Journal of Current Studies in SDGs
Homepage : https://journal.i-ros.org/index.php/JOCSIS
Email : jocsis@i-ros.org

p-ISSN : XXX-XXX ; e-ISSN XXX-XXX
Vol. 1, No. 3, January 2025
Page 33-46

A Comprehensive Analysis of STEAM Learning Implementation to Foster Critical Thinking Skills for Equitable and Quality Physics Education in High Schools

Lailatul Fajriati[1*], Hanan Zaki Alhusni[1], Rahmatta Thoriq Lintangesukmanjaya[1]
[1]Universitas Negeri Surabaya, Surabaya, Indonesia

Check for updates OPEN ACCESS

DOI :

Sections Info

Article history:
Submitted: February 1, 2025
Final Revised: February 11, 2025
Accepted: February 12, 2025
Published: February 19, 2025

Keywords:
Critical Thinking;
Literature Study;
Physics;
SDGs;
STEAM Learning.

ABSTRACT

Objective: *The objective of this study is to examine the implementation of STEAM learning in enhancing the critical thinking skills of high school students in Physics, particularly in Indonesia.* **Method:** *The methodology consists of a literature review, which involves identifying and evaluating articles or journals related to STEAM learning and its impact on students' critical thinking in Physics. Through a systematic screening process, the initial 40 articles were narrowed down to 30, and ultimately, 20 articles were selected for detailed review.* **Results:** *The findings reveal that the application of STEAM learning has a significant positive effect on the critical thinking abilities of high school students with respect to Physics.* **Novelty:** *This approach aligns with global and national initiatives such as the Sustainable Development Goals (SDGs), highlighting the need for innovative educational programs that address contemporary challenges. In the 21st century, critical thinking, analytical skills, and creativity are essential. STEAM education – integrating science, technology, engineering, arts, and mathematics – serves as an effective strategy to equip students for future demands in education and beyond.*

INTRODUCTION

The 21st century is marked by a pressing need for quality Human Resources (HR), with an emphasis on understanding and utilizing science and technology to evaluate their impacts on the natural and social environments of communities (Usmeldi et al., 2017). In contrast, Indonesia struggles with its education quality, lagging behind many ASEAN nations. To address this issue, the Sustainable Development Goals (SDGs) program has been introduced to enhance the welfare of the population, particularly in the educational sector (Usmeldi, 2016). The government employs a strategy aimed at producing high-quality Indonesian human resources through integrated educational initiatives that focus on enhancing education quality. The SDGs are instrumental in achieving various government programs (Nurfatimah et al., 2016). Consequently, the education sector is challenged to develop students into creative, innovative, intelligent, and globally competent individuals (Suganda, 2021). To meet these expectations, students need to develop four key competencies: Effective communication, collaboration with peers, critical thinking skills to address challenges, and creativity (Kurniawati, 2022).

Indonesia faces significant challenges regarding the quality of its education system, particularly when compared to other ASEAN nations. In response to these issues, the Sustainable Development Goals (SDGs) program has been implemented to enhance the welfare of the population, with a particular focus on education (Humaida et al., 2020). Specifically, SDG number 4 aims to provide inclusive, equitable, and quality education, as well as promote lifelong learning opportunities for individuals of all ages.

The SDGs advocate for inclusivity by engaging various stakeholders and emphasizing that every country has a moral obligation to work toward achieving these universal goals and targets (Annur, 2018). This collaborative approach is crucial for ensuring that educational advancements benefit all segments of society in Indonesia.

Emphasizing on the 21st century, individuals have access to information from a multitude of sources, particularly regarding educational content (Fardani, 2017). However, with this wealth of information comes the challenge that not all answers, methods, or opinions are accurate. This underscores the importance of critical thinking skills, which are essential for evaluating the information gathered from various sources and forming appropriate responses. To navigate the complexities of problem-solving and to draw informed conclusions, it is imperative to cultivate critical thinking abilities. These skills enable individuals to assess different possibilities and arrive at reasoned decisions, providing a foundation for effective learning and reasoning in an information-rich environment.

According to the critical thinking skills report from the Program for International Student Assessment (PISA), the quality of education in Indonesia remains quite low. The data from PISA 2018 indicates that Indonesian students exhibit critical thinking skills that are positioned at a low level, despite showing high equity. This presents an opportunity for Indonesia to enhance its critical thinking abilities by leveraging its existing capacities and potential (Azizah et al., 2018). Critical thinking encompasses several character traits and activities, which include: identifying and articulating problems clearly, gathering and evaluating relevant information, interpreting data effectively, deriving logical solutions and conclusions, and testing these against established criteria. Additionally, critical thinkers should demonstrate open-mindedness, assess implications and assumptions critically, consider practical consequences, and effectively communicate their findings and solutions (Paul & Elder, 2019). These traits are essential for fostering a more robust educational framework and improving overall student outcomes in Indonesia.

