



Systematic literature review: STEM integrated biology learning based on 21st century learning models

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Article Information	Abstract
Keyword: Biology; Problem-based learning; Project-based learning; STEM approach Kata Kunci: Biologi; Pembelajaran berbasis masalah; Pembelajaran berbasis proyek; Pendekatan STEM History: Received : 02/12/2024 Revised : 18/02/2025 Accepted : 20/02/2025 Published : 24/02/2025	Science, Technology, Engineering, and Mathematics (STEM) is an integrated approach in the 21st century that aims to develop learners' soft skills and form human resources through 4C skills, namely critical thinking, creative, innovative, communicative and collaborative where the learning process is based on real-life problems. The STEM approach combined with the 21st century learning model can help students in optimising learning outcomes and forming character as human resources with 4C skills. This study aims to examine STEM-integrated Biology learning in Problem-Based Learning (PBL) and Project-Based Learning (PjBL) learning models and provide an overview of education in the STEM approach over the past decade at all levels of education in Indonesia. This research used a systematic literature review (SLR) method adapted from the PRISMA model. The results of this study reveal some interesting facts and findings related to the STEM approach in PBL and PjBL models, that student skills and learning outcomes also affect the approach, model and learning media used in Biology learning. STEM integration is able to overcome problems in learning Biology through scientific phenomena and real-world applications that support the learning process. This research suggests developing and deepening findings in the field of STEM Biology in order to achieve optimal, quality and relevant learning outcomes by harmonising the demands of future scientific and technological developments. <i>Abstrak. Science, Technology, Engineering, and Mathematics (STEM) merupakan pendekatan terintegrasi di abad 21 yang bertujuan untuk mengembangkan soft skill peserta didik dan membentuk sumber daya manusia melalui kecakapan 4C yaitu berpikir kritis, kreatif, inovatif, komunikatif dan, kolaboratif dimana proses pembelajarannya berbasis masalah dalam kehidupan nyata. Pendekatan STEM yang dipadukan dengan model pembelajaran abad 21 dapat membantu peserta didik dalam mengoptimalkan hasil belajar dan membentuk karakter sebagai sumber daya manusia dengan kecakapan 4C. Penelitian ini bertujuan untuk mengkaji pembelajaran Biologi terintegrasi STEM dalam model pembelajaran Problem-Based Learning (PBL) dan Project-Based Learning (PjBL) serta memberikan gambaran pendidikan dalam pendekatan STEM selama satu dekade terakhir pada semua jenjang pendidikan di Indonesia. Penelitian ini menggunakan metode tinjauan literatur sistematis (SLR) yang diadaptasi dari model PRISMA. Hasil kajian ini mengungkapkan beberapa fakta dan temuan menarik terkait pendekatan STEM dalam model PBL dan PjBL, bahwa keterampilan dan hasil belajar siswa turut berpengaruh pada pendekatan, model hingga media pembelajaran yang digunakan dalam pembelajaran Biologi. Integrasi STEM mampu mengatasi permasalahan dalam pembelajaran Biologi melalui fenomena ilmiah dan aplikasi dunia nyata yang menunjang proses pembelajaran. Penelitian ini menyarankan untuk mengembangkan dan memperdalam temuan di bidang Biologi STEM agar tercapainya hasil belajar yang optimal, berkualitas dan relevan dengan menyelaraskan tuntutan perkembangan ilmu pengetahuan dan teknologi yang akan datang.</i>

A. Introduction

Education is a bridge to acquire knowledge and build human character. Currently, the rapid development and advancement of technology requires the education field in the learning process to be in line with this. The integration of technology in education is a learning innovation in the 21st century, with the aim of developing 4C skills namely critical thinking and problem solving, communication, creativity and innovation, and collaboration (Dare et al., 2021). This innovation replaces previous methods, models and approaches to learning that are still conventional towards newer and more effective learning. In addition, teachers are required to master technology and modern learning platforms in order to apply them in the classroom. Through the applied learning innovations, it is expected to be able to build students' learning skills as demanded by 21st century learning today (Nadelson et al., 2012).

