improving critical thinking, creative, analytical, collaborative, and scientific communication skills. Learning is no longer focused on the result, but rather on the process of deep and reflective scientific thinking. Through cooperative and contextual activities, students are trained to evaluate information, devise solutions, and convey their ideas in a logical and structured form. This forms a generation of learners who are not only able to understand concepts but also able to implement them in real life. In the science literacy dimension, STEM integration is proven to encourage students to understand scientific concepts not only as theoretical knowledge, but as a foundation for thinking and acting in social and environmental contexts. Students are encouraged to construct data-based arguments, make ethical decisions, and foster concern for global issues such as climate change, conservation, and public health. Science literacy developed through STEM is holistic, combining cognitive, affective, and psychomotor domains, and is needed in shaping the Society 5.0 generation that is information literate, solutive, and open-minded.

In the context of Society 5.0, the integration of the STEM approach in biology learning represents a new direction of education that is adaptive, reflective, and future-oriented. This approach not only answers the need to strengthen contextual science literacy, but also becomes an important strategy in forming a generation of learners who can think across disciplines and act solutively amid the complexity of modern life. By placing real issues as the foundation of learning, STEM opens space for a more profound pedagogical transformation that connects knowledge, skills, and human values in a learning system that is intact and relevant to the demands of the times. To illustrate the relationship between the application of STEM-based learning through various media and methods and its impact on strengthening science literacy, the following is a scheme of STEM-based learning and its effects as shown in Figure 3.

Figure 3 shows that STEM integration in science learning is done through two main approaches, namely the development of digital media and the application of contextual learning methods. Media such as digital flipbooks, LKPDs, e-books, and STEM-based LKPDs have proven effective in significantly improving students' science literacy. Several studies recorded high N-Gain improvement and excellent media validity, as well as active student engagement in the technology-based and contextual learning process. In terms of methods, models such as STEAM-PJBL, teacher training with PJBL-STEM, and STEM-based projects support the improvement of students' critical thinking skills and creativity. In addition to a significant increase in science literacy scores, STEM-based learning also trains students to face the challenges of the 21st century, especially in developing creativity, logical thinking, and problem-solving skills that are relevant for the Society 5.0 era.