STEAM (Science, Technology, Engineering, Art, and Mathematics) is an integrated approach designed to enhance learning by developing students' skills and fostering inquiry throughout the educational experience. According to Kang (2019) and Ozkan & Topsakal (2021), STEAM learning actively engages students in exploring and comprehending the subject matter, with teachers facilitating this exploration. This collaborative approach allows learners to work together to understand key concepts within the classroom (Ozkan & Umdu, 2021). Implementing the STEAM approach is expected to enhance students' capabilities in the 21st century (Nurhasanah & MS, 2021). STEAM represents an evolution of the STEM framework, with the addition of the arts providing a broader context for creativity and innovation in education (Colucci et al., 2019). However, many existing studies have not adequately highlighted the importance of standardized learning designs in STEAM implementation. Additionally, the readiness of teachers, who play a crucial role as facilitators, often goes unaddressed, potentially hindering optimal learning outcomes. Therefore, this research aims to serve as a valuable resource in addressing these gaps and supporting the effective implementation of STEAM education.

Building on the previous discussion, this study aims to analyze the implementation of STEAM learning as a means to enhance the critical thinking skills of high school

students in physics. Utilizing a literature study method, we explore how the STEAM approach can be integrated into physics education to encourage students to reflect on their learning experiences in school. Traditionally, physics education has focused primarily on theoretical concepts; however, integrating STEAM aspects can transform this into a more practical and engaging experience (Amiruddin et al., 2022). The goal of STEAM-based learning is to ensure that students gain a deeper understanding of science, technology, engineering, art, and mathematics. By fostering this comprehensive understanding, students are better equipped to tackle real-world problems and make informed decisions that contribute to human progress and innovation. This study seeks to highlight the effectiveness of STEAM learning in cultivating critical thinking within the physics curriculum, ultimately aiming to improve educational outcomes for students.

RESEARCH METHOD

This research article employs a literature study as its primary data collection method, which involves reviewing relevant books, literature, notes, and reports related to the issue under investigation (Becker & Park, 2011). The study focuses on analyzing the implementation of STEAM learning to enhance the critical thinking skills of high school students in the context of physics material. The research procedure consists of five distinct stages designed to facilitate a thorough review of the problem in Figure 1 (Wahyuningsih et al., 2020). Through this structured approach, the study aims to gather comprehensive insights into how STEAM learning can effectively contribute to the development of critical thinking among students, ultimately aiming for improved educational outcomes in physics education.

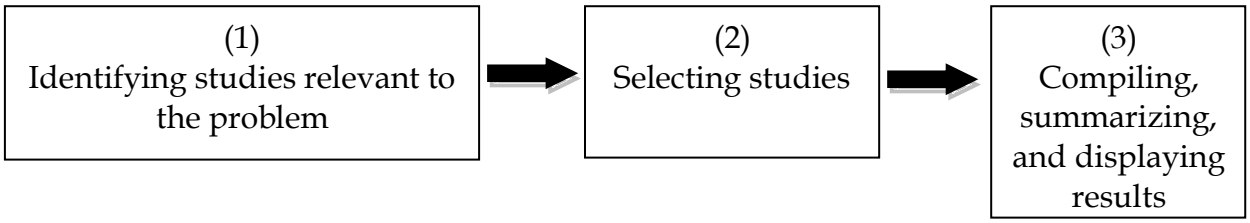

Figure 1. Research flow chart

In this study, data management involves collecting information from various sources, including Google Scholar, Scopus, and other academic databases, covering the period from 2011 to 2023. The research examines students' critical thinking skills in the context of physics education, with the dependent variable being the students' critical thinking abilities and the independent variable being the students' grade levels in high school. Data collection takes place through literature sources, where the research article data is summarized, including aspects such as the introduction, research objectives, educational levels, and materials utilized in the studies. This approach, following the literature review method, facilitates easier analysis of the gathered articles, allowing researchers to draw meaningful conclusions based on the data analysis. Ultimately, this structure aims to provide clear explanations that align with the study's objectives and contribute to the understanding of how STEAM learning can effectively enhance critical thinking skills among high school students in physics.

