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Systematic Literature Review: Strengthening Teacher Competence through Creative Project-Based STEAM Implementation in Physics Learning

***N Suprapto[1], U A Deta[1], M N Fahmi[1], D A Dermawan[2], D Nurmalasari[3], H N Hidayatullaah[4], E Monica[4], A B Damarsha[5], N F Citra[6]**

[1]Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Surabaya 60231, Indonesia
[2]Departement of Informatics Management, Faculty of Vocational, Universitas Negeri Surabaya, Surabaya 60231, Indonesia
[3]SMAN 1 Taman, Sidoarjo 61257, Indonesia
[4]Doctor's Program in Science Education, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Surabaya 60231, Indonesia
[5]Master's Program in Physics Education, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Surabaya 60231, Indonesia
[6]Master of Education in Digital Learning, Faculty of Education, Monash University, Clayton VIC 3800, Australia

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ABSTRACT

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach is a new form of teaching that places students in real-world situations around them by following the concept of interdisciplinary teaching. STEAM is highly relevant in supporting students' 21st-century skills. As is well known, 21st-century skills encourage students' critical thinking, communication, collaboration, innovation, and creativity. In physics learning, it is not uncommon for students to have difficulty understanding the subject. Teachers, as learning facilitators, are expected to be able to integrate STEAM into physics education. Teachers must have the skills to develop learning tools. Through research using the SLR method, this study aims to investigate the importance of teachers' competencies in implementing project-based STEAM learning in physics education. Project-based learning emphasizes collaborative learning activities among heterogeneous groups of students. The analysis results show that the implementation of the STEAM approach in learning is still limited. Physics teachers are important agents in equipping students with the necessary physics knowledge and scientific investigation skills. Therefore, physics teachers need support in improving their understanding of STEAM. In learning activities involving project-based STEAM, it is known that it can increase students' creativity and innovation in problem solving.

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INTRODUCTION

Current developments encourage students to acquire skills that can support development in various sectors. 21st-century skills encourage students to develop critical thinking, communication, collaboration, innovation, and creativity skills (Shi & Rao, 2022). The application of traditional education in the 21st century cannot improve students' creative thinking skills (Topalska, 2021). Therefore, alternatives are needed to improve students' abilities. One science learning model that can build 21st-century skills in students is project-based learning. This type of learning is student-centered and provides meaningful experiences during the learning process

(Lestari, 2021). Project-based learning emphasizes collaborative learning activities with heterogeneous groups. Project-based learning has the potential to increase student activity and motivation to learn (Kristanti et al., 2016). These projects are designed to create learning activities that are relevant to the real world so that students can connect theory with practice (Ramadhan & Hindun, 2023).

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach is an innovative teaching method that places students at the center of real-world problems, applies cross-disciplinary learning concepts, and gradually builds students' ability to solve practical challenges through project-based learning (Shi & Rao, 2022). STEAM is highly relevant in supporting students' skills in the 21st century. Rizki (2022). The integration of arts into STEM (Science, Technology, Engineering, Mathematics) provides students with the opportunity to develop imagination and innovation, which are essential in the modern era (Nihayati & Wulandari, 2020).

STEAM is an expanded approach to STEM, adding positive, rich, and beneficial elements of art to civilization. Applied arts are extremely diverse, encompassing visual arts (paintings, printmaking, sculpture, crafting), communication (advertisement, literature, multimedia, social media, etc.), performance (drama, films, music, theatre, dance, etc.), lifestyle (interior, fashion, design, product design, etc.), and character (behavior, culture, attitude, etc.) (Liliawati et al., 2017). The inclusion of artistic elements in science education not only increases interest in learning but also stimulates students to find innovative solutions related to everyday life (Puspitaningtyas et al., 2025).

The implementation of the STEAM approach in Indonesia is still limited; according to Kismawardani (2022), it was found that 72% of the 25 teachers who completed the questionnaire were familiar with and understood the STEAM approach, but in practice only 50%, or half of the teachers, successfully applied the STEAM approach in physics learning activities. Learning objectives can be achieved when teachers receive tailored training and ongoing guidance in the projects they undertake (Ortiz-Laso et al., 2023). Effective learning requires teachers who are proficient in selecting teaching strategies and resources that are compatible with the topics being taught (Netshivhumbe, 2025). Teachers use learning models as a means to improve the quality of learning and reach learning objectives (M.I. Nuraeni et al., 2024). Teachers must have the skills to develop learning tools as a form of teacher readiness and as a strategy for implementing quality learning activities (Irdalisa et al., 2022).

