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Literature Study: Analysis of STEAM-Based Physics Learning Practices to Train Students' Creative Thinking Skills

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Abstract

In conjunction with the rapid advancement of science and technology, current education system necessitates transformative changes to align with the evolving demands of the 21st century. As current issues require multidisciplinary solutions, STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach offers an opportunity to expand students' analytical perspectives while simultaneously developing the skills needed to thrive in the 21st century, including creative thinking that appears as one of the valuable skills that enables students to identify problems and formulate effective solutions. Thus, this study aims to analyze previous studies regarding the practices of STEAM-based physics learning among high school students in incorporating creative thinking skills. These papers will be used to assess the extent of creative thinking development in STEAM-based physics education. The research method was carried out by collecting data from relevant literature pertinent to the research objectives. Based on literature review, the findings indicate that the STEM-based 5E learning model effectively equips students with the critical thinking and problem-solving skills essential for the 21st century. The application of the STEAM approach, coupled with the assistance of spectra-plus on sound wave material, has significantly enhanced the 21st-century skills of students. This approach has fostered collaborative and effective communication among students, enabling them to identify existing problems through comparative observations. By analyzing the results of their observations, students are empowered to devise solutions to existing challenges.

Keywords: *STEAM, Creative Thinking Skills, Physics Learning*

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INTRODUCTION

In the rapidly evolving 21st-century scientific and technological landscape, the integration of technology into the educational system has emerged as a pressing necessity. Lolanessa et al. (2018) identify 21st-century skills into three distinct categories: (1) cognitive skills, including creative, innovative, critical thinking, problem-solving, decision-making, and effective learning; (2) interpersonal and teamwork skills; and (3) global citizenship skills, such as developing awareness as a responsible citizen in shaping one's life and career, and assuming personal and social responsibilities.

Creative thinking skills are defined as abilities that allow students to develop new and appropriate solutions or ideas from various perspectives based on existing data or information (Rizal et al., 2020). Particularly through problem-oriented learning, students' potential for creative thinking can be nurtured, enabling them to identify challenges and devise multifaceted solutions (Nuha, et al., 2018). Safaria and Sangila (2018) frame four indicators of creative thinking ability, namely (1) Fluency, is the ability of students to produce solutions that are relevant to problems, (2) Flexibility, is the ability of students to produce a diverse solution to a problem, (3) Originality, is the ability of students to produce new ideas from a problem, (4) Elaboration, is the ability of students to complete the ideas that have been conveyed.

The creativity possessed by students is closely related to the creative thinking skills they have. In the realm of life, whether in the form of work or other professions, it is imperative to possess resources that demand high-level skills. Consequently, individuals and society need to cultivate a lifelong habit of learning, reasoning, thinking creatively, making sound decisions, and resolving problems effectively. In this context, it is evident that students with creative thinking skills possess the ability to draw reliable conclusions, gain comprehensive insights, make judicious decisions, produce high-quality products, and make groundbreaking discoveries. Consequently, creative thinking is regarded as a crucial element that supports students in their pursuit of comprehending concepts.

Scientific experiments can be conducted to discover concepts that involve fundamental skills, and these practicum activities can be enhanced in the laboratory setting. The primary objective of laboratory practicum is to equip students with the necessary skills and knowledge to adhere to scientific procedures effectively. This training aims to foster the development of scientific values and competencies (depdiknas, 2004).

One of the efforts made to equip graduates with the ability to apply their acquired knowledge to practical applications in the educational sector is the adoption of an integrative approach. An integrative approach is a learning methodology that integrates multiple disciplines. Science, Technology, Engineering, and Mathematics (STEM) approach is a novel approach in the development of the educational landscape that seamlessly integrates multiple disciplines. The National Center for STEM Education (*Pusat Pendidikan STEM Nasional*) (2013) asserts that STEM learning encompasses not only the strengthening of practical education within the STEM field but also the development of an educational approach that harmoniously integrates science, technology, engineering, and mathematics, with a primary focus on education.