RESULTS AND DISCUSSION

Results

Table 1. Articles with a focus on STEAM-based e-module studies

No	Researcher and Year	Result Findings
1.	Ananda et al. (2021)	The study examines how Project-Based Learning (PjBL) influences critical thinking skills across different grade levels. The analysis is grounded in various metrics such as grade level, article scale, type of tests administered, sample size, subject matter, effect size, and how the approach is incorporated into the PjBL framework.
2.	Muntamah et al. (2024)	The findings indicated that the t-test results showed t-count greater than t-table (9.320 > 1.995) with a significance level of 0.00. Additionally, the N-gain was observed at 73.75%, suggesting a significant improvement in critical thinking skills when using ESD-oriented IPAS project learning alongside the STEAM approach, categorized as moderately effective. This study provides valuable insights for the implementation of ESD-oriented IPAS projects and STEM methodologies. It is anticipated that these findings will serve as an alternative strategy to enhance critical thinking skills, particularly for students in vocational schools.
3.	Wardani et al. (2023)	The research conducted at Singosari Junior High School, focusing on class VIII, assessed the feasibility of STEAM-based e-modules. The validation results from media experts indicated an average score of 3.6, categorized as good, with a percentage of 91.6%, falling into the category of worthy of testing with revisions. In comparison, the validation from language experts yielded an average score of 3.7, also in the good category, with a percentage of 94.4%, similarly classified as worthy of testing with revisions. Material expert assessments resulted in an average score of 3.1, categorized as good enough, with a percentage of 79.2%, again suggesting it is worthy of testing with revisions.
4	Viona et al. (2022)	The study's results highlight the development of STEAM-integrated CBL steps supported by Sevima Edlink, which were derived from a comprehensive analysis of various literature sources. It was determined that the STEAM-integrated CBL model, aided by Sevima Edlink, has a positive influence on students' creative thinking skills across the disciplines of science, technology, engineering, art, and mathematics. This model enables students to tackle pressing problems, propose solutions linked to real-world issues, and take appropriate actions, thereby fostering opportunities for enhancing their creative thinking skills.

No	Researcher and Year	Result Findings
5	Kartika et al. (2022)	The analysis indicates that STEAM-based learning effectively incorporates the principles of constructivism. This approach includes using real-life problems to stimulate the learning process, facilitating an inquiry process through investigation and experimentation. Additionally, it fosters an environment that encourages students to ask questions and interact with instructors, thereby providing opportunities for students to discover new knowledge independently.
6	Rahma I. (2022)	The results revealed that in the pretest, both individually and collectively, 100% of students did not achieve scores above the Minimum Completion Criteria (KKM). In contrast, during the posttest, out of 36 students, 86.11% were able to meet the KKM standards. Additionally, student engagement in the learning process was in line with expectations, indicating an overall improvement in their performance and participation.
7	Suryaningsih et al. (2021)	The research data was collected using a Google Form questionnaire consisting of 14 items. The findings indicate positive outcomes, with science process skills achieving a score of 4.164, representing a high category with a percentage of 83.3%. Similarly, students' creative thinking skills also showed good results, scoring 4.134, which falls within the high category at 82.7%. The integration of STEAM project learning through the WhatsApp group application and the use of Instagram as a social media platform has proven to enhance students' science process skills, creative thinking abilities, as well as their science and digital literacy, and motor skills. These findings could serve as an innovative approach to improving the science learning process.
8	Prameswari et al. (2023)	The findings of this analysis reveal that STEM research is predominantly characterized by the use of experimental methods, accounting for 53.33%. Additionally, it shows a significant emphasis on STEM as a learning approach at 71.1%. Specifically, Project-Based Learning (PjBL) constitutes 24.44% of the research, while Problem-Based Learning (PBL) represents 17.78%. However, there is a noticeable gap in STEM research related to learning and the development of learning tools based on models other than PjBL and PBL, indicating that this area has not been extensively explored.
9	Fika et al. (2020)	The results indicate that the implementation of the STEM approach in Indonesia positively influences various aspects, including students' creative thinking

No	Researcher and Year	Result Findings
		skills, Learning Activities Sheets (Worksheet), student books, and their ability to navigate the challenges of the Industrial Revolution 4.0. Additionally, it enhances mathematical literacy, supports STEM implementation through robotics, and shapes teacher perceptions regarding STEM learning.
10	Tsaniyah et al. (2023)	The results of this study demonstrated that students' critical thinking skills improved following the implementation of the STEAM Project-Based Learning (PJBL) model over two cycles. The project focused on alternative energy materials, specifically through the creation of automatic solar garden lights. In the first cycle, the pretest and posttest results showed a shift from the low to moderate category. In the second cycle, there was an average increase of 12.08% between the pretest and posttest scores. This indicates that the implementation of the STEAM PJBL model for two cycles effectively enhanced students' critical thinking skills.
11	Wella et al. (2023)	These results suggest that the integration of STEAM into mathematics learning can significantly contribute to the development of critical thinking skills among primary school students. This approach prepares them to tackle complex problems effectively, equipping them with the necessary skills to navigate real-world challenges.
12	Khoiriyah et al. (2018)	The results indicated that the average N-gain value in the experimental class was 0.63, while the control class recorded an N-gain of 0.35, both falling within the moderate category. These findings suggest that the implementation of the STEM learning approach has a positive effect on enhancing students' critical thinking skills.
13	Rafaelovich (2023)	The results indicate that students' critical thinking skills are high; however, this research is limited to an examination of students' critical thinking specifically related to temperature and heat material. Future research could expand the scope by incorporating additional variables, allowing for a more comprehensive comparison of the results. This would provide deeper insights into students' critical thinking across different topics.
14	Zafirah et al. (2022)	The results indicate that the STEM approach, when integrated into the learning model, demonstrates significant influence. Specifically, the highest average influence value without an integrated model was recorded at 2.93. Additionally, regarding learning materials, the highest average influence was observed in