Physics teachers have been acknowledged to play an important role in providing students with the physics knowledge and scientific investigation skills they need, but little attention has been paid to exploring physics teachers' perceptions of sustainable physics education. Therefore, support for maintaining physics education needs to be provided by facilitating the attainment of sustainable development goals or sustainable physics education (Nasri et al., 2020). Physics teachers as educators need to be provided with facilities to participate in STEAM training to improve their competencies.

Physics is known to be one of the subjects that uses many mathematical formulas. These mathematical formulas can make students think that physics is a scary subject, which can result in difficulties for students in understanding physics lessons (Fitria et al., 2023). Interdisciplinary experience and learning skills gained through the application of basic physics to real-world solutions can create links between the world of research and society (Tuveri et al., 2024). Physics students should have a scientific attitude, which means being able to accept other people's opinions properly and correctly, being curious, being able to act systematically in solving problems, being able to think critically, not giving up easily, being open-minded, and being persistent (Sakdiah et al., 2022).

STEAM-based physics learning shows that STEAM-based physics learning tools can increase students' creativity and learning outcomes (Khoiri et al., 2023). In addition, introducing students to physics topics by integrating them with STEAM can foster their interest in learning about physics content (Tuveri et al., 2024). Through these analytical activities, it is hoped that deeper and more relevant insights can be gained. However, according to research conducted by Abra (2023), teachers' ability to teach STEAM shows that their ability to combine project-based learning with their pedagogical approach indicates that STEAM training for teachers is still minimal (Olivato & Silva, 2023). Teachers, as educators, play an important role in the delivery of learning, so teacher training related to STEAM for learning needs to be improved.

The research was conducted by analyzing various studies related to education, STEAM, and physics that were selected using the PRISMA method in SLR model research. The literature review conducted by researchers aims to investigate the importance of teacher competence in implementing STEAM learning through project-based learning activities in physics education. Based on the screening results, ten journals related to this SLR research were found. This SLR research is expected to provide three benefits, namely 1) This SLR research can help identify research findings sourced from Scopus journals; 2) This SLR research can serve as a resource for physics or science teachers or prospective teachers in developing insights into the integration of STEAM in physics education, which can influence students' creativity, innovation, interest, and motivation; 3) This SLR research, by collecting international and national journals, can enhance insights in determining appropriate policies for integrating STEAM into physics education. The research results are expected to contribute to the importance of improving the competence of physics teachers in STEAM-based learning.

RESEARCH METHOD

This study uses the SLR (systematic literature review) research method with the aim of identifying, evaluating, and conducting a methodical analysis of specific research (Tm et al., 2025). The focus of this study is to analyze or identify the strengthening of teachers' competencies in the STEAM approach to physics education. The data collected comes from the Scopus database over the past five years (2020–2025). A total of 181 documents were obtained using the keywords "education," "STEAM," and "physics." The systematic review of the literature requires mastery of complex research methodologies. This necessitates a structured process that defines the review questions, identifies which studies to include, evaluates them, selects them, and then synthesizes the findings. Therefore, the methodology outlined in the PRISMA procedure was selected (Stracke & Trisolini, 2021). The PRISMA procedure consists of two stages: (1) literature retrieval, which includes identification, screening, and eligibility for review, and (2) data abstraction and analysis (Jamaluddin et al., 2023).

The research involved 181 articles on teachers, STEAM, and physics from 2020 to 2025. The analysis was conducted using the Scopus database. The article selection process used in SLR employed the PRISMA model, the analysis results are presented in Figure 1, and the findings showing an overview of the research can be seen in Table 1.