STEAM learning emerged in response to the need to enhance students' interests and skills in *Science, Technology, Engineering, and Mathematics* (STEM) (Quigley, Herro, & Jamil, 2017). STEAM combines the "*arts*" with STEM learning for the purpose of increasing student engagement, creativity, innovation, problem-solving skills, and other cognitive benefits (Liao, 2015) and to enhance the work skills (e.g., teamwork, communication, adaptability) necessary for career and economic advancement (Colucci-Gray et al., 2017).

STEAM is a learning approach that gives students the opportunity to expand their knowledge in the sciences and humanities and at the same time develop the skills needed to thrive in the 21st century – such as communication skills, critical thinking skills, leadership, teamwork, creativity, resilience, and other skills. STEAM was initiated by *the Rhode Island School of Design* which added "*arts*" to the STEM framework. According to the Rhode Island School of Design, the goal is to foster innovation that thrives by combining the mind of a scientist or technologist with an artist or designer. The addition of "*arts*" to the STEM framework is important as a practice, such as modeling, developing explanations, and generating criticism, and evaluation (argumentation), which has often been emphasized in the context of mathematics and science education.

In this context, the term "arts" encompasses not only activities such as coloring or drawing with crayons or paint but also serves as a means of expressing and showcasing the non-analytical and creative aspects of an individual's cognitive abilities. It is the side of the brain that allows a person to solve problems creatively, which allows a person to "*think outside the box."* Everything from typical art, music, dance, to "new" art, such as 3D printing falls under the category of art (Perignat & Katz-Buonincontro, 2018).

Various studies have shown that art activities have helped to support and foster creativity, an essential skill for innovation. STEM education alone appears insufficient; instead, it should be complemented with the "*arts"* to form STEAM. The integration of STEM education with the arts (STEAM) offers a platform to foster innovation that is crucial for the emerging global economy. Arts enrich interdisciplinary learning and engage students in ways that traditional pedagogy does not. Art can be regarded as a means for students to engage in reflection, creation, expression, and representation of ideas, serving as an alternative to traditional reading, writing, speaking, and listening activities.

STEAM empowers educators to employ project-based learning that integrates five disciplines: science, technology, engineering, arts, and mathematics. This inclusive learning environment ensures that all students can actively engage and contribute. In contrast to conventional teaching methods, educators utilizing the STEAM framework may harmoniously combine disciplines, enhancing the dynamic synergy between the modeling process and mathematical and scientific content. Through this holistic approach, students can simultaneously develop cognitive abilities on both sides of their brains. Even for students who do not pursue careers in STEM or STEAM fields, the skills acquired through STEAM learning can be applied to a wide range of future professions. Properly taught STEM/STEAM education equips students for life, regardless of their chosen career path. STEM/STEAM education instills critical thinking and problem-solving skills, valuable tools that can be utilized throughout life to navigate challenges and seize opportunities as needed.

Based on the provided explanation, an analysis of the results of previous studies was conducted using a literature study method to assess the development of creative thinking skills among high school physics students engaged in STEAM-based learning. This study aimed to evaluate the extent to which STEAM-based physics learning contributes to the enhancement of creative thinking abilities. The importance of creativity in STEAM education is paramount, as it fosters independent and flexible thinking, cultivates creative self-efficacy, and enhances problem-solving skills. Numerous studies have demonstrated that creativity can be acquired through modeling and practice. Consequently, educators are expected to embody creative values and behaviors while maintaining a conducive learning environment.

From the initial discussion, it is clear that the research gap has not been clearly outlined. Although various studies have demonstrated the benefits of STEAM-based learning in developing 21st-century skills, most still focus on problem-solving and critical thinking skills. Meanwhile, specific studies on how STEAM can systematically foster creative thinking skills, especially in the context of physics learning at the secondary school level, are still limited. This is what makes this study important, as it seeks to clarify the contribution of STEAM in improving creative thinking skills. The novelty of this research lies in its effort to synthesize various recent studies that not only emphasize the integration of STEAM in physics learning but also link it to strengthening creative thinking indicators, namely fluency, flexibility, originality, and elaboration, through descriptive analysis.

METHOD

The methodology employed in this study is a literature review, which entails analyzing data derived from relevant literature pertinent to the research objectives. Literature review is a research approach that involves reading books, journals, articles, and other publications related to a specific topic to generate new writing (Marzali, 2017). The collected data is subsequently subjected to descriptive analysis, which aims to elucidate the facts and data obtained. The findings are subsequently presented in a new article, serving as an introduction to the research topic for those interested in the subject matter.