The 21st century learning should be interconnected with the challenges and demands of real life, including developing competencies to collaborate, be creative and innovative in solving problems, think critically and master technology (Rawung et al., 2021). The character and civilisation of a dignified nation is formed through national education, skills development, and nation building, as outlined in Law No. 20 of 2003. The purpose of education is to help students grow into responsible, productive, innovative, and loyal members of society who can make positive contributions to local, national, and global communities (Mu'minah, 2021). In education, there are many disciplines that are taught, including phenomena, and processes that are difficult to express and illustrate the connection with the natural world (Suwono et al., 2015). In addition, traditional teaching methods generally use lectures, where students only hear and write the teacher's delivery without any depiction of material through props properly. The existence of limitations in visualising material during the learning process can certainly hinder students in their cognitive development such as the ability to think, problem solve to demonstrate ideas or ideas that are thought of. Thus, the active involvement of students in scientific learning is still lacking and requires innovative teaching methods and learning approaches. While in essence, Biology is the study of life (lifesience), symptoms, and social interactions in various aspects of living things (Sudarisman, 2015). At the same time, learning biology is learning with scientific and real learning experiences to gain a meaningful understanding of the interactions between nature and living things in it, including plants, animals, and microbes (Banila et al., 2021).

When faced with these challenges, the STEM (Science, Technology, Engineering, and Mathematics) approach can be an alternative solution. The STEM approach in modern times is a strategy that includes things to help students hone their abilities obtained

through the learning process based on real-life problems and connects them with four disciplinary fields (Susanti & Kurniawan, 2020). In addition to the approach, a learning model is also needed to determine the presentation of material to classroom management and facilities used during the teaching and learning process. The appropriate learning model combined with the STEM approach is the PBL model and PjBL which is a 21st era teaching and learning concept with 4C skills in it. With the teaching and learning approaches and models applied to biology learning, it is hoped that it can help students in optimising learning outcomes and forming character as human resources with 4C skills that have critical thinking, creativity, innovation, communication, and collaboration (Roehrig et al., 2021).

The integration of STEM approach in biology learning can be done at all levels of education, from elementary school to university. Therefore, this study aims to obtain an overview of the STEM approach in Indonesia by using 21st century learning models, namely PBL and PjBL in Biology learning at various levels of education through SLR research.

Systematic Literature Review (SLR) research is still rarely found in discussing the topic of STEM-integrated Biology learning using PBL and PjBL models. There are ten articles with inclusion criteria related to this research topic found through the journal search database. Through this SLR, it is expected not only to increase theoretical knowledge, but also to have important practical implications in improving STEM-integrated Biology learning through 21st century learning models. Therefore, the authors in this study aim to obtain an overview of the STEM approach in Indonesia using 21st century learning models, namely PBL and PjBL in Biology learning at various levels of education. To harmonise the above research objectives and background, the research questions of this study are organised as follows:

- Q1 : What is the STEM approach to learning biology?
- Q2 : How is the integration of STEM approach to PjBL and PBL models in biology learning?
- Q3 : What media are used in learning biology using the STEM approach?

B. Material and method

In presenting the information factually, this study uses the systematic literature review (SLR) method, which summarises the findings of previous research. By using the SLR method, it is possible to systematically identify journals or articles and follow established article writing procedures in each step (Thovawira et al., 2021). The SLR method is used to identify, critically evaluate, and summarise findings from related research that describe STEM-integrated learning models and teaching processes (Thibaut et al., 2018).

For the preparation of articles, the SLR method has several procedures that can help researchers in

writing. The SLR procedure (see Figure 1) includes the following: formulation of research questions (developing research questions), developing a search strategy for articles or literature in accordance with the research theme (developing the search strategy), applying inclusion criteria to select articles (selection criteria), evaluating and analysing data (evaluating and analysing data), and reporting research results (interpreting) (Elfiyani, 2024; Thovawira et al., 2021).

The process of collecting data through research articles or journals was carried out using the help of

Publish or Perish software and databases from Google Scholar, Directory Open Access Journal (DOAJ), Researchgate, SINTA and SCOPUS. The articles used were articles that had criteria in accordance with the research question. Inclusion criteria used in this study include: articles according to the theme, namely STEM in Biology learning, articles containing media used in the STEM approach or articles containing STEM integration of Biology learning models. Publication of articles or journals used between 2018-2024 and indexed both nationally and internationally.

