e-ISSN 3090-5354
Vol.1, No.2, August 2025
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Literature Review: Effectiveness of Applying the STEAM Method in Training Students' Creative Thinking in High School Physics Learning

Khofifatur Risma Faradillah[1], Cahyo Febri Wijaksono[2]
[1]State University of Surabaya, Surabaya, Indonesia
[2]Universität für Weiterbildung Krems, Krems an der Donau, Austria

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DOI : https://doi.org/10.26740/jdpe.1.239005

Sections Info

Article history:
Submitted: February 22, 2025
Final Revised: June 21, 2025
Accepted: June 21, 2025
Published: July 12, 2025

Keywords:
Creative Thinking;
Effectiveness;
Methode;
Physics Learning;
STEAM.

ABSTRACT

Objective: *This research aims to determine the effectiveness of the STEAM (Science, Technology, Engineering, Art, and Mathematics) approach in enhancing high school students' creative thinking skills within the context of physics learning. The study addresses the need for innovative learning strategies to foster creativity, problem-solving, and interdisciplinary integration in science education.* ***Method:*** *The study employed a systematic literature review method. A total of 20 articles published between 2019 and 2024 were selected from national and international journals indexed in Sinta, Scopus, and DOAJ. The selected articles met the criteria of being relevant to STEAM implementation in high school physics learning and its effect on students' creative thinking skills. The data were analyzed through thematic synthesis to identify patterns, outcomes, and pedagogical strategies.* ***Results:*** *The findings indicate that implementing STEAM in physics education significantly enhances students' creativity. The reviewed studies show that STEAM facilitates active involvement in design, innovation, and interdisciplinary problem-solving. Students demonstrate increased creative thinking, especially in formulating ideas, constructing models, and exploring solutions collaboratively.* ***Novelty:*** *This study synthesizes recent empirical evidence on the effectiveness of STEAM in physics learning, highlighting its role in promoting creativity. The review emphasizes STEAM's potential as an effective pedagogical alternative to traditional physics instruction, particularly in nurturing 21st-century skills in secondary education.*

INTRODUCTION

Physics is a scientific discipline that studies and supports the development of technology, which is an important foundation in modern life. In addition, physics also serves as a link between various fields of knowledge, both from a practical and analytical perspective (Sulman et al., 2022). One important aspect of physics lessons at the secondary level is students' ability to think creatively. Creativity is essential for overcoming challenges in solving complex problems that arise during physics learning (Rosha et al., 2023). The ability to think creatively is essential for students to solve problems and make decisions in various aspects of life, particularly when faced with multiple choices (Sumarni & Kadarwati, 2020). Creative thinking enables systematic problem-solving, formulates innovative questions, and yields a variety of original solutions (Rohman et al., 2021). Previous research has emphasized the importance of developing creative thinking abilities in students, particularly in light of the current demands (Amelia et al., 2021). It is hoped that students will be able to analyze and solve problems by contributing creative ideas as solutions to everyday challenges. Due to the importance of this creative thinking ability, several studies have been conducted to investigate the impact of implementing specific learning models and methods. This is

done to observe improvements in the quality of learning with the hope that students' creative thinking abilities will also improve as a result.

Currently, many students in Indonesia still lack critical, creative thinking, and scientific processing abilities (Syukri et al., 2023). To enrich creative thinking abilities, it is necessary to fulfill four main aspects: Fluency, Flexibility, Originality, and Elaboration (Layyina et al., 2021). However, many teachers still have not fully developed their students' creative thinking skills (Mulder et al., 2023). This has an impact on students' ability to convey ideas and create new expressions. This obstacle is also influenced by learning activities in the classroom, which are related to the use of media, methods, models, and approaches employed in the learning process.

Previous research suggests that students' creative abilities can be hindered by a lack of active engagement in learning. This phenomenon arises from the use of learning methods that are still teacher-dictated, resulting in students' low self-confidence and interest in physics lessons (Ridha et al., 2022). A student's lack of creativity is evident when they complete assignments or questions given during the learning process. Students often struggle to answer physics questions that assess their level of creativity. Misunderstanding of concepts is one of the main factors hindering increased creativity. If students have a strong understanding of concepts, it will be easier for them to generate new ideas and improve their creative abilities (Marwani & Sani, 2020).