This literature review was compiled by examining several articles published between 2018 and 2022, reflecting the latest developments in research on the application of STEAM (Science, Technology, Engineering, Arts, and Mathematics)-based learning. Articles were selected based on topic relevance, focusing on the integration of STEAM into science learning and its efforts to develop 21st-century skills such as critical thinking, creativity, communication, collaboration, and students' soft skills. Based on the reviewed articles, there is a continuity of research from conceptual-theoretical to practical-applicable, and from elementary to secondary education levels. This demonstrates that STEAM is an adaptive and relevant approach to be applied in various learning contexts, with the primary goal of preparing young people to face the challenges of the 21st century. Data obtained from various relevant literature were then analyzed using descriptive analysis. This analysis was conducted by organizing previous research findings, identifying key themes, and highlighting variations in STEAM implementation. This step provided a picture of how students' creative thinking skills are developed in physics learning, as well as patterns of success and limitations that emerged from the various studies reviewed.

To provide a clearer picture of the research procedure, Figure 1 below shows the flow of the literature review stages. This flow systematically explains the process of topic identification, selection of relevant articles, and data analysis and interpretation, which form the basis for drawing research conclusions.

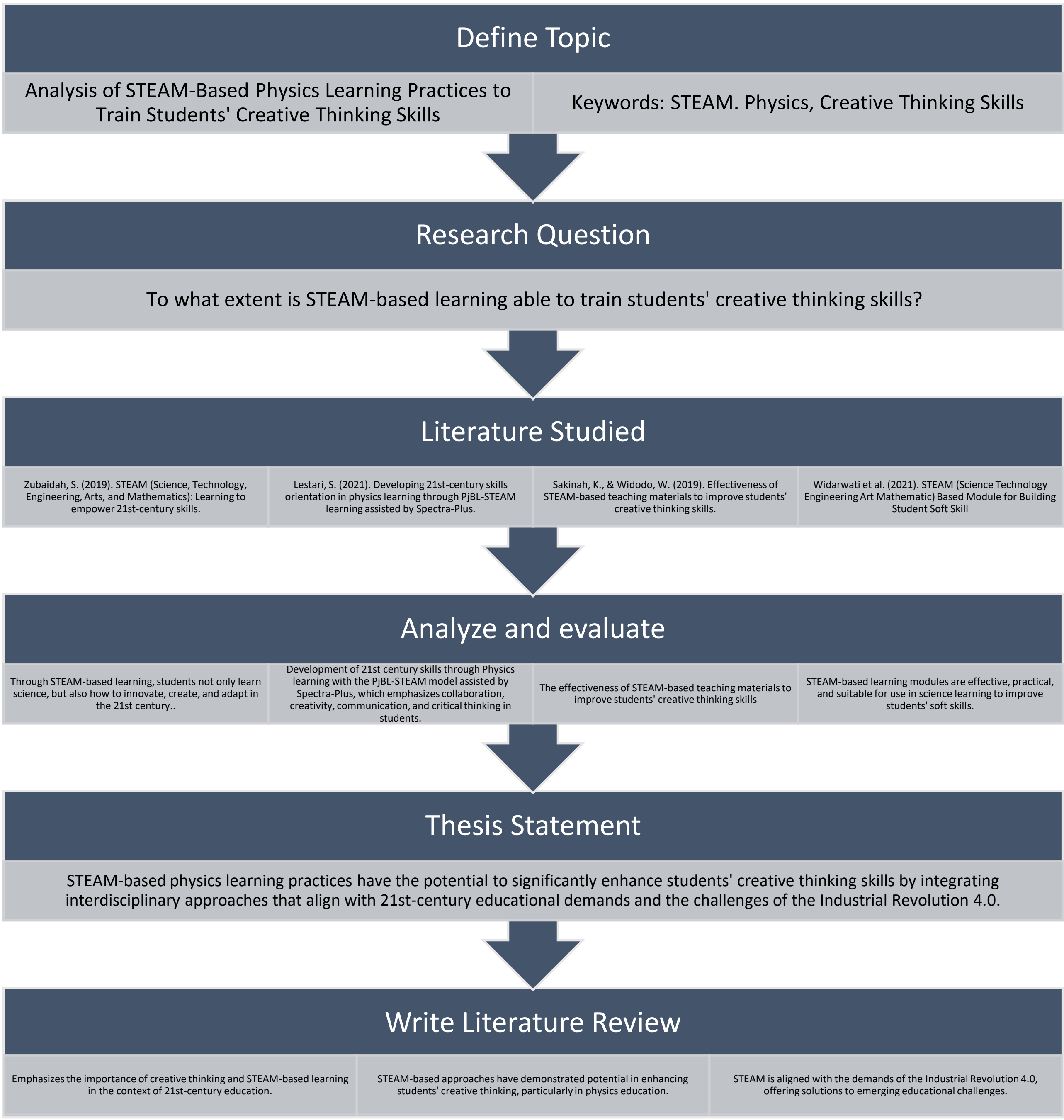

Figure 1. Literature Study Research Flow

RESULTS AND DISCUSSION

The findings from the inaugural research journal titled "Integration of STEM in Science Learning to Confront the Challenges of the Industrial Revolution 4.0 (*Integrasi STEM pada pembelajaran IPA untuk menghadapi tantangan revolusi industri 4.0*)" were published in the Proceedings of the National Seminar on Science Learning, held at the Universitas Negeri Malang in 2019. The learning cycle-5E model and the STEM approach are student-centered learning methodologies (Ejiwale, 2013; Rahayuningsih et al., 2012). Furthermore, these approaches emphasize training students to foster collaboration, activeness, and hands-on learning experiences (Rahayuni, 2016; Rosicka, 2016) underscores that STEM-based learning presents opportunities for students to enhance their critical thinking abilities, as STEM disciplines encompass elements that promote curiosity development, critical review, evaluation, and questioning.