No	Researcher and Year	Result Findings
		dynamic electricity and Newton's law of gravity. When examining the application of the STEM approach on students' thinking skills, essential thinking skills showed an average effect of 2.66, while creative thinking skills had a lower average impact of 1.47. Overall, the findings suggest that the STEM approach enhances both creative and critical thinking skills among students when integrated with high school physics learning models and materials.
15	Hidayati et al. (2024)	The study results were analyzed using descriptive analysis techniques, revealing that the feasibility of the lesson plan falls into the exemplary implementation category. Students' learning outcomes, encompassing knowledge, critical thinking, psychomotor skills, and attitudes, were classically complete. All students demonstrated an improvement in critical thinking skills, progressing from the unskilled-less skilled category to unskilled-skilled, and further advancing to the unskilled-very skilled category. These findings were supported by observations of student activities during the learning process.
16	Febriansari et al. (2022)	This research aims to develop a combined framework that integrates the STEAM learning model with design thinking, specifically tailored for application in renewable energy education. This framework is expected to enhance the learning experience and equip students with the necessary skills to tackle challenges in the field of renewable energy.
17	Sulastri & Putri (2021)	The results indicated a significant difference in students' critical thinking skills before and after receiving project-based learning treatment utilizing the STEAM approach in the online learning of service company financial statements material. This treatment led to a notable enhancement in students' critical thinking abilities.
18	Zaidi et al. (2023)	The results of this research indicate that STEAM can be effectively integrated into various subjects and educational levels. Furthermore, the application of STEAM can facilitate the development of students' 21st-century skills, accommodating technological advancements and the growing demands of modern education. In the context of physics learning, incorporating the STEAM approach can actively engage students in the teaching and learning process, fostering a more interactive and dynamic educational experience.
19	Syukri et al. (2022)	The results indicated that the pre-test scores ranged from a minimum of 5 to a maximum of 50, while the post-test scores had a minimum of 60 and a maximum

No	Researcher and Year	Result Findings
		of 95. The average increase in students' scores from the final test was greater than the average pretest score. Data analysis revealed a significance (Sig. 2-tailed) value of 0.000, which is less than 0.05. This outcome leads to the rejection of H_0, indicating a significant difference in the critical thinking results of the students.
20	Salsabila et al. (2021)	The results of the study demonstrate that the STEAM approach, supported by parental involvement, can significantly enhance children's creativity while learning at home during the pandemic. This approach incorporates science, technology, engineering, art, and mathematics, which encourages children to explore and seek solutions to real-world challenges. Parental support plays a crucial role by appreciating and valuing children's creations, thereby boosting their confidence. As a result, this environment fosters an increase in children's creativity.

Discussion

Research conducted using the literature review method indicates that the STEAM approach encourages students to construct their understanding of the learning process by integrating various aspects of real life, thereby refining and enhancing their skills. This aligns with the Sustainable Development Goals (SDGs), particularly the principle of "No One Left Behind" (Alfa et al., 2018; Capah et al., 2023). The importance of the SDGs in education relates directly to their objectives, which aim to ensure equitable access to education and expand learning opportunities, ultimately leading to the realization of quality education for all (Wahyuningsih, 2017). Through STEAM learning, students become more engaged and proactive in their educational journey. They take the initiative to expand their knowledge by constructing concepts through observation, investigation, and inquiry-based questioning (Hasanah et al., 2021; Marmon, 2019). This active involvement not only fosters critical thinking skills but also encourages a more profound understanding of the interconnectedness of different disciplines in real-world contexts.

Quigley et al. (2017) conducted prior research focused on critical thinking skills, specifically using physics material to evaluate students' abilities in this area. Their study highlighted the importance of critical thinking in understanding physics concepts and problem-solving. Additionally, the articles referenced above provide insights into the application of the STEAM approach across various contexts and how it influences student skills in learning physics. By examining these studies, we can better understand how STEAM methodologies can enhance critical thinking and overall learning outcomes for students in the field of physics.