To overcome these challenges, one solution that can be implemented is the use of effective learning methods that stimulate creative thinking abilities (Fitriyah & Ramadani, 2021). One approach that can be used is to apply the STEAM (Science, Technology, Engineering, Art, and Mathematics) learning model. The STEAM approach is a concept that combines various scientific disciplines, which developed from the STEM approach by incorporating elements of art into the learning process. In this approach, the "A" element of STEAM refers to the creativity generated during learning, where art is an integral part of the process. The addition of this art aims to train students in terms of expression, communication, creativity, imagination, observation, perception, and thinking, all of which aim to improve students' cognitive abilities (Sakdiah et al., 2022). STEAM learning aims to develop student independence in enhancing the scientific abilities of the younger generation and also emphasizes the importance of the value of art and creativity as essential aspects of the learning process (Aguilera & Ortiz-Revilla, 2021). Learning with a STEAM approach can motivate students to explore their unique potential and talents. Apart from that, the STEAM approach is also capable of producing diverse and unexpected works from each individual or group (Lestari, 2021). The STEAM approach can be applied by utilizing constructivist learning models, such as Problem-Based Learning, Inquiry-Based Learning, Cooperative Learning, and Project-Based Learning (Baran et al., 2021).

Studies on the effectiveness of the STEAM method in developing students' creative thinking skills in physics learning are important and interesting for further investigation. Therefore, this research was conducted to investigate the effectiveness of

applying the STEAM method in developing students' creative thinking skills in physics learning at the high school level, as well as identifying effective strategies or techniques for implementing the STEAM method to enhance creative thinking skills in high school physics learning.

RESEARCH METHOD

This study is a literature review that examines research results from various articles related to the effectiveness of applying the STEAM method in enhancing students' creative thinking in high school physics learning. The method employed is a literature review, which aims to identify, review, evaluate, and interpret all relevant research on a particular phenomenon, focusing on a specific research question (Triandini et al., 2019). The articles included in this literature review were chosen because they are relevant to high school physics learning using the STEAM method and increasing students' creative thinking abilities. The articles reviewed were sourced from various journals, both national and international, through Sinta, Scopus, and DOAJ and were published between 2019 and 2024. The number of articles reviewed is limited to 20. The steps taken in this research include: 1) Collecting information regarding the effectiveness of applying the STEAM method in developing students' creative thinking abilities in high school physics lessons from various journals; 2) Evaluate all collected data according to the researcher's point of view; and 3) Summarize the conclusions from the literature analysis that has been carried out.

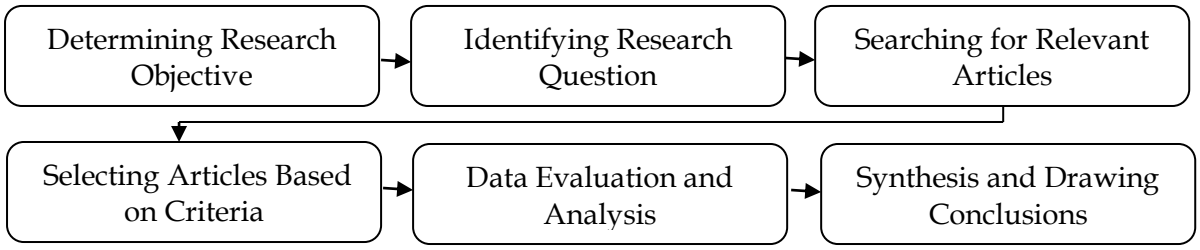

Figure 1. Research flow chart

RESULTS AND DISCUSSION

Results

Analysis of 20 articles explaining the effectiveness of applying the STEAM method in training students' creative thinking in high school physics learning is shown in Table 1.