The STEM-based learning approach aligns seamlessly with the Learning Cycle-5E model, as proposed by Novianti et al. (2014). This model emphasizes that each stage of the Learning Cycle-5E provides students with opportunities to develop critical thinking skills, particularly during the exploration, elaboration, and evaluation stages. At these stages, students are required to analyze, apply concepts to novel situations, and evaluate their learning experiences. This process enhances critical thinking indicators, which are essential for students' overall cognitive development (Latifa et al., 2017). By integrating the Learning Cycle-5E with STEM, the learning model and approach are mutually strengthened, enabling students to acquire high levels of critical thinking skills. Table 1 summarizes the learning syntax of the Learning Cycle-5E.

Table 1. STEM-based learning cycle-5E syntax (Rosicka, 2016)

Syntax	Activities	STEM Elements
Commitment	Teachers stimulate students' knowledge and curiosity,	*Technology:* Investigating and defining problems through the data presented and existing problem-solving Engineering: Conceptualizing a problem
Exploration	Students conduct experiments on phenomena and concepts	*Technology:* Create and implement digital tools *Engineering:* Bringing the plan to life Realize design Testing the plan *Mathematics:* Use and apply mathematical concepts, facts and procedures to solve problems in the field of mathematics
Explanation	Students explain scientifically the phenomenon studied based on the evidence obtained	*Science:* Processing and analyzing data or information Mathematics: Explaining and evaluating the results of calculations
Elaboration	Students use and apply the concepts and explanations that have been learned to new contexts	*Science:* Using and applying concepts that are already known Technology: Using or making technology Engineering: Designing and designing a tool
Evaluation	Students review and reflect on the learning and knowledge they have gained	

Research on STEM-based learning cycle models has been conducted on various variables. Kaniawati and Suryadi (2016) concluded that STEM-based learning cycle-5E can develop problem-solving skills in students. Ceylan and Ozdilek (2015) indicated that the STEM approach to the 5E learning cycle-5E model enhances critical thinking skills. Dass (2015) asserted that integrating STEM into the 5E learning cycle can assist students in identifying solutions to real-world problems by combining knowledge, processes, and practices.