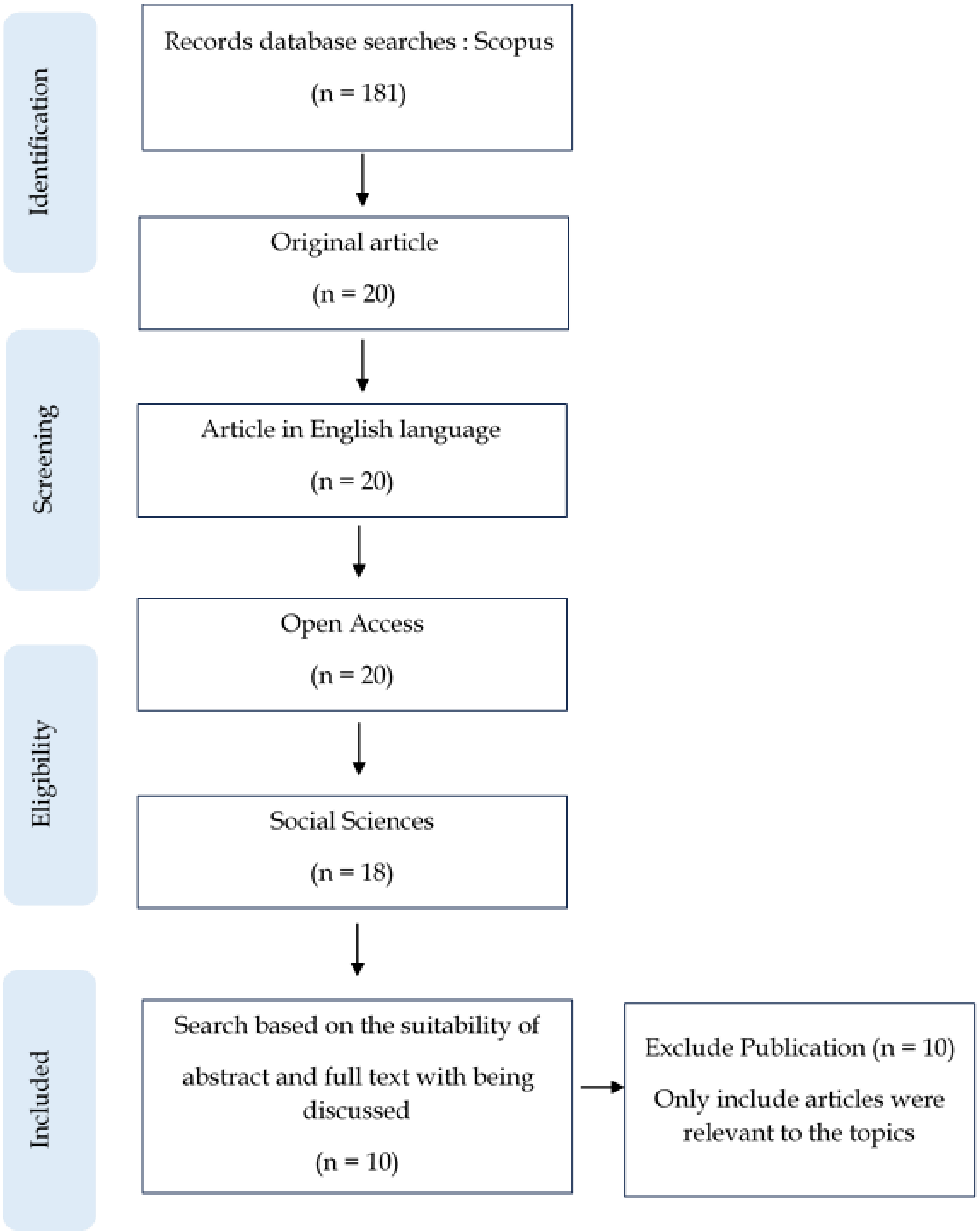

Figure 1. Selection of articles used in SLR using the PRISMA model

RESULTS AND DISCUSSION

Based on the analysis of articles conducted using the PRISMA method, 10 articles relevant to the study were found. These articles were then reviewed based on the author, title, year of publication, and research results. The results of the article analysis are presented in Table 1 below.

Table 1. Analysis of articles on the implementation of STEAM in physics teaching by teachers

Author	Title	Year	Result
(Anisimova et al., 2020).	Formation of design and research competencies in future teachers in the	2020	The implementation of the STEAM education concept enables the enhancement of the "Arts" component to a new level,