Table 1. Literature Search Synthesis Analysis

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
1	Agnesi Sekarsari Putri, Zuhdan Kun Prasetyo, Lusila Andriani Purwastuti, Anti	International Journal of Evaluation and Research in Education (2023,	Effectiveness of STEAM-based blended learning on students' critical and	The research results show that blended STEAM learning can improve students' critical and creative thinking skills in all indicators in the medium to

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
	Kolonial Prodjosantoso, Himawan Putranta	Vol. 12, No. 1, 44-52)	creative thinking skills	high category. The increase in students' critical and creative thinking skills in the experimental class was higher than in the control class. Apart from that, there are differences in learning outcomes between the control class and the experimental class. The author explains that blended STEAM learning can be an alternative for teachers to solve the problem of students' low critical and creative thinking skills. The results of this research show that STEAM-based blended learning can be an effective strategy in improving students' critical and creative thinking skills, and can help teachers improve the quality of education.
2	D. N. Ahmad, M. M. Astriani, M.Alfahnu, L.Setyowati	Jurnal Pendidikan IPA Indonesia (2021, Vol 10, No. 1, 103-110)	Increasing creative thinking of students by learning organization with steam education	The results of this journal research show that the STEAM method has a positive impact on students' creative thinking abilities. In this research, 27 5th semester students at Indraprasta University PGRI were given a STEAM-based project assignment which involved learning activities consisting of four stages: preparation, idea development, discussion and presentation. The research results showed that students experienced an increase in the average score of 2.26 from 78.26 before using the STEAM method to 80.52 after using the STEAM method. Data analysis also shows that students experience changes in the creative thinking process, with a significant increase in creative thinking abilities

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
				before and after being given lessons using the STEAM method. The results of this research indicate that STEAM can improve students' creative thinking abilities by providing hands-on experience through the project work process. This positive impact can help students develop the creative thinking skills needed to face global challenges.
3	Alexey A Chistyakov, Sergei P Zhdanov, Elena L Aydeeva, Elena A Dyadichenko, Maria L Kunytsina, Roza I Yagudina	Eurasia Journal Of Mathematics, Science and Technology Education (2023, Vol. 19, No. 5)	Exploring Characteristic And Effectiveness of Project based learning For Science and STEAM education	The main content of the journal is "Exploring the Characteristics and Effectiveness of Project-Based Learning for Science and STEAM Education". This journal discusses the use of a project-based learning approach (PjBL) in natural science (IPA) and technology, science, engineering, art and mathematics (STEAM) education. The author, Alexey A. Chistyakov and team, conducted a literature review of 36 articles related to PjBL in science and STEAM. The results show that PjBL can improve student learning outcomes, improve critical thinking skills, and increase student participation in the learning process. This journal also provides several recommendations for increasing the effectiveness of PjBL in science and STEAM education.
4	Wasito Utomo, Wiwid Suryono, Jimmi, Tomi Apra Santosa, Ika Agustina	Jurnal Penelitian Pendidikan IPA (2023, Vol 9, Issues 9, 742-750)	Effect of STEAM-Based Hybrid Based Learning Model on Students' Critical Thinking Skills	This study focuses on a meta-analysis that explores the effects of a hybrid-based STEAM learning model on students' critical thinking abilities. This research aims to find out how much influence the hybrid-based STEAM learning model has on

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				students' critical thinking abilities. The author emphasizes the importance of critical thinking skills in the 21st century, citing various studies that highlight the need for students to develop critical thinking skills to be successful in their academic and professional careers. They also reminded that the current education system often fails to integrate critical thinking effectively, so students' critical thinking abilities tend to be low. This research aims to overcome this problem by exploring the effects of a hybrid-based STEAM learning model on students' critical thinking abilities. Analysis of the selected studies showed a strong mean effect size or summary effect size ($p < 0.01$; ES = 1.052). These findings explain that the hybrid-based learning model has a significant effect on students' critical thinking abilities. The hybrid-based STEAM learning model has a greater effect on students' critical thinking abilities compared to conventional learning models.
5	Gulbin Ozkan	Research in Science & Technological Education (2021, Vol 39, Issues 4, 441-460)	Investigating the effectiveness of STEAM education on students'	The research results show that STEAM education has a positive effect on students' conceptual understanding and reduces or changes the number of conceptual errors. The conceptual understanding scores of research group students after treatment were higher than the scores of control group students. Interviews with students show that STEAM education supports a student-centered