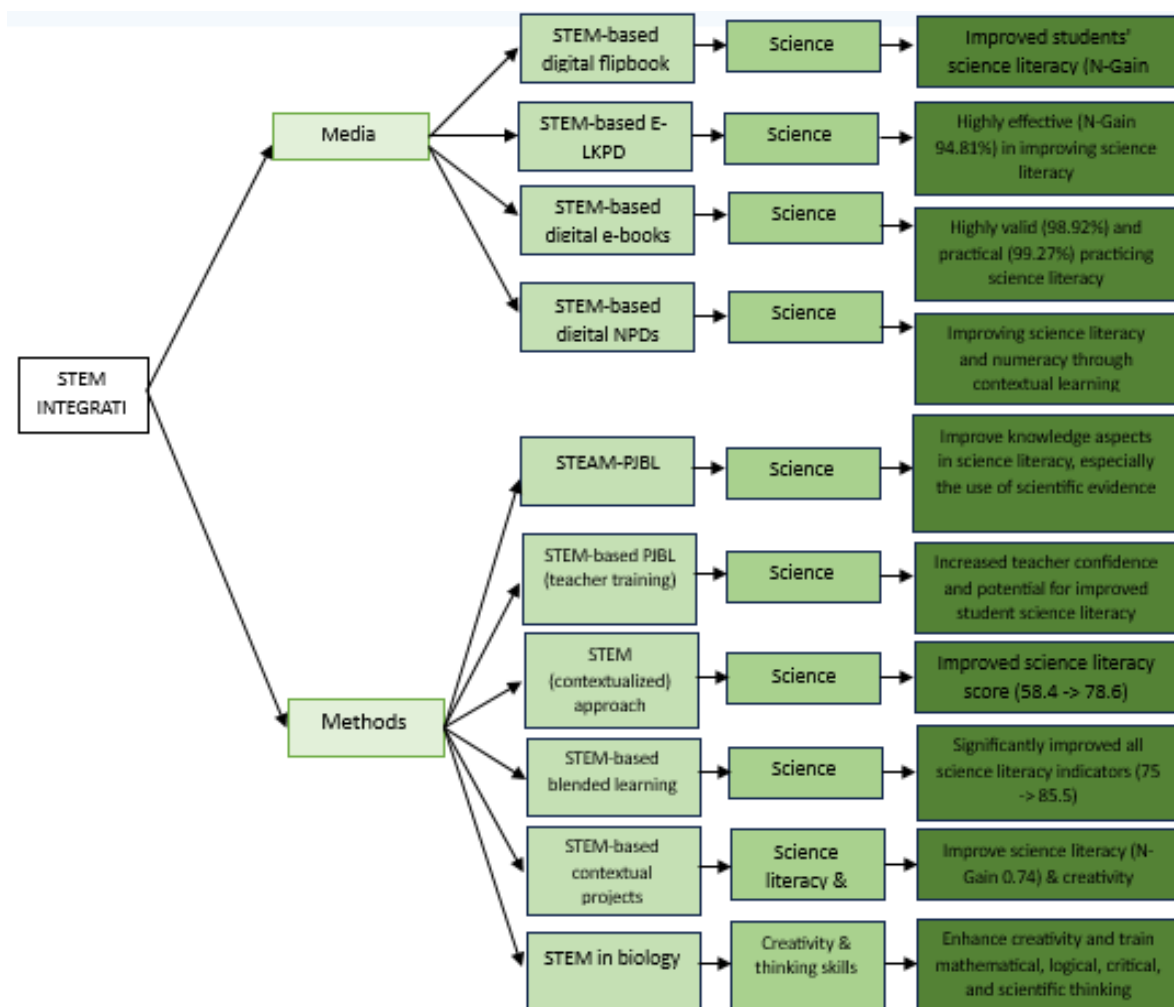


Figure 3 Schematic of STEM-based learning and its effects

Conclusion

The results of this study conclude that the STEM approach contributes significantly to strengthening contextual science literacy in biology learning. STEM integration allows the connection between scientific concepts and the reality of students' daily lives, while encouraging the development of critical, creative, collaborative, and problem-solving thinking skills. This approach also facilitates pedagogical transformation towards more meaningful, interactive, and learner-centered learning. Scientifically, these findings indicate that STEM-based Biology education can be a relevant future learning strategy in shaping the Society 5.0 generation that is adaptive, technologically literate, and oriented towards solving real problems. Future research is recommended to develop a more applicable local context-based STEM implementation model at various levels of education, as well as to explore broader cross-disciplinary collaboration in biology learning.

Acknowledgement

The authors would like to thank the Biology Education Study Program, Faculty of Teacher Training and Education, Lambung Mangkurat University, for the moral support and facilities provided during the process of preparing this article. Gratitude is also extended to the editorial team of the Journal of Biology Creative Education for the opportunity and guidance in the process of publishing the article. Special appreciation is given to all co-researchers who have contributed to the literature collection and analysis process. This article is the result of an independent study and is not funded by any organization.

References

- Abdi, A., Aristya, P. D., & Budiarmo, A. S. (2023). Pengembangan modul flipbook digital berbasis STEM materi sistem pencernaan manusia untuk meningkatkan literasi sains. *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, 13(1), 57–66. <https://doi.org/10.24929/lensa.v13i1.294>
- Andaresta, & Nadia. (2021). Pengembangan e-book berbasis STEM pada materi ekosistem untuk melatih kemampuan literasi sains siswa. *BioEdu*, 10(1), 635–646. <https://doi.org/10.26740/bioedu.v10n3.p635-646>
- Astuti, W., Sulastri, S., Syukri, M., & Halim, A. (2023). Implementasi pendekatan science, technology, engineering, and mathematics untuk meningkatkan kemampuan literasi sains dan kreativitas siswa. *Jurnal Pendidikan Sains Indonesia*, 11(1), 25–39. <https://doi.org/10.24815/jpsi.v11i1.26646>
- Banila, L., Lestari, H., & Siskandar, R. (2021). Penerapan blended learning dengan pendekatan STEM untuk meningkatkan kemampuan literasi sains siswa pada pembelajaran biologi di masa pandemi COVID-19. *Journal of Biology Learning*, 3(1), 25–33. <https://doi.org/10.32585/jbl.v3i1.1348>
- De Bortoli, L., Underwood, C., & Thomson, S. (2023). *PISA 2022: Reporting Australia's results. Volume I: Student performance and equity in education* (Vol. I). <https://doi.org/10.37517/978-1-74286-725-0>
- Hadi, H., Nur'aini, W. M., & Marhamah. (2024). Pengaruh pembelajaran biologi berbasis STEAM terintegrasi literasi sains terhadap kemampuan berpikir kreatif siswa. *Cocos Bio*, 9(1), 18–23. <https://doi.org/10.29408/cob.v9i1.26890>
- Kade, A., Ningsih, P., Mubarik, Z. M., Khair, F., & Amalia, M. (2023). Mengoptimalkan literasi sains melalui implementasi STEM-project based learning model dalam pembelajaran IPA. *Jurnal Pengabdian Kepada Masyarakat Nusantara (JPkMN)*, 4(4), 3770–3776. <https://ejournal.sisfokomtek.org/index.php/jpkm/article/view/1897/1327>
- Kamal, F. A., Subali, B., Astuti, B., Rusilowati, A., & Widiyatmoko, A. (2024). Pengembangan LKPD digital berbasis STEM untuk meningkatkan literasi numerasi dan sains peserta didik. *Jurnal Penelitian Pendidikan IPA*, 10(5), 2454–2464. <https://doi.org/10.29303/jppipa.v10i5.6689>
- Putra, S. B., & Maheswara, R. (2024). Implementasi pembelajaran berbasis STEM dalam pendidikan biologi untuk meningkatkan literasi sains siswa. *Jurnal Cakrawala Pendidikan dan Biologi*, 1(3), 82–91. <https://doi.org/10.61132/jucapenbi.v1i3.180>
- Sabila, S., Tanjung, I. F., & Jayanti, U. N. A. D. (2023). Pengembangan e-LKPD berbasis STEM untuk meningkatkan kemampuan literasi sains siswa pada materi bioteknologi. *BiosciED: Journal of Biological Science and Education*, 4(1), 33–43. <https://doi.org/10.37304/bed.v4i1.10762>
- Srigati, R. E. (2020). Uji pembelajaran berbasis proyek (PjBL)-STEM untuk meningkatkan literasi sains pada siswa MTsN 28 Jakarta Timur. *Jurnal Balai Diklat Keagamaan Jakarta*, 1(1), 72–83. <https://doi.org/10.53800/wawasan.v1i1.56>