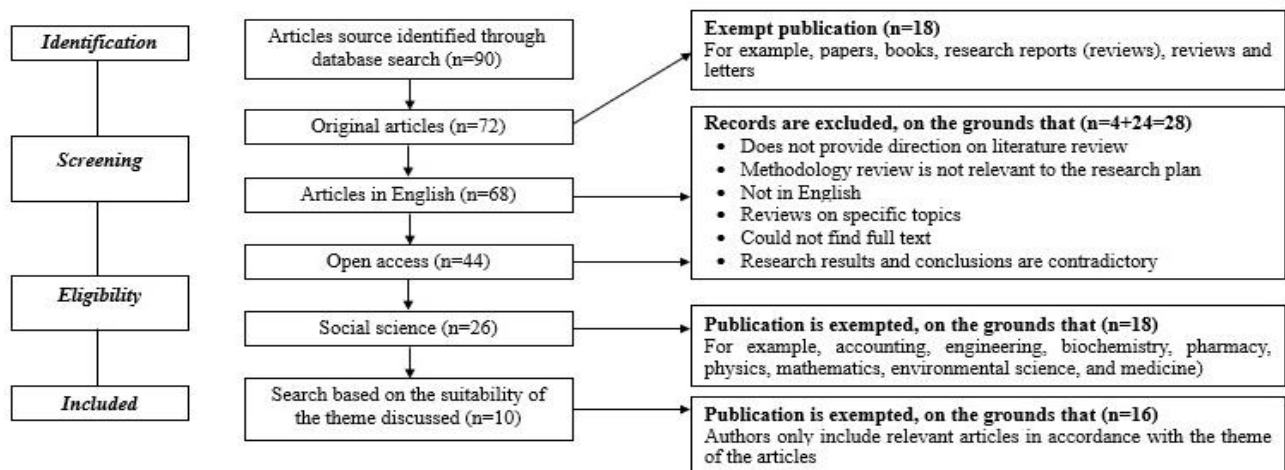


Figure 1 Articles selection used in SLR using PRISMA model (Source: Result of PRISMA process)

C. Results and discussion

This study reviewed ten articles on STEM-integrated Biology learning in 21st century learning models, namely PBL and PjBL learning models from 2018 to

2024 using the Google Scholar database, DOAJ, Researchgate, SINTA and SCOPUS. The results of the selected articles can be seen in the Table 1.

Table 1 Analysis results of STEM-integrated biology learning articles on PBL and PjBL learning models

No.	Author	Article title and year	Conclusion
1.	Furi et al. (2018)	Experimentation of PjBL and STEM integrated PjBL models to improve student learning outcomes and creativity in basic competencies of milk processing technology.	The N-gain score is greater than the PjBL learning model, indicating that learning using PjBL-STEM can improve learning outcomes in the cognitive element. Compared to the PjBL learning model, the skill scores obtained from the milk processing innovation practicum were higher when using PjBL-STEM, indicating that this learning approach improved psychomotor learning outcomes. The average level of student creativity when taught the basics of milk processing technology through the PjBL-STEM learning model was higher than when taught using the PjBL paradigm.
2.	Astuti et al. (2019)	STEM integrated PjBL model to improve concept mastery and student learning activities.	The results of the research and analysis showed that the STEM-integrated PjBL model achieved a high level of success in improving concept mastery and student activeness on Ecosystem material.
3.	Fadhilah & Wajdi (2022)	Integration of STEM-PBL through online towards critical thinking skills of biology education students.	The findings of this study indicate that the implementation of online PBL-STEM learning has an impact on students' critical thinking skills in teaching biology. This can be seen from the high N-gain values obtained from both classes. The improvement of critical thinking skills is one of the results of the implementation of the STEM-PBL approach. Students' ability to provide explanations ranks highest, while self-regulation ranks lowest among the skill indicators.
4.	Sabtu & Tamalene (2022)	Application of PBL model through STEM approach in biology learning to improve student learning outcomes on senior high school.	Biology grade XI students at SMA Negeri 7 South Halmahera can benefit from the use of PBL model combined with STEM approach to improve their learning. This is indicated by student learning outcomes in each cycle, namely pre-cycle learning outcomes, such as the percentage of students who completed learning (17 out of 52, or 47.22%) and those who did not complete learning (9 out of 52, or 52.78%). There was an improvement after the first cycle action; specifically, 23 students (63.89% of total) and 13 students