The second research article is "Development of 21st Century Skill Orientation in Physics Learning through Spectra-Plus-Assisted PjBL-STEAM approach (*Pengembangan Orientasi Keterampilan Abad 21 Pada Pembelajaran Fisika melalui Pembelajaran PjBL-STEAM Berbantuan Spectra-Plus*)," conducted by Sri Lestari, was published in Teacher Ideas: Journal of Teachers' Scientific Works in 2021. Research conducted by Fatimah (2017) demonstrates that the application of the STEAM approach in learning using PjBL can foster the development of 21st-century skills, including critical thinking and problem-solving, creativity and innovation, communication and collaboration, information literacy, media literacy, technology literacy, flexibility, and adaptability.

The project-based learning (PjBL)-STEAM model is an educational approach that integrates project-based learning models with the science, technology, engineering, art, and mathematics (STEAM) disciplines. This model fosters students' acquisition of in-depth knowledge by encouraging active exploration of real-world challenges and problems. Each component of STEAM contributes to the development of students' creative thinking skills, drawing parallels with scientific creative thinking. The assessment rubric for evaluating scientific creative thinking is presented in Table 2.

Table 2. Rubric for scoring the assessment of scientific creative thinking skills

No.	Aspects	Assessment Guidelines
1.	Fluency (fluency)	The students' answers are summed up, with a score of 1.
2.	Flexibility	By aggregating the responses from students with diverse perspectives, a score of 1 is obtained.
3.	Originality	If a student's response aligns with 5% of the class's responses, a score of 3 is awarded. If 5% to 10% of the class's responses match the student's, a score of 2 is granted. In the absence of a response, a score of 0 is assigned.
4.	Fluency-Science Knowledge	If the student does not respond, they receive a score of 0. If the student can explain the design but lacks a connection to the concept, they receive a score of 1. If the student neither responds nor explains, they receive a score of 0.

To obtain a more comprehensive picture of the effectiveness of STEM/STEAM-based learning in the context of science education, particularly physics, researchers conducted a review of several relevant articles. This review focused on research findings related to the development of STEM/STEAM-based modules and teaching materials, as well as their contribution to improving 21st-century skills such as problem-solving, critical thinking, creativity, and students' soft skills. A summary of research findings from various sources can be seen in Table 3.

Table 3. Literature Review Summary

No.	Author Name (Year)	Title	Result
1.	Alfika et al. (2019)	Problem-Solving STEM Module with a Dome House Theme	STEM-based modules can improve problem-solving skills with an n-gain value of 0.29. This indicates a moderate increase in students' problem-solving skills after using STEM-based modules.
2.	Febriyanti et al. (2018)	The Effectiveness of the Module- based STEM (Science, Technology, Engineering, Mathematics) to Study Physics at Vocational High School	The effectiveness of STEM-based modules based on the N-gain test obtained a score of 0.63. These results indicate that STEM-based modules in physics learning are effective in improving student learning outcomes.
3.	Sakinah & Widodo (2019)	Effectiveness of STEAM-based Teaching Materials to Improve Students' Creative Thinking Skills	STEAM-based teaching materials improved students' creative thinking skills with an n-gain score of 0.31. STEAM-based teaching materials are suitable for use in learning and can enhance students' creative thinking skills.
4.	Widarwati et al. (2021)	STEAM (Science Technology Engineering Art Mathematic) Based Module for Building Student Soft Skill	The validity test results for the STEAM-based module obtained a score of 3.40, which is considered very feasible. Student responses to the STEAM-based module were very engaging and easy to understand. The n-gain test results for the STEAM-based module obtained a score of 0.64. Based on the results, the STEAM-based module is feasible, practical, and effective in improving students' soft skills.

The results of a literature review indicate that STEM- and STEAM-based learning modules are quite effective in improving student competency. Several studies report improvements in student abilities, demonstrated by moderate to high n-gain scores, ranging from 0.29 to 0.64. A STEM module with a dome house theme, for example, was shown to improve students' problem-solving skills with an n-gain of 0.29 (Alfika et al., 2019). Furthermore, the use of STEM-based modules in physics learning at a vocational school resulted in an n-gain score of 0.63, demonstrating their effectiveness in improving student learning outcomes (Febriyanti et al., 2018).