Author	Title	Year	Result
	framework of STEAM education		which has significant potential in shaping the project-research competencies of prospective teachers. Through robotics classes, teachers can develop creative and communicative competencies, technical and design skills, as well as research abilities.
(Jesionkowska et al., 2020)	Active learning augmented reality for STEAM education—a case study	2020	Active learning methods act as catalysts in the development of student skills. Research shows that combining STEM subjects and the arts, using active learning formats, can provide a more holistic and engaging education.
(Juškevičiene, 2020)	Steam teacher for a day: A case study of teachers' perspectives on computational thinking	2020	Teachers need support and examples of STEAM activities that are appropriate and focused on the implementation of computational thinking.
(Bassachs et al., 2020)	Fostering critical reflection in primary education through STEAM approaches	2020	The STEAM approach has a significant impact on understanding scientific and artistic concepts and increases individual responsibility and promotional interaction.
(Conradty et al., 2020)	How creativity in STEAM modules intervenes with self-efficacy and motivation	2020	STEAM offers an educational roadmap for various successful learning experiences, proving that creativity drives motivation through self-efficacy.
(Montés et al., 2022)	EXPLORIA, STEAM Education at University Level as a New Way to Teach Engineering Mechanics in an Integrated Learning Process	2022	The application of STEAM learning in the EXPLORIA project to enhance physics course learning shows that applying course material to problems related to their profession yields results by demonstrating positive emotional abilities, strengthening the learning process, and providing motivation to continue learning.
(Khoiri et al., 2023)	Integration of STEAM and ESD: Improving the understanding of fluid concepts and creativity	2023	Research shows that STEAM-based physics learning tools can boost students' creativity and learning outcomes.
(Olivato & Silva, 2023)	Interdisciplinary teaching practices in STEAM education in Brazil	2023	Most teachers are accustomed to incorporating project-based learning into their pedagogical approaches and are aware of STEAM education training.
(Filipe et al., 2024)	Integrated STEAM Education for Students' Creativity Development	2024	The integration of STEAM education and digital competencies can develop students' creativity in problem solving.
(Tuveri et al., 2024)	Using storytelling to foster the teaching and learning of gravitational waves physics at high-school	2024	Introducing students to contemporary physics topics and guiding them toward STEAM can foster their interest in learning about these subjects.

STEAM for Teachers

This study analyzed ten articles on the influence of STEAM on learning conducted by teachers. The results of the analysis show that one innovation in preparing teachers for STEAM-based education is to include the discipline of "Robotics" in the training content for prospective teachers of physics, mathematics, technology, visual arts, and others (Anisimova et al., 2020). This is a distinctive feature of STEAM with the involvement of art. Teachers are not only prepared to implement new educational programs but also to carry out practice-based educational activities that focus on developing design and research competencies. Robotics in education is suitable for all ages in its implementation in learning. Robotics in education encompasses interdisciplinary classes that integrate science, technology, engineering, art, and mathematics, based on the use of interactive learning methods (Anisimova et al., 2020).

The integration of STEM and the arts, using active learning formats, can provide a more holistic and engaging education. In addition to the integration of "robotics" learning, the integration of Augmented Reality (AR) technology is also one of the technologies in education that can demonstrate the potential of resources, particularly for education in the fields of Science, Technology, Engineering, Arts, and Mathematics (STEAM). Teachers interested in the AR Active Learning approach require support in creating and organizing learning materials and scenarios. Therefore, teachers must be given the opportunity to learn and develop their skills (Jesionkowska et al., 2020). This can be done by physics teachers through training.

STEAM emphasizes students' problem-solving skills. In the field of problem-solving, computational thinking is often associated with algorithmic thinking, programming, problem-solving, and STEAM. In a case study within the research of Juškevičiene (2020), thirteen teachers from various disciplines (national language, computer science, dance, crafts, physics, and mathematics) and levels (preschool, elementary school, high school, and vocational school) participated in the study. All of them were interested and experienced in integrating STEAM disciplines into computational thinking and believed that it could help improve learning. The research results indicate that computational thinking can be implemented in various subjects. (Juškevičiene, 2020).

The STEAM approach in an experiential environment encourages teachers to reflect on a variety of aspects, including competencies, attitudes, and emotions. Experiential activities show that what must be considered in developing STEAM activities in learning is a continuous experimental cycle process that has a reciprocal relationship (Bassachs et al., 2020). Experimental activities oriented towards products that can be used in problem solving.

Another study conducted by Abra et al. (2023) shows that teachers are familiar with project-based learning but do not yet understand the application of STEAM in learning. In the study, teachers as research subjects showed self-efficacy in supporting STEAM teaching through training. The use of project-based learning methodology in STEAM education gives students a more active role and is able to encourage the development of 21st-century skills (Olivato & Silva, 2023). Teachers' interest in learning and self-motivation based on their self-efficacy become the driving force for teachers to improve their quality in delivering STEAM-based learning.

Physical education must be supported, and this can be done by improving teacher competence. Applying the STEAM approach to the Indonesian curriculum is no easy task. It takes creativity and skill on the part of teachers to integrate the learning process based on the curriculum so that the learning results produce students who are ready to take on the world of the 21st century (Kismawardani et al., 2022). By providing facilities for teachers to achieve sustainable development goals, the following can be done: 1) ensuring that physics teachers have the necessary academic qualifications and training in all schools, and 2) carefully designing the fulfillment of the professional development needs of physics teachers with an emphasis on broader thinking about physics and awareness of careers in the field of physics (Nasri et al., 2020).