No.	Author	Article title and year	Conclusion
			(36.11% of total) completed the tasks. A total of 36 students (94.44% of total) improved their participation in Cycle II, while 2 students (5.56% of total) were not incomplete. Nonetheless, 80.55 was the average calculation. Students' learning outcomes in biology subject can be improved by combining PBL model with STEM learning approach.
5.	Hasanah et al. (2021)	Implementation of PBL model combined with STEM based student worksheet to improve critical thinking skills on environmental pollution material.	Students who learn biology by memorising principles without using student worksheets to do practicum are considered less able to develop their critical thinking skills. The research shows that using the PBL learning model combined with STEM-based student worksheet can help high school students develop their critical thinking skills in environmental pollution material.
6.	Ardiansyah et al. (2021)	The effect of PBL model with STEM approach on students' cognitive competence on digestive system material for grade XI in SMA/MA.	Students' cognitive abilities on digestive system material were significantly affected both before and after treatment using the PBL learning model with the STEM approach. This situation can be understood through the average results of testing from both classes, thus the use of PBL models through the STEM approach can be used further to determine the cognitive competence of students not only in digestive system material but also in several materials that require the same model and approach.
7.	Hidayati et al. (2021)	Analysis of the application of STEM approach in biology learning.	Conclusions drawn from the investigation into the STEM approach in biology education indicate that it is compatible with a variety of learning approaches and resources. In addition, students' critical thinking, science literacy, creativity and scientific thinking skills can be enhanced when the STEM approach is used in biology lessons. Having said that, it does little to improve competence in using technology or making informed decisions. The reason for this could be that the research was conducted at the wrong time or with the wrong subjects, so the results are not applicable.
8.	Lutfi et al. (2018)	The effect of STEM integrated PjBL on science literacy, creativity and learning outcomes of learners.	Students responded positively and benefited from the STEM-integrated PjBL model when taught in a biology class focusing on environmental pollution. The results of hypothesis testing showed a marked difference between the two classes; specifically, that the experimental group outperformed the control group in terms of science literacy, creativity, and learning outcomes. Science literacy, creativity, and student learning achievement were influenced by STEM PjBL at SMAN 11 Sinjai.
9.	Noviani et al. (2023)	PjBL with STEM application towards improving science process skills in the biology scope of chili plant crosses in class on senior high school.	The study findings state that the quality of the PjBL model with a STEM approach to science learning creativity of students in class XII MIPA 3 SMA Negeri 1 Banjar produces a positive impact. This can be seen with the project activities made by students in teacher monitoring during the learning process, where during the project students are actively involved in asking questions about concepts that have not been understood and discussing. In addition, the activities of working together in completing the student worksheet given by students also follow the rules of workmanship and collection that have been set. Active participation of students in project activities increases understanding of the concept of biotechnology, especially the development of genetic engineering to produce chili products with different colors through crossing chili plants (<i>Capsicum annum</i>). The ability of students to conduct scientific investigations, especially students of class XII SMA Negeri 1 Banjar, can be improved through the integration of the PjBL learning model with the STEM approach.
10.	Fitriyani et al. (2020)	Implementation of PjBL-STEM model to improve higher level thinking skills.	The results stated that through the STEM approach in PjBL has a positive influence on students' knowledge and ability to collaborate in creating a product. STEM-integrated PjBL builds students' character in developing creative ideas in solving problems and provides quite innovative solutions in making products as solutions in biotechnology material. The learning experience that students get through PjBL-STEM is able to connect the knowledge gained by students from real life and apply it in biotechnology material to solve problems and design products (design skills) so as to improve higher order thinking skills. In addition, students are also required to be able to collaborate with the team so that students can build good communication and cooperation in achieving common learning goals. Thus, PjBL-STEM has encouraged students to enrich their learning insights through higher order thinking skills and collaboration on biotechnology materials.