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
				learning environment, thereby enriching students' understanding of concepts.
6	R E Anggraeni Suratno	Journal of Physics: Conference Series (2021, Conf. Ser. 1832 012050)	The analysis of the development of the 5E-STEAM learning model to improve critical thinking skills in natural science lesson	The results of this research show that the 5E-STEAM learning model can improve students' critical thinking skills in natural science subjects. This model was developed using a 4D development model which consists of four stages: define, design, develop, and disseminate. In this research, it was found that only 10% of teachers used the STEAM approach in the learning process, while 70% of teachers did not know about the 5E learning cycle. The research results also show that teachers must have the ability to develop critical thinking skills in students through the STEAM approach. In the 5E-STEAM model, the stages used are Engagement, Exploration, Explanation, Elaboration, and Evaluation. The Engagement stage involves students in activities that are relevant to everyday life, Exploration allows students to find their own answers, Explanation allows students to explain concepts, Elaboration allows students to collaborate, and Evaluation allows teachers to provide feedback and find out students' abilities.
7	Kurnia Santi	Journal of Physics: Conference Series (2021, Conf. Ser. 1796 012097)	STEAM in environment and science education: Analysis and bibliometric mapping of the research	The main results of the study "STEAM in Environment and Science Education: Analysis and Bibliometric Mapping of the Research Literature (2013-2020)" are: STEAM research has developed significantly

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
			literature (2013-2020)	in recent years, with an increase in the number of publications and linkages between researchers, Korea The South showed the highest engagement in STEAM research, with 11 publications published. Raden Intan Lampung State Islamic University and Jakarta State University show the highest correlation in STEAM research. 91% of the researchers in this study had only one publication, while 8% had two publications and 1% had three publications. The topics of STEAM education, STEAM, engineering education, computing education, and students are the topics most frequently studied in STEAM research. This research shows that STEAM has become a very important research topic in science and environmental education, with the potential to increase linkages between researchers and improve the quality of science and environmental education.
8	Erica Andreotti Renaat Frans	Journal of Physics: Conference Series (2021, Conf. Ser. 1832 012050)	The Connection Between Physics, Engineering and Music as an Example of STEAM Education	This research discusses the development of STEAM (Science, Technology, Engineering, Arts, and Mathematics) pedagogy which was developed in the European project iMuSciCA. This research shows that by using the STEAM approach, students can understand physics concepts deeper and more relevant to everyday life. day. In this research, STEAM pedagogy is applied through learning scenarios that allow students to move

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
				between these disciplines. For example, the "Design & Play a Guitar in Your Own Tuning" scenario allows students to design and play a guitar in their own tuning. In this process, students must understand the physics concepts of string frequencies and parameters, as well as their application in guitar design and engineering. The results of this research show that the STEAM approach can improve students' understanding of physics and increase their motivation to study physics. STEAM pedagogy also helps students develop 21st century skills such as collaboration, creativity, and problem solving. Thus, STEAM pedagogy can be an effective alternative in improving the quality of STEAM education.
9	Tasta Witdiya, Gito Supriadi, Atin Supriatin, Jhelang Annovasho	Jurnal Ilmiah Pendidikan Fisika (2023, Vol 39, Issues 4, 441-460)	The Effect of STEAM Learning on Improving Each Indicator of Students' Creative Thinking in Physics Learning	This research was conducted at SMA Negeri 1 Mentaya Hilir Utara in the 2022-2023 academic year. The research population was students of class XI IPA, with class XI IPA I as the experimental class and class XI IPA II as the control class. Research data was collected using the creative thinking test and analyzed using the Wilcoxon test, Mann-Whitney test and N-gain test. The research results show that STEAM learning has a very positive effect on students' creative thinking abilities. The indicator that increased the most was elaboration, while the originality indicator increased the lowest. This research found that STEAM (Science,