In line with the improvement of teacher competence, research conducted by Topalska (2021) shows that through STEAM training attended by teachers in Bulgaria, teachers have a positive view of the application of STEAM in learning activities. The implementation of STEAM in learning activities is very beneficial for students as preparation for the future (Topalska, 2021). Basically, teachers have positive views and attitudes toward STEAM training. Teachers realize that implementing STEAM in learning is beneficial for developing students' thinking and competencies that will be needed in the future.

Implementation of STEAM in Students

Entering the 21st century, the integration of STEAM and digital skills in physics education can enhance students' creativity in problem-solving. As is well known, creativity and digital competence will be fundamental in the 21st century. This study reinforces the substance of integrated STEAM education as an effective methodology for developing student competence (Filipe et al., 2024). STEAM-based learning can be applied to learning that can have a significant impact on students' understanding of science concepts, artistic concepts, and sense of responsibility (Bassachs et al., 2020).

Research findings related to increasing student motivation with STEAM to pursue careers in science show that career motivation depends on the individual's self-confidence, which is then reinforced by perceived creativity. Creativity is considered part of intrinsic motivation indicators, and by increasing it, others will adjust accordingly (Conradty et al., 2020). The involvement of art in STEAM learning stimulates student creativity. The application of STEAM in learning projects can improve the learning process. The success of these learning activities is inseparable from the role of teachers. Teachers not only play a role in connecting subjects but also act as facilitators of knowledge (Montés et al., 2022).

The implementation of STEAM integrated with ESD in physics learning can improve students' understanding and creativity in fluid material. Physics learning becomes more interesting. The results of this study can be considered in curriculum development in physics teaching in facing future developments (Khoiri et al., 2023). The artistic creativity of STEAM in physics learning can be born from literature. Introducing students to physics themes by involving STEAM, such as monologues and poetry, can increase their interest and motivation in learning it (Tuveri et al., 2024).

STEAM learning has better accuracy than traditional learning. STEAM education is a new type of education that places students in real-life problem situations, follows interdisciplinary teaching concepts, and gradually develops students' problem-solving skills through project-based learning (Shi & Rao, 2022). Therefore, improving teachers' competence as learning facilitators is an important concern in improving the abilities of students as the next generation.

CONCLUSION

This study analyzes the importance of the STEAM approach in supporting learning activities in the current 21st century, especially in physics education. The implementation of the STEAM education concept enables an increase in competence in the field of "Arts" at a new level, which has significant potential in project formation. The research shows that by improving teachers' competencies in STEAM learning, students can improve their ability to learn physics. Physics teachers, as learning facilitators, have realized the importance of STEAM in the future. As learning facilitators, teachers are expected to receive support in improving their competencies in the field of STEAM. However, the study shows that STEAM learning training for teachers is still limited, so it is necessary to pay more attention to STEAM training for teachers. Therefore, it can be concluded that STEAM learning can affect students' creativity and competencies in physics learning and that teachers as facilitators are important in obtaining STEAM-based learning training that can be implemented in learning.

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Author (s):

* Nadi Suprapto (Corresponding Author)
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya
Jl. Ketintang, Surabaya 60231, Indonesia
Email: nadisuprapto@unesa.ac.id

Utama Alan Deta
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya
Jl. Ketintang, Surabaya 60231, Indonesia
Email: utamadeta@unesa.ac.id

Muhammad Nurul Fahmi
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya

Jl. Ketintang, Surabaya 60231, Indonesia
Email: muhammadfahmi@unesa.ac.id

Dodik Arwin Dermawan
Departement of Informatics Management, Faculty of Vocational,
Universitas Negeri Surabaya
Jl. Ketintang, Surabaya 60231, Indonesia
Email: dodikdermawan@unesa.ac.id

Dewi Nurmalasari
SMAN 1 Taman
Jl. Raya Sawunggaling No.2, Taman, Sidoarjo 61257, Indonesia
Email: nadisuprapto@unesa.ac.id

Hasan Nuurul Hidaayatullaah
Doctor's Program in Science Education, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: hasannuurulh@gmail.com

Elsa Monica
Doctor's Program in Science Education, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: 25030966008@mhs.unesa.ac.id

Adrian Bagas Damarsha
Master's Program in Physics Education, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: 24031635009@mhs.unesa.ac.id

Nina Fajriyah Citra
Master of Education in Digital Learning, Faculty of Education,
Monash University,
Clayton VIC 3800, Australia
Email: ncit0004@student.monash.edu