This study collected and analysed five articles discussing STEM-integrated Biology learning in the PjBL model, four articles discussing STEM-integrated biology teaching and learning in the PBL model and one other article discussing STEM-integrated biology

learning in general. Analysis of this article shows that the use of PBL and PjBL learning models has been widely used in education, especially at the secondary level to universities by adjusting the criteria and needs of students and students as the intended target.

What is the STEM approach to learning biology?

The STEM approach is one of the 21st century learning that integrates four disciplines of science, technology, engineering, and mathematics in learning experiences, especially in the field of Biology to help students train soft skills through 4C skills in the demands of 21st century learning, namely critical thinking, creative and innovative, communicative, and collaborative (Istiqomah & Putri, 2024). Based on the analysis of ten articles conducted, the application of STEM in 21st century education requires mastery of critical thinking skills, collaboration, communication, and creativity in a deep and integrated manner.

The STEM approach can improve students' critical thinking skills. Studying environmental pollution using the STEM approach trains students to think more focused and provides opportunities to solve problems with facts scientifically and focuses attention on identifying problems by connecting them to life and environmental phenomena so as to encourage students to be active and think critically (Ritonga, 2021). The use of the PjBL model in learning Biology has a positive impact on improving students' creativity, learning outcomes and science literacy. The application of PjBL integrated with STEM in environmental pollution material makes students enthusiastic in solving problems so as to encourage an active learning process in the classroom (Lutfi et al., 2018). There is an increase in students' critical thinking concepts in the STEM-based PBL model so as to produce meaningful learning through knowledge, concepts and skills that are combined during the learning process (Hasanah et al., 2021).

Integrated STEM in Biology learning by using PBL and PjBL models in the classroom learning process has a good impact on students. It is suspected that actively engaged learning and real-world applications have been associated with increased learner engagement and motivation in learning and high curiosity, resulting in greater understanding and more positive scientific attitudes towards Biology (Fitriyah & Ramadani, 2021). In addition, integrity and collaboration between teachers are also very important in integrating STEM in Biology learning, so that the delivery of material can be well integrated and provide a comprehensive learning experience for students. To achieve optimal and comprehensive learning in the classroom, educational institutions and schools also need to pay attention to the balance between theory and practice, and pay attention to student diversity so that the application of STEM in Biology learning can provide an inclusive and meaningful learning experience (Sari et al., 2023).

The concept of STEM fully extends a strong foundation to meet these demands, as it allows learners to develop understanding and skills through a multidimensional interdisciplinary approach. In this context, STEM provides ample space for students to learn by being active, exploring complex concepts

holistically, and generating creative solutions in the real world. In addition, STEM learning in Biology can also prepare students to understand the latest developments in science and technology, thus encouraging career interest in STEM fields. Thus, STEM learning in Biology is very important to prepare future generations who are ready to face the challenges of the modern world (Kamaruddin et al., 2023).

How is the integration of STEM approach to PjBL and PBL models in biology learning?

Fadhilah & Wajdi (2022) state STEM integration in the PBL model has a positive effect on the critical thinking skills of Biology education students. In this case, Biology education students are required to be active and able to master the problems given and concrete solutions. The use of the PBL model in learning activities will encourage students to think more independently in finding concepts. While the findings of Noviani et al. (2023), STEM-PjBL-based Biology learning is able to improve students' science process skills through mastery of the concept of biotechnology in chili plants and is able to provide concrete examples.

The integration of STEM approach in PjBL and PBL models in Biology learning can provide in-depth, holistic, and sustainable learning experiences for students. Through the integrated STEM approach, students can develop analytical, critical, collaborative, and creative skills in science, technology, engineering, and mathematics, and apply them in real situations. In addition, this approach gives learners the opportunity to see the complex interrelationships between subject matter and understand how concepts in Biology can be applied to real-world contexts. Learners are also encouraged to think interdisciplinarily and engage knowledge from different fields to solve complex and relevant problems (Anggraini & Huzaifah, 2017). In essence, both PBL and PjBL models integrated with STEM are learning innovations in supporting student learning skills in the 21st century today which require students to actively participate both individually and in groups, because through cooperation in groups will involve students in the process of investigation and good collaboration in problem solving (Na'imah et al., 2015).