In Table 1, the researchers compiled five articles that emphasize STEAM-based approaches in physics, specifically aimed at enhancing students' critical thinking skills. This focus is particularly relevant given the limited number of studies available in this area. The analysis of these articles reveals a positive shift in the implementation of STEAM-based learning within the context of high school physics education, effectively

supporting the development of critical thinking skills. From the summarized objectives, methods, and results in the table, it is evident that adopting STEAM-based learning is a promising strategy for fostering student interest and skills in science, technology, engineering, and mathematics (Isralidin & Rahma, 2022; Suryaningsih & Ainun, 2021). This research has also been enhanced through updated data from a more diverse range of study locations, contributing to the validity and variability of the findings. However, it is important to note that this study is limited to the examination of students' critical thinking skills in physics materials. While the focus allows for a thorough analysis, future research should consider expanding the variables to facilitate a more comprehensive comparison and understanding of the various aspects influencing critical thinking in different subjects.

While STEAM learning offers several advantages, it is not without its drawbacks, particularly since this learning model is still relatively new and requires a period of adaptation. One of the main challenges is the insufficient emphasis on explicitly developing critical thinking skills. Many implementations of STEAM tend to prioritize technical aspects and project outcomes, which can result in the neglect of essential components such as analysis, evaluation, and reflection (Henriksen, 2017). Additionally, the effectiveness of the STEAM approach relies heavily on the presence of highly competent teachers capable of facilitating cross-disciplinary integration. This can present significant challenges, especially in schools that face limitations in teacher resources and training (Quigley et al., 2020). Moreover, the lack of structured guidance within STEAM learning may prevent students from systematically engaging in the critical thinking processes that are vital for their academic growth. Therefore, it is essential for the STEAM approach to be better designed to ensure that critical thinking development is a central focus of all learning activities. By addressing these shortcomings, educators can enhance the overall effectiveness of STEAM learning and better prepare students to think critically and creatively in a complex, interconnected world.

Among the 20 articles reviewed concerning STEAM learning, several focus on analyzing the impact of various instructional methods such as Project-Based Learning (PjBL), Project-Based Learning (PjBL) with a focus on community, and Education for Sustainable Development (ESD). Additionally, the research examines the influence of the Challenge-Based Learning (CBL) model within the STEAM framework, aiming to enhance students' critical thinking skills. These methodologies foster more effective collaboration among students by encouraging them to discuss ideas, consider diverse perspectives, and present well-reasoned arguments. As a result, the development of critical thinking skills not only improves learning outcomes but also equips students to tackle complex real-world challenges. In this modern era, fostering critical thinking is a fundamental educational goal, and continual advancements in teaching strategies are essential for preparing students for future demands. This underscores the importance of ongoing development in educational practices to enhance the overall quality of learning.

According to Hmelo-Silver (2004), an effective STEAM approach requires a structured and problem-based learning design to develop students' critical thinking skills effectively. One key recommendation is the integration of a Problem-Based Learning (PBL) approach, where students collaboratively solve complex real-world problems across various disciplines. This collaboration not only enhances their critical thinking but also facilitates deeper understanding and application of knowledge. To

support this process, it is essential for teachers to undergo specialized training that equips them to facilitate critical discussions, stimulate in-depth questioning, and help students connect concepts from different disciplines within the STEAM framework (Herro et al., 2017). Furthermore, STEAM learning can be significantly enriched through the principles of Project-Based Learning (PJBL), as it helps students draw connections between theoretical knowledge and real-world applications. When guided appropriately, PJBL creates an active and reflective learning environment that encourages students to engage in independent problem-solving, making their learning experiences more relevant and meaningful. This comprehensive approach ultimately prepares students to navigate and address the challenges of the modern world effectively.

In addition to PBL and PJBL, another effective approach is integrating the STEAM (Science, Technology, Engineering, Arts, and Mathematics) framework with Education for Sustainable Development (ESD). This combination offers an excellent opportunity to enhance students' critical thinking skills. Through ESD-oriented STEAM, students are encouraged to critically analyze environmental challenges, evaluate potential solutions with a focus on sustainability, and make informed decisions that account for long-term impacts (Wiek et al., 2011). This approach fosters holistic thinking by connecting scientific and technological knowledge with social and ethical considerations. To successfully implement this method, it is essential to design activities that address real-world problems, promote cross-disciplinary collaboration, and actively involve students in exploring innovative ideas. As a result, ESD-oriented STEAM learning not only sharpens students' critical thinking abilities but also empowers them to become agents of change in today's society. By leveraging digital technology and interactive learning tools, teachers can create a motivating learning environment that encourages students to engage deeply and reflectively with the material. This active engagement supports the development of critical competencies necessary for addressing complex global challenges and promotes a culture of sustainability among future generations.