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				Technology, Engineering, Arts and Mathematics) learning can improve students' creative thinking abilities in learning physics. The research results show that STEAM learning has a very positive effect on students' creative thinking abilities. The indicator that increased the most was elaboration, while the indicator of originality increased the lowest. The results of this research show that STEAM learning can be used as an innovation in physics learning in schools to improve students' creative thinking abilities.
10	Khadijah Sakina, Wahono Widodo	Pensa E-Jurnal:Pendidikan Sains(2021, Vol 7 No 3, 338-342)	Efectiveness Of STEAM-Based Teaching Materials To Improve Students' Creative Thinking Skills	The results of this research show that STEAM (Science, Technology, Engineering, Art, Mathematics) based teaching materials are effective in improving students' creative thinking abilities. The results of this research were that 75% of students improved their creative thinking skills in the medium category, and 25% of students in the low category based on the N-Gain score. There was an increase in each indicator of creative thinking ability based on the N-Gain score, namely 0.24 on the originality indicator, 0.30 on the flexibility indicator, and 0.42 on the fluency indicator. According to the author in his synthesis, this research shows that STEAM teaching materials can improve students' creative thinking abilities, as well as contribute to the development of critical thinking skills and problem solutions needed in the global era.

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
11	Sh. Ramankulov, A.Choruh, S. Polatuly	Iasaui Universitetinin Habarshysy (2022, Vol 4, Issues 4, 126-135)	Технология STEAM как средство развития креативности обучающихся: на примере школьного курса физики" (STEAM Technology as a Tool for Developing Creativity of Students: On the Example of a School Physics Course)	The results of this research show that STEAM technology can be used as a tool to develop student creativity, especially in the example of physics courses at school. This research also found that a lack of knowledge in academic literature in the STEAM field, as well as a lack of demonstration space and equipment in schools, can be barriers to developing students' abilities in physics. The results of this research also show that STEAM can be used to increase the number of students who are creative and can work on various projects that produce new ideas. Thus, STEAM can be used as a tool to improve students' abilities in physics and develop their ability to work with more advanced technology.
12	Deden Dicky Dermawan, Kinanti Andartiani	Hipotenusa : Journal of Mathematical Society(2022, Volume 4 Issue 1)	Worksheets Electronic Development of STEAM-Based to Improve Students' Creative Thinking Ability	The results of this research indicate that the development of STEAM-based E-LKPD can improve students' creative thinking abilities. The research results show that the E-LKPD developed has high validity, effectiveness and practicality. The research results also show that E-LKPD can improve students' creative thinking abilities in the aspects of speed, flexibility, origin and explanation. Apart from that, the research results also show that E-LKPD can improve students' creative thinking abilities with an N-Gain score reaching 0.61 with moderate criteria. The results of this research indicate that the development of STEAM-based E-LKPD can be an

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
				effective alternative in improving students' creative thinking abilities.
13	Sayrung Tongsoong, Rossarin Jermtaisong	Advances in Social Science, Education and Humanities Research, volume 520, 2021	Learning Management Through the Combination of STEAM Education and Phenomenon-Based Learning to Develop Creative Thinking of Secondary 6 (Grade 12) Students	This research found that learning management combined with STEAM education and phenomenon-based learning can improve students' creative thinking abilities. The results showed that students who learned through STEAM and phenomenon-based learning management had higher creative thinking scores compared to students who learned through traditional learning management. In addition, research also finds that STEAM and phenomenon-based learning management can improve students' abilities in critical thinking and collaboration. The results of this research show that the STEAM and phenomenon-based approach can be an effective strategy in improving students' abilities in creative thinking and critical thinking, as well as improving cooperation and communication skills.
14	Wee-Ling Tan, Mohd Ali Samsudin,Mohd Erfy Ismail, Nur Jahan Ahmad, Corrienna Abdul Talib	EURASIA Journal of Mathematics, Science and Technology Education, 2021, 17(12)	Exploring the Effectiveness of STEAM Integrated Approach via Scratch on Computational Thinking	This research found that the STEAM (Science, Technology, Engineering, Art, Mathematics) approach integrated through Scratch was effective in improving computational thinking skills among male and female students. The research results show that male and female students have the same computational thinking abilities after following this STEAM approach. Apart from that, this research also found that the STEAM approach can