In the context of globalisation and the rapidly growing advocacy for relevant education in the 21st century, the integration of the STEM approach in Biology learning is a highly relevant and strategic effort to prepare students to become competent, adaptive and innovative individuals. This approach not only trains students in complex problem solving and deep critical thinking, but also equips them with the skills needed in facing the increasingly complex and diverse challenges of the future. Thus, the integration of STEM approach can provide a strong foundation for quality Biology learning and produce graduates who are ready to face the real world with confidence and high ability (Ilmi et al., 2021).

What media are used in learning biology using the STEM approach?

Based on review results, the AR/VR technology media used and help students in understanding material objects conveyed through visualisation of images and audio that are easy to understand in real terms (Fadhilah & Wajdi, 2022). The use of electronic portfolios as learning media has an impact on improving higher-level thinking skills that support students in exploring hypotheses and phenomena scientifically (Fitriyani et al., 2020). The use of teaching aids through project-based assignments received positive support from students involved in small project assignments so as to improve psychomotor skills and increase learning experience through practical activities and be able to apply STEM principles (Lutfi et al., 2018).

The role of media is very important in STEM-integrated Biology learning. By using various types of media available, such as images, videos, graphics and animations, learners can obtain information in a more interactive and fun way. By combining visual and audio elements, this learning media can stimulate learners' senses and strengthen their understanding of the biological concepts taught. Thus it can be concluded that the use of media in learning cannot stand alone and it must be clear how to show it in the classroom, so there needs to be an appropriate learning approach (Afriana et al., 2016).

With the massive development of technology today requires innovation in every lesson including the use of Biology learning media. Through innovative media can influence the learning process of students and develop skills in applying technology-based media. Skills in applying technology are not only demands for students, but educators are also required to be able to develop various kinds of learning media and skills in integrating them in the classroom.

Overall, the use of media in learning Biology is very important to increase learners' interest and motivation in learning. Media allows them to obtain information more interactively, presents actual and visual information, and helps learners to hone their skills of searching, analysing, and evaluating information. Thus, media can be an effective tool in supporting comprehensive and effective Biology learning.

D. Conclusion

Interest in STEM approaches in Biology learning has grown rapidly in the last decade, and findings have shown that the integration of STEM practices in 21st century learning models such as PBL and PjBL in Biology subjects has a major impact on improving students' skills and learning outcomes. The results of this study provide an overview at the time of the research that has been carried out in Biology learning integrated with the STEM approach is stated to be able to provide new learning experiences for students

where they are proactively involved in the learning process. It is not uncommon for students to independently solve problems and relate them to concrete examples scientifically. In addition, there is a development of student learning skills such as critical thinking, collaboration, communication, and creativity as an output of STEM-integrated Biology learning combined with PBL and PjBL learning models, as well as the use of appropriate learning media. With the learning models and media applied, the learning process will be more structured and the learning process will be more real through the depiction of the media used.

Based on the results of this study, it is important to remember that the role of teachers is also very important in ensuring the effectiveness of STEM learning in Biology. Teachers need to receive continuous and in-depth professional development to implement STEM learning methods well. With proper professional development, teachers can be effective facilitators to guide students to dig deeper into Biology concepts through an interdisciplinary approach. In addition, it is crucial to ensure that students in STEM Biology programs learn to think critically in addition to acquiring conceptual knowledge. Students who are able to think critically will be better able to analyse facts, solve complex problems, and base their conclusions on scientific evidence. In scientific phenomena, where issues are complex and subject to change, this will help students thrive in the 21st century by encouraging them to strengthen their critical thinking skills scientifically and factually.

This basic research will certainly raise important questions to develop and deepen findings in this field in the future. Thus, further research needs to ensure that the development of research to be carried out can support the STEM approach, especially in Biology learning which is relevant to the demands of scientific and technological developments so that both students and teachers as teaching practitioners benefit from the learning that is carried out.

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