Utilizing e-modules in STEAM learning represents an innovative approach to enhancing students' critical thinking skills. E-modules provide interactive, adaptive, and structured content delivery, enabling students to learn at their own pace and according to their individual needs (Sari et al., 2020). These modules can be enriched with multimedia features such as videos, simulations, and interactive quizzes, which not only boost student engagement but also deepen their understanding of the concepts being taught (Kurniawan et al., 2018). The integration of technology through e-modules facilitates the development of essential analytical, evaluative, and reflective skills that are crucial for critical thinking. By encouraging students to actively participate and interact with the learning material, e-modules can significantly enhance the overall learning experience. To effectively implement these approaches, it is vital to ensure that qualified resources are available. Adequate support in terms of technology, training, and instructional materials is necessary to optimize the development of critical thinking skills through STEAM learning. This comprehensive approach can lead to more meaningful educational outcomes and better prepare students to tackle complex challenges in the future.

CONCLUSION

Fundamental Findings: STEAM learning is an interdisciplinary approach that integrates science, technology, engineering, art, and mathematics, providing a framework for understanding concepts in relation to real-world applications. **Implications:** The implementation of STEAM learning can significantly enhance students' critical thinking skills. By incorporating various content areas, STEAM encourages students to actively explore and seek solutions to existing problems, fostering a deeper engagement with the material. **Limitations:** The educational aspect of the Sustainable Development Goals (SDGs) plays a crucial role in achieving other components. The urgency of the SDGs in education emphasizes the need for equal access to educational opportunities, ensuring that quality education is attainable for all. **Future Research:** The STEAM approach holds considerable promise for identifying more effective strategies to enhance students' critical thinking skills. Future studies should focus on developing a Project-Based Learning (PjBL) STEAM model that encourages students to collaboratively analyze problems, evaluate data, and devise creative solutions. Additionally, exploring the use of digital technologies, such as interactive e-modules, could further facilitate the integration of disciplines within the STEAM framework, providing engaging and impactful learning experiences.

ACKNOWLEDGEMENTS

In this study, the researcher would like to express gratitude to the various researchers whose work has contributed to the foundation of this literature review. Special thanks are extended to those who have provided assistance and support throughout the research process, helping to ensure that this study was conducted successfully and accurately. Your contributions are greatly appreciated and have played a vital role in the completion of this research.

REFERENCES

Alfa, Akbar., Thaher, & Syafrizal. (2018). Pemetaan tridarma program studi teknik sipil Universitas Islam Indragiri dalam pencapaian Sustainable Development Goals (SDGs). *Jurnal Bappeda, 4*(2), 73-80.

Annur, S. (2018). Sustainable Development Goals (SDGs) dan peningkatan kualitas pendidikan. Seminar Nasional Pendidikan, 251–255.

Arani, Fika, T., Islamiani, & Safitri. (2020). Systematic literature review: Implementasi pendekatan STEM (manfaat dan tantangan) di Indonesia. *Jurnal Pendidikan Matematika*, 355-371.

Azizah, M., Sulianto, J., & Cintang, N. (2018). Analysis of critical thinking skills of elementary school students in learning mathematics curriculum 2013. *Jurnal Penelitian Pendidikan, 35*(1), 61-70.

Becker, K & Park, K. (2011). Effects of integrative approaches among Science, Technology, Engineering, And Mathematics (STEM) subjects on students' learning: A preliminary meta analysis. *Journal of STEM Education, 12*(5-6), 23–37.

Bin Amiruddin, M. Z., Magfiroh, D. R., Savitri, I., & Binti Rahman, S. M. I. (2022). Analysis of the application of the STEAM approach to learning in indonesia: Contributions to physics education. *International Journal of Current Educational Research, 1*(1), 1–17. https://doi.org/10.53621/ijocer.v1i1.139

Capah. (2023). Implementasi SDGS-12 melalui pengembangan komunitas dalam program CSR. *Social Work Journal, 13*(1): 150-161.