Furthermore, research on STEAM-based learning materials also demonstrates a positive contribution to higher-order thinking skills. Sakinah and Widodo (2019) reported that STEAM-based learning materials can improve students' creative thinking skills with an n-gain score of 0.31. Beyond cognitive aspects, STEAM modules also play a role in developing non-cognitive skills. Widarwati et al. (2021) revealed that the STEAM module was feasible and effective for use in learning, with a validity score of 3.40 (very feasible) and an n-gain of 0.64. This module not only improves learning outcomes but also helps develop students' soft skills, such as cooperation, communication, and social skills.

In general, findings from various studies consistently show that implementing STEM/STEAM-based modules can improve students' conceptual understanding, creative thinking skills, problem-solving abilities, and soft skills. However, most research still focuses on specific aspects, so further development of integrative modules that can accommodate various competencies simultaneously is needed. Further research is also needed to test the long-term sustainability of these modules' use to provide a more comprehensive picture of the effectiveness of STEM/STEAM-based learning.

The results of this study have several implications. In the realm of physics education, STEAM integration can be an effective means of enhancing students' creative thinking capacity, a crucial skill for addressing complex real-world problems. For teachers, these findings emphasize the importance of designing learning that not only instills scientific concepts but also involves creative activities that require collaboration, communication, and innovative thinking. Meanwhile, at the policy level, the results of this study provide recommendations for curriculum developers to incorporate the STEAM approach more structuredly, with an emphasis on developing creative thinking skills as part of the core competencies of the 21st century.

The Value of Novelty in Research

A literature review shows that the STEM/STEAM approach to physics learning offers innovation in various aspects, from improving problem-solving abilities, cognitive learning outcomes, creativity, to developing students' soft skills. The reviewed articles confirm that STEM/STEAM integration is not only effective in improving learning outcomes but also fosters higher-order thinking skills. This is validated through appropriate research instruments and supported by n-gain calculations. This demonstrates that STEM/STEAM is no longer merely a concept but has been developed into modules, e-modules, and project activities that are applicable in the classroom.

In line with these findings, physics learning using the STEAM approach, supported by Spectra-Plus, is a new innovation that can develop 21st-century skills in students. In this learning, teachers are expected to facilitate students' creativity and integrate concepts of science, technology, engineering, art, and mathematics comprehensively into the learning process. The implementation of activity-based STEAM can diversify the knowledge dimension in physics learning, and through the provision of projects, students can practice decision-making in finding solutions to problems. Thus, the STEAM approach not only develops conceptual skills but also encourages students to generate creative and innovative ideas in line with advances in science and technology. This confirms the research's novelty, positioning STEAM as a strategic tool for developing basic competencies and 21st-century skills, enabling students to be more adaptive in facing real-life problems.

CONCLUSION

Based on the literature reviewed, it can be concluded that the STEM-based 5E learning cycle model effectively develops essential 21st-century skills, particularly critical thinking, problem solving, collaboration, and communication. The integration of the STEAM approach, assisted by spectra-plus on sound wave material, encourages students to critically analyze problems, create products that foster new knowledge, and build stronger peer relationships through project-based learning. Most students show high interest and positive attitudes toward this learning model. However, the study has several limitations. As a literature review, the findings rely heavily on the quality and scope of the analyzed articles, with most studies originating from specific regions, thereby limiting generalizability. In addition, the absence of meta-analysis and effect size calculations weakens the strength of the evidence. Future research should include empirical classroom studies across various educational levels and cultural contexts to validate the effectiveness of STEAM in enhancing creative thinking skills in physics learning. Mixed-methods designs and longitudinal approaches are also recommended to provide a more comprehensive and sustainable evaluation of STEAM-based learning outcomes.

AUTHOR CONTRIBUTIONS

Ridwan Akbar Nur Rahman: Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, and Writing - Original Draft; **Imam Sucahyo:** Conceptualization, Validation, and Project Administration; **Mita**

Anggaryani: Validation, Writing - Review & Editing, and Supervision; and **Nina Fajriyah Citra:** Writing - Review & Editing. All authors have read and approved the final version of this manuscript.

DECLARATION OF COMPETING INTEREST

The authors state that no financial or personal conflicts of interest could affect the results reported in this manuscript.

DECLARATION OF ETHICS

The authors state that the research and writing of this manuscript have complied with research and publication ethical standards, in accordance with scientific principles, and are free from plagiarism.