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
				improve students' abilities in critical, creative and cooperative thinking, as well as increase their ability to solve problems. The results of this research have practical implications for the design of learning tasks that are more interactive and effective in improving students' computational thinking abilities.
15	Zayyinah Zayyinah, Erman Erman, Zainul A. I. Supardi, Eko Hariyono, Binar K. Prahani	Advances in Social Science, Education and Humanities Research, volume 627(2022)	Proceedings of the Eighth Southeast Asia Design Research (SEA-DR) & the Second Science, Technology, Education, Arts, Culture, and Humanity (STEACH) International Conference (SEADR-STEACH 2021)	The results of this research show that the STEAM-integrated project-based learning model can improve students' abilities in 21st-century skills, such as the ability to think critically, think creatively, communicate and work together. The research results also show that STEAM-PjBL can improve students' abilities to think independently, discover, create and observe. Apart from that, STEAM-PjBL can also improve students' abilities to think scientifically and improve critical and creative thinking skills. In several studies, STEAM-PjBL is also associated with increasing students' ability to think systematically and improving their ability to think analytically. The results of this research indicate that STEAM-PjBL can be an effective alternative in improving students' abilities in 21st-century skills.
16	Olga Shatunova, Tatyana Anisimova, Fairuza Sabirova, Olga Kalimullina	Journal of Social Studies Education Research Volume 10, Number 2, Jun 24, 2019	STEAM as an Innovative Educational Technology	This research discusses the implementation of STEAM (Science, Technology, Engineering, Arts, and Mathematics) in education, with a focus on developing students' abilities and

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				competencies to meet the needs of industry 4.0. This research shows that the use of creative spaces for student and student project activities allows them to develop the skills and competencies required in the digital industry. The results of this research also show that STEAM education can help increase students' interest in science and improve their ability to think critically and creatively. Apart from that, this research also shows that STEAM education can help students develop teamwork skills and effective communication skills.
17	Nur Khoiri, Fenny Roshayanti, Rezki Widarti	Journal of Education and e-Learning Research Vol. 10, No. 3, 578-584, 2023	Integration of STEAM and ESD: Improving the understanding of fluid concepts and creativity	The research results obtained from this research show that the STEAM model integrated with ESD is very valid, has good practicality, and is effective in increasing understanding of fluid dynamics concepts. The results of this research also show that the STEAM model integrated with ESD can increase student creativity and their learning outcomes. Apart from that, the results of this research also show that the STEAM model integrated with ESD can improve students' abilities in critical thinking and increase their awareness of environmental issues. In synthesis, the results of this research indicate that the STEAM model integrated with ESD can be an effective alternative in improving the quality of education and increasing students' awareness of the importance of the environment.

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
18	Rezki Widarti, Fenny Roshayanti	Unnes Physics Education Journal (Vol. 10, No. 3, 290-295, 2021)	Potensi Implementasi STEAM (Science, Technology, Engineering, Art and Mathematic) berorientasi ESD (Education for Sustainable Development) dalam Pembelajaran Fluida	The potential implementation of ESD-oriented STEAM in Fluid learning has been carried out by teachers at Madrasah Aliah Demak Regency, although it has not been stated in the learning plan. The learning process is carried out using a project based learning (PBL) learning model which allows students to learn not only theory, but also through practice that produces products. Teachers have implemented STEAM in fluid learning, with 52% of teachers who have implemented STEAM in fluid learning and stating that the implementation of STEAM in fluid learning is able to overcome the problem of students' learning difficulties. Based on the results of the questionnaire, 90% of teachers are familiar with the STEAM learning approach, and 62 % of teachers are familiar with the potential of ESD. In addition, 86% of teachers have linked fluid material with environmental issues, and 95% of teachers have used waste as practical material in fluid learning. Fluid learning is carried out using the PBL model, which allows students to link science activities with technology, engineering, art., and mathematics.
19	Hobri, S Adeliyanti, M Fatekurrahman, H T Wijaya, E Oktavianingtyas, I W S Putri, Z R Ridlo	Journal of Physics: Conference Series, Conf. Ser. 1839 012036, Vol. 1839, No. 1, 2021	E-Comic mathematics based on STEAM-CC and its effect on students creative thinking ability	The results of this research show that the development of a mathematics e-comic based on STEAM-CC (Science, Technology, Engineering, Arts, and Mathematics - Caring Community) is effective in improving students' creative thinking