Colucci-Gray, L., Burnard, P., Gray, D., & Cooke, C. (2019). A critical review of STEAM (Science, Technology, Engineering, Arts, and Mathematics). In Oxford Research Encyclopedia of Education. Oxford University Press. https://doi.org/10.1093/acrefore/9780190264 093.013.398

Fardani, Z & Surya, E. 2017. Meningkatkan kemampuan berpikir kritis dalam pembelajaran matematika untuk membangun karakter bangsa. https://www.researchgate.net/publicati on/321780441

Febriansari, D., Sarwanto , S., & Yamtinah , S. (2022). Konstruksi model pembelajaran STEAM (Science, Technology, Engineering, Arts, and Mathematics) dengan pendekatan design thinking pada materi energi terbarukan. *JINoP (Jurnal Inovasi Pembelajaran), 8*(2). 186-200. https://doi.org/10.22219/jinop.v8i2.22456.

Hasanah, A., Zaqiah, QY, & Heryati, Y. (2021). Model pembelajaran STEAM untuk meningkatkan keterampilan abad 21.

Hidayati, Arin., Munasir., Elok, Sudibyo. (2024). Pengembangan perangkat pembelajaran fisika model problem based learning untuk meningkatkan keterampilan berpikir kritis siswa SMA. DOI: https://doi.org/10.46245/ijorer.v5i1.496.

Henriksen, D. (2017). Creating STEAM with design thinking: beyond STEM and arts integration. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *90*(1), 40–46.

Herro, D., Quigley, C., & Andrews, J. (2017). Co-Measure: developing an assessment for student collaboration in STEAM activities. *International Journal of STEM Education*, *4*(1), 26.

Hmelo-Silver, C. E. (2004). Problem-based learning: what and how do students learn? *Educational Psychology Review*, *16*(3), 235–266.

Humaida, N., Aula, M., Nida, N. H., Islam, U., & Antasari, N. (2020). Pembangunan berkelanjutan berwawasan lingkungan dalam perspektif islam. *18*(1), 131–154. https://doi.org/10.18592/khazanah. v18i1.3483

Isralidin, Rahma. (2022). Implementasi pendekatan STEAM dalam meningkatkan kemampuan berpikir kritis siswa SD Negeri 1 Bireuen. *Jurnal Edukasi Matematika dan Sains, 3*(1), 33–35.

Kang, N. H. (2019). A review of the effect of integrated STEM or STEAM (science, technology, engineering, arts, and mathematics) education in South Korea. *Asia-Pacific Science Education, 5*(1), 6. https://doi.org/10.1186/s41029-019-0034-y

Khoiriyah, Nailul, Abdurrahman, Ismu, Wahyudi. (2018). Implementasi pendekatan pembelajaran STEM untuk meningkatkan kemampuan berpikir kritis siswa SMA pada materi gelombang bunyi. *JRKPF UAD*, *5*(2).

Kurniawan, D. A., Suana, W., & Putri, N. M. S. (2018). The effect of interactive e-module with problem-based learning on students' critical thinking skills. *Jurnal Pendidikan IPA Indonesia*, 7(4), 442–450.

Kurniawati, F. N. A. (2022). Meninjau permasalahan rendahnya kualitas pendidikan di indonesia dan solusi. *Academy of Education Journal*, *13*, 1–13.

Marmon, M. (2019). Munculnya kreativitas dalam STEM: mengembangkan pendekatan alternatif untuk sains, teknologi, teknik, dan pengajaran matematika melalui penggunaan seni. Dalam STEAM Education (hlm. 101-115). Pegas, Cham.

Nabilah, Tsaniyah R., Agus, Anndy, Abu, Zainuddin., Munasir. (2023). Implementasi pembelajaran model project based learning pendekatan STEAM untuk melatihkan keterampilan berpikir kritis peserta didik. *Inovasi Pendidikan Fisika*. *12*(1), 36-43.

Nurfatimah, S.A.,dkk. (2022). Membangun kualitas pendidikan di indonesia dalam mewujudkan program Sustainable Development Goals (SDGs). *Jurnal Basicedu, 6*(4): 6145-6154.

Paputungan. (2023). Mengenal Sustainable Development Goals (SDGs). *Journal of Hulonthalo Service Society, 2*(2).

Nurhasanah, A., & MS, Z. (2021). Penerapan pembelajaran inovatif STEAM di sekolah dasar. *JIKAP PGSD: Jurnal Ilmiah Ilmu Kependidikan, 5*(2), 204. https://doi.org/10.26858/jkp.v5i2.20309

Ozkan, G., & Topsakal, U. (2021). Exploring the effectiveness of STEAM design processes on middle school students' creativity. *International Journal of Technology and Design Education, 31*(1), 95–116. https://doi.org/10.1007/s10798-019- 09547-z

Pasca, Wella E., Wardono., Budi Waluya. (2024). Integrasi STEAM dalam meningkatkan kemampuan berpikir kritis siswa sekolah dasar. *PRISMA 7* (2024): 301-308.

Paul, R., & Elder, L. (2019). The miniature guide to critical thinking concepts and tools. Rowman & Littlefield.