STATEMENT OF USE OF ASSISTIVE TECHNOLOGIES IN THE WRITING PROCESS

The authors state that Generative *Artificial Intelligence* and other assistive technologies are not overused in the research and writing process of this manuscript. Specifically, *ChatGPT* is used for brainstorming ideas and refining text. The authors have reviewed and edited all AI-generated content to ensure accuracy, completeness, and compliance with ethical and scientific standards, and are fully responsible for the final version of the manuscript.

REFERENCES

Alfika, Z.A., Mayasari, T., & Kurniadi, E. (2019). Modul STEM berbasis pemecahan masalah dengan tema rumah dome. *JPF (Jurnal Pendidikan Fisika)*, **7**(1), 93–105. DOI: http://dx.doi.org/10.24127/jpf.v7i1.1566.

Annisa, R., Effendi, M.H., & Damris, M. (2019). Peningkatan kemampuan berpikir kreatif siswa dengan menggunakan model project based learning berbasis STEAM (science, technology, engineering, arts, dan mathematics) pada materi asam dan basa di SMAN 11 Kota Jambi. *Journal of the Indonesian Society of Integrated Chemistry*, **10**(2),14-22. DOI: https://doi.org/10.22437/jisic.v10i2.6517.

Ceylan, S. & Ozdilek, Z. (2015). Improving a sample lesson plan for secondary science courses within the STEM education. *Procedia - Social and Behavioral Sciences*, **177**, 223–228. DOI: https://doi.org/10.1016/j.sbspro.2015.02.395.

Colucci-Gray, L., et al. (2017). *Reviewing the potential and challenges of developing STEAM education through creative pedagogies for 21st learning: How can school curricula be broadened towards a more responsive, dynamic, and inclusive form of education?* London: British Educational Research Association. Retrieved from: https://www.bera.ac.uk/project/bera-research-commissions/reviewing-the-potential-and-challenges-of-developing-steam-education-2.

Depdiknas (2004). *Kerangka Dasar Kurikulum 2004*. Jakarta: Pusat Kurikulum.

Ejiwale, J. (2013). Barriers to successful implementation of STEM education. *Journal of Education and Learning*, **7**(2), 63-74. DOI: https://doi.org/10.11591/edulearn.v7i2.220.

Fatimah, C. (2017). *Penerapan pendekatan STEAM (science, technology, engineering, arts, and mathematics) dalam upaya mengembangjan keterampilan abad 21 menggunakan Project Based Learning*. Skripsi. Jakarta: UIN Jakarta. Retrieved from: http://repository.unj.ac.id/id/eprint/25275.

Febriyanti, E., Indrawati, Supeno, Sutarto, & Mahardika, I.K. (2018). The effectiveness of the module-based STEM (science, technology, engineering, mathematics) to study physics at vocational high school. *International Journal of Advanced Research*, **6**(5), 1367–1370. DOI: https://doi.org/10.21474/ijar01/7168.

Habsy, et al. (2023). Filsafat dasar dalam konseling psikoanalisis: Studi literatur. *Indonesian Journal of Educational Counseling*, **7**(2), 189-199. DOI: https://doi.org/10.30653/001.202371.227.

Idin, S. (2018). An overview of STEM education and industry 4.0. In M. Shelley & S.A. Kiray (Ed). *Research Highlights in STEM Education* (pp. 194-208). Turkey: ISRES Publishing. Retrieved from: https://www.isres.org/an-overview-of-stem-education-and-industry-40-110-s.html.

Kaniawati, D.S. & Suryadi. (2016). Pengembangan Kreativitas Siswa SMA Dalam Membuat Remodeling Produk Teknologi Sederhana Melalui Implementasi Pembelajaran Learning Cycle 6E dengan Pendekatan STEM. *Simposium Nasional Inovasi dan Pembelajaran Sains (SNIPS 2016)*, 92. Rerieved from: https://ifory.id/abstract/92PLAbtjUNyn.

Latifa, B.R.A., Verawati, N.N.S.P., & Harjono, A. (2017). Pengaruh model learning cycle 5E (Engage, Explore, Explain, Elaboration, & Evaluate) terhadap kemampuan berpikir kritis peserta didik kelas X

MAN 1 Mataram. *Jurnal Pendidikan Fisika dan Teknologi*, **3**(1), 61–67. DOI: https://doi.org/10.29303/jpft.v3i1.325.