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
				abilities. The research results also show that e-comic media can influence students' creative thinking abilities. In this study, the test results showed that students who used STEAM-CC e-comics had higher scores compared to students who did not use this media. Apart from that, the results of interviews with students also showed that they did not experience difficulties in using e-comic media. The results of this research indicate that the development of the STEAM-CC e-comic can be an effective alternative in improving students' creative thinking abilities, especially in mathematics subjects.
20	Lintang Rizkyta Ananda, Yuli Rahmawati, dan Fauzan Khairi.	Journal of Technology and Science Education JOTSE, 2023 – 13(1): 352-367	Critical Thinking Skills of Chemistry Students by Integrating Design Thinking with STEAM-PjBL	The main result of this research is that the integration of Design Thinking with STEAM-PjBL can improve students' critical thinking skills in learning chemistry related to everyday problems. Critical thinking skills are developed through the Design Thinking stages which are integrated with STEAM-PjBL, including the Empathize, Define, Ideate, Prototype and Test stages. Online learning is carried out by involving students in problem solving activities. Based on analysis of observation data, reflective journals, researchers' notes, and interviews with students, students' critical thinking abilities were found to have developed and reached three categories, namely Information Search

No.	Author's Name	Journal Name (Year, Vol., No., Page)	Article Tittle	Result
				(Advanced level in the aspects of Investigation Presentation, Comprehension, Information Gathering, and Source Evaluation), Interpretation Creative and Thinking (Advanced level in the Organizational aspect and Proficient in the Meaning Making aspect), and Reflection and Self-Regulation (Advanced level in the Reflection, Planning and Mindset aspects). The results of this research show that Design Thinking can help students apply oxidation-reduction chemistry concepts to everyday problems, such as pollution of the Ciujung River due to detergent waste.

Discussion

Based on the results of the analysis of 20 articles related to the title "Effectiveness of Applying the STEAM Method in Training Students' Creative Thinking in High School Physics Learning," the research results show that the STEAM (Science, Technology, Engineering, Arts, and Mathematics) method has a significant effect in improving abilities students' creative thinking in learning physics in high school. Various studies have shown that STEAM can enhance students' critical and creative thinking skills by providing hands-on experience through the project-based learning process. Additionally, it can enhance students' creative thinking abilities by offering hands-on experience through project work.

The application of blended learning-based STEAM education can also enhance students' critical and creative thinking skills across all indicators, categorized as medium to high. STEAM-based blended learning can be an effective strategy for improving students' critical and creative thinking skills, and it can help teachers enhance the quality of education. Factors that influence the success of STEAM-based combined learning in improving students' critical and creative thinking abilities include the use of technology, student involvement in the learning process, the use of interactive teaching materials, the application of inquiry learning methods, and the provision of rewards to students who demonstrate critical and creative thinking abilities.

The STEAM method can enhance students' creative thinking abilities through the use of STEAM-based project assignments, which involve learning activities comprising four

stages: preparation, idea development, discussion, and presentation. Students experience changes in their creative thinking process, with a significant increase in creative thinking abilities both before and after receiving lessons using the STEAM method. STEAM can improve students' creative thinking abilities by providing hands-on experience through the project work process. This positive impact can help students develop the creative thinking skills needed to face global challenges.