Prameeswari, Pradnya., Suyanto, Sutoyo., Utiya, Azizah (2023). Scoping literature review of stem research in indonesia in improving critical thinking skills and concepts mastery. *Indonesian Journal Of Educational Research And Review*, *6*(2), 383-388.

Rafaelovich, Pesakh A., Feliza, Paramitha S., Febriana R.W. (2023). Deskripsi kemampuan berpikir kritis siswa sekolah perkotaan di bahan fisika. *8*(2).

Salsabila, Nadifa., Abdul Muhid. (2021). Efektivitas pendekatan STEAM berbasis parental support untuk meningkatkan kreativitas anak belajar dari rumah selama masa pandemi Covid-19. *6*(2). DOI: https://doi.org/10.29303/jipp.v6i2.194.

Sari, D. P., Marpaung, T. R. T., & Sitorus, M. A. (2020). The development of e-module to improve critical thinking ability in science learning. *Journal of Physics: Conference Series*, *1428*(1), 012093.

Suganda, E., Latifah, S., Irvandani. Sari, P. M. Rahmayanti, H., Ichsan, I.Z., Rahman M. M.(2021). steam and environment on students' creative thinking skills: a meta-analysis study. Journal of Physics: Conference Series, 1796(1). https://doi.org/10.1088/1742-6596/1796/1/012101

Sulastri, Gita, Putri C. (2021). Pengaruh project based learning dengan pendekatan STEAM Terhadap kemampuan berpikir kritis pada pembelajaran online di SMK Negeri 12 Malang. *Jurnal Pendidikan Akuntansi (JPAK)*, *9*(3).

Suryaningsih, S., Nisa, A. N. (2021). Kontribusi STEAM project based learning dalam mengukur keterampilan proses sains dan berpikir kreatif siswa. *Jurnal Pendidikan Indonesia, 2*(6), 1097-1106.

Syukri, M., Zaifatul, U. (2023). Pengaruh penerapan pembelajaran berbasis STEAM terhadap kemampuan siswa kemampuan berpikir kritis. *Jurnal Pendidikan Sains Asia*, *4*(2), 37–45.

Usmeldi. (2016). The development of research-based physics learning model with scientific approach to develop students' scientific processing skill. *Jurnal Pendidikan IPA Indonesia. 5* (1) 134-139. DOI: 10.15294/jpii.v5i1.5802.

Usmeldi, R. Amini, S., Trisna. (2017). The development of research-based learning model with science, environment, technology, and society approaches to improve critical thinking of students. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 318-325. DOI:10.15294/jpeg.v6i2.10680.

Wahyuningsih. (2017). Millenium Development Goals (MDGs) and Sustainable

Development Goals (SDGs). *Jurnal Bisnis dan Manajemen, 11*(3), 390-399.

Wahyuningsih, S., Nurjanah, N. E., Rasmani, U. E. E., Hafidah, R., Pudyaningtyas, A. R., & Syamsuddin, M. M. (2020). Pembelajaran STEAM dalam pendidikan anak usia dini: sebuah tinjauan literatur. *Jurnal Internasional Pedagogi dan Pendidikan Guru, 4*(1), 33-44.

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: a reference framework for academic program development. *Sustainability Science*, *6*(2), 203–218.

Quigley, C., Herro, D., & Jamil, F. M. (2017). Mengembangkan model konseptual praktik pengajaran STEAM. *Sains dan Matematika Sekolah, 117*(1-2), 1-12.

Quigley, C. F., Herro, D., & Jamil, F. M. (2020). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics, 120*(2), 55–65.

Zafirah, Puti, M. S., Yunita, Jellyah, J. P., Ferdy, P, & Desnita. (2022). Meta-analisis pengaruh pendekatan STEM terhadap kreatifitas dan kreativitas siswa keterampilan berpikir kritis dalam pembelajaran fisika di SMA. *10*(1), 61-73. DOI: http://dx.doi.org/10.31258/jgs.10.1.61-73.

Zaidi, M. A., Dhela, R. M. (2022). Analisis penerapan pendekatan STEAM pada pembelajaran pada Indonesia: kontribusi pada pendidikan fisika. *IJOCER, 1*(1). DOI: https://doi.org/10.53621/ijocer.v1i1.139.

***Lailatul Fajriati (Corresponding Author)**
Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Surabaya, Indonesia
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: lailatul.22065@mhs.unesa.ac.id

Hanan Zaki Alhusni
Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Surabaya, Indonesia
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: hanan.20068@mhs.unesa.ac.id

Rahmatta Thoriq Lintangesukmanjaya
Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Surabaya, Indonesia
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: rahmattathoriq.20038@mhs.unesa.ac.id