Lestari, S. (2021). Spectra-Plus Assisted STEAM Approach 21st Century Skills Orientation in Learning Physics. *Ideguru: Jurnal Karya Ilmiah Guru*, **6**(3), 272-279. DOI: https://doi.org/10.51169/ideguru.v6i3.243.

Liao, Y.W., Huang, Y.M., & Wang, Y.S. (2015). Factors affecting students' continued usage intention toward business simulation games: An empirical study. *Journal of Educational Computing Research*, **53**(2), 260–283. DOI: https://doi.org/10.1177/0735633115598751.

Marzali, A. (2017). Menulis kajian literatur. *ETNOSIA: Jurnal Etnografi Indonesia*, **1**(2), 27-36. DOI: https://doi.org/10.31947/etnosia.v1i2.1613.

Novianti, et al. (2014). Pengaruh model pembelajaran learning cycle terhadap keterampilan berpikir kritis peserta didik. *EDUSAINS*, **6**(1), 111–116. Retrieved from: https://repository.uinjkt.ac.id/dspace/handle/123456789/31212.

Nuha, et al. (2018). Online social networking threats. In: Alhajj, R., Rokne, J. (eds) *Encyclopedia of Social Network Analysis and Mining*. New York: Springer. DOI: https://doi.org/10.1007/978-1-4939-7131-2_100808.

Perignat, E. & Katz-Buonincontro, J. (2018). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity,* **31**, 31-43. DOI: https://doi.org/10.1016/j.tsc.2018.10.002.

Pusfarini, Abdurrahman, & Jalmo, T. (2016). Efektivitas LKPD sains berorientasi model pembelajaran berbasis masalah dalam menumbuhkan kecakapan berpikir kreatif. *Jurnal Pendidikan Progresif*, **6**(1), 86-96. DOI: https://doi.org/10.23960/jpp.v6.i1.201601.

Rahayuni, G. (2016). Hubungan keterampilan berpikir kritis dan literasi sains pada pembelajaran IPA terpadu dengan model PBM dan STM. *Jurnal penelitian dan pembelajaran IPA*, **2**(2), 131–146. DOI: https://dx.doi.org/10.30870/jppi.v2i2.926.

Rahayuningsih, R., Masykuri, M., & Utami, B. (2012). Penerapan siklus belajar 5E (learning cycle 5E) disertai peta konsep untuk meningkatkan kualitas proses dan hasil belajar kimia pada materi kelarutan dan hasil kali kelarutan kelas XI IPA SMA Negeri 1 Kartasura tahun pelajaran 2011/2012. *Jurnal Pendidikan Kimia*, **1**(1), 51–58.

Rosicka, C. (2016). *From concept to classroom translating STEM education research into practice*. Camberwell: Australian Council for Education Research.

Safaria, S.A. & Sangila, M.S. (2018). Kemampuan berpikir kreatif matematis siswa SMP Negeri 9 Kendari pada materi bangun datar. *Jurnal Al-Ta'dib*, **11**(2), 73-90. Retrieved from: https://ejournal.iainkendari.ac.id/index.php/al-tadib/article/view/986.

Sakinah, K. & Widodo, W. (2019). Efectiveness of STEAM-based teaching materials to improve students' creative thinking skills. *PENSA E-Jurnal: Pendidikan Sains*, **7**(3), 338–342. Retrieved from: https://ejournal.unesa.ac.id/index.php/pensa/article/view/32290/29216.

Torrance, E.P. (1974). *Norm-technical manual torrance test of creative thinking, verbal test, form a and b. figural test, form A and B*. Lexing ton, Massachusetts: Personal Press Inc.

Trilling, B. and Fadel, C. (2009). *21st century skills: Learning for life in our times*. Hoboken: John Wiley & Sons.

Widarwati, D., Utaminingsih, S., & Murtono. (2021). STEAM (science technology egineering art mathematic) based module for building student soft skill. *Journal of Physics: Conference Series*, **1823**, 012106. DOI: https://doi.org/10.1088/1742-6596/1823/1/012106.