The project-based learning (PjBL) approach can also help students develop problem-solving skills, critical thinking skills, and creative thinking skills in science and STEAM education. PjBL can enhance student learning outcomes, foster critical thinking skills, and increase student engagement in the learning process. PjBL can also help students develop problem-solving, critical thinking, and creative thinking skills. Apart from that, PjBL can increase students' awareness of the importance of natural science and technology in everyday life. Recommendations to increase the effectiveness of PjBL in science and STEAM education include increasing student participation in the learning process through PjBL, Enhancing students' critical thinking and problem-solving skills through PjBL, and Increasing student awareness of the importance of natural science and technology in everyday life via PjBL.

These studies also demonstrate that STEAM can enhance student learning outcomes, foster critical thinking skills, and increase student engagement in the learning process. In several studies, STEAM has been found to have a greater impact on students' critical thinking abilities compared to conventional learning models. In addition, STEAM was also found to enhance students' creative thinking abilities by providing hands-on experiences through the project work process.

CONCLUSION

Fundamental Finding: This study confirms that the STEAM (Science, Technology, Engineering, Art, and Mathematics) approach holds significant potential in enhancing high school students' creative thinking abilities in physics learning. The integration of STEAM into the learning process enables students to think critically and creatively, participate more actively, and engage in interdisciplinary problem-solving. It offers an effective pedagogical alternative to traditional methods, fostering a more profound understanding and innovation in science education. **Implication:** The findings suggest that educators and curriculum developers should consider adopting STEAM-based learning, particularly those that integrate hybrid models and Project-Based Learning (PjBL) to improve both student engagement and learning outcomes. Implementing STEAM in physics education can better equip students with the competencies needed to face the demands of the 21st century, such as adaptability, innovation, and global awareness. **Limitation:** This study is limited by its reliance on secondary data through literature review, which may not fully capture the contextual nuances of STEAM implementation in different classroom settings. The number of articles reviewed was also limited to 20, which might not represent the entire scope of available research on this topic. **Future Research:** Further studies are encouraged to conduct empirical research involving classroom implementation of STEAM-based physics learning. Comparative studies that explore the effectiveness of different STEAM models, as well as research focusing on specific aspects such as assessment methods or student attitudes, could provide more comprehensive insights into maximizing STEAM's impact in educational settings.

ACKNOWLEDGEMENTS

The author would like to thank all parties who have provided support in preparing this article entitled "Literature Review: Effectiveness of Applying the STEAM Method in Training Student's Creative Thinking in High School Physics Learning." Thank you to the teachers and colleagues who have shared knowledge and insight, as well as to family and friends who always provide moral encouragement. The author would also like to express his thanks to the educational institutions that have provided facilities and support during this research process. The author is open to constructive input, criticism, and suggestions that benefit the common good and promote the progress of humanity. The author would also like to apologize for any grammatical or presentation imperfections in this research. Hopefully, this article can make a positive contribution to the world of education, especially in efforts to increase students' creative thinking through the STEAM method.

AUTHOR CONTRIBUTIONS

Khofifatur Risma Faradillah: Conceptualization, Methodology, Investigation, Formal Analysis, Writing – Original Draft, Visualization; **Cahyo Febri Wijaksono**: Supervision, Validation, Writing – Review & Editing, Project Administration. All authors have read and approved the final version of this manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare no known financial conflicts of interest or personal relationships that could have influenced the work reported in this manuscript.

DECLARATION OF ETHICS

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

DECLARATION OF ASSISTIVE TECHNOLOGIES IN THE WRITING PROCESS

The authors declare that generative artificial intelligence (Gen AI) and other AI-assisted tools were used prudently, not excessively, during the research and preparation of this manuscript. Specifically, ChatGPT was used for brainstorming ideas, structuring paragraphs, and refining academic language; Grammarly for grammar and style correction; and ChatPDF for extracting key points and summarizing reference articles. All AI-generated material was reviewed and edited for accuracy, completeness, and compliance with ethical and scholarly standards. The authors accept full responsibility for the final content of the manuscript.

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Khofifatur Risma Faradillah
State University of Surabaya
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: khofifatur.22045@mhs.unesa.ac.id

Cahyo Febri Wijaksono
Universität für Weiterbildung Krems
Dr.-Karl-Dorrek-Straße 30, 3500 Krems an der Donau, Austria
Email: cahyofebri06@gmail.com