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Innovative Digital Approaches to Physics Teaching through STEAM Integration

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ABSTRACT

Objective: *This study aims to analyze the development of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in physics learning in Indonesia. It explores various aspects commonly investigated in related studies, such as types of research, subjects, instruments, physics topics, measured variables, learning media, findings, and research recommendations.* ***Method:*** *This research employs a literature review method, using secondary data collected from relevant scientific journals published in Indonesia. The analysis focuses on identifying patterns and trends in the implementation of STEAM-based physics education.* ***Results:*** *The results indicate that the STEAM approach has a significant positive impact on physics learning. It enhances students' creativity, conceptual understanding, critical thinking, and overall learning outcomes. Various learning media, especially digital tools, have been integrated effectively within the STEAM framework. However, some challenges remain, such as aligning STEAM implementation with the national curriculum and managing limited classroom time.* ***Novelty:*** *This study provides a comprehensive overview of how STEAM has been applied in physics education in the Indonesian context. It highlights key trends, benefits, and barriers, offering valuable insights for educators and policymakers aiming to integrate interdisciplinary, digitally enriched learning approaches into physics instruction.*

INTRODUCTION

Physics education in Indonesia is expected to produce young people with 21st-century skills, such as critical thinking, creativity, innovation, and the ability to solve problems. This capability is crucial to address complex and dynamic global challenges. Physics teaching is integral to the educational curriculum to prepare students with a solid understanding of the natural sciences. However, in the face of the challenges of the ever-evolving times, the hope of creating engaging and relevant learning is increasing. It is expected that physics learning not only enhances cognitive knowledge but also helps students become creative, critical thinking, skills, communication, and active in solving real-world problems. Students must have strong critical thinking skills and knowledge through physics teaching.

However, reality shows that physics learning in Indonesia is still fixated on rote memorization and theory. This has led to low student interest and motivation in physics and a lack of expected 21st-century skills development. A TIMSS (Trends in International Mathematics and Science Study) survey found that students' problem-solving ability is low. This is indicated by many students' difficulties in solving mathematical problems. The paramount ability that students must have in physics lessons is to make decisions to solve life problems. Physics plays an important role in developing future technologies that can be achieved through scientific processes. On the other hand, the reality is that many students have difficulty understanding physics concepts in depth, which may be due to a less engaging approach to teaching and less involvement of students in the teaching-learning process.

There is a significant gap between expectations and reality in physics learning. This gap shows problems in the physics teaching methods applied today. This problem is increasingly becoming a concern because it can impact low interest in learning and unsatisfactory academic results. Learning physics in schools is often limited to routines (Wiyanto, 2017). Teachers often give students formulas, sample problems, and exercises so that students get bored quickly. Many complain that learning physics is complicated, so students prefer to teach it by avoiding boring routines. In physics, many things must be learned, not only complicated mathematical formulas and calculations but also how to solve physics problems through thinking processes or stages to find solutions.

Integrating STEAM in physics learning is one way that can be used. STEAM strategies not only help specific fields but also integrate science, technology, engineering, and mathematics in the problem-solving process. As stated by Asmuniv in Khaeroningtyas et al., STEAM approaches can shape students' ability to think critically, logically, and systematically. By using this approach, the learning process becomes more meaningful, and students are expected to be able to solve problems, especially in physics lessons (Putri et al., 2019). The contextual learning model uses the STEAM approach (Yakman & Lee, 2023). Students can study and understand natural phenomena and everyday problems using the STEAM approach. The STEAM approach also allows students to communicate, cooperate, and cooperate in groups, which increases their knowledge (Lestari, 2021). STEAM learning can increase students' knowledge. By applying it, students can solve problems and answer questions (Nasrah, 2021). The goal of STEAM learning is to improve literacy. Students can use real experiences in everyday life to learn the material so that learning has meaning (Nurhasanah & MS, 2021). STEAM learning can also establish relationships between teaching materials, learning models, and the environment (Sochaka et al., 2016).

Research on the STEAM approach should be conducted to inform teachers that the STEAM approach has a positive effect on education, especially on learners' progress. The study should also instruct teachers on applying the STEAM approach (Bedewy et al., 2023). Positive impacts of implementing the STEAM approach in Indonesia can include improving memory, contextual understanding of science, increasing participation and innovation, and preparing for future challenges. Because the STEAM approach is essential for education in Indonesia, especially in the field of physics (Bin Amiruddin et al., 2022; Kusmiarti, 2021; Rahmawati et al., 2021).

This study aims to see how the STEAM approach in physics learning has developed in Indonesia. This research provides information about things often used in this study, such as the type of research, subjects, instruments, physical materials, variables measured, learning media used, research results, and research suggestions. This is very important to direct, improve, and determine further research policies. This includes the type of research to be done, areas that require special attention, and products that will be created for physics learning using the STEAM approach.

RESEARCH METHOD

This research is a type of literature research and uses literature data collection methods. The data used is secondary data obtained from journals relevant to the research. Journal searches are carried out through Google Scholar that meet the criteria according to research. The study reviews various STEAM research journals of physics studies published in the last ten years, which are indexed in Sinta or National or International

Proceedings. The qualitative approach in literature review is used to synthesize (summarize) qualitative descriptive research results. The method of synthesizing (summarizing) the results of qualitative research is called meta-synthesis, the technique of integrating data to obtain new theories and concepts or a deeper and more thorough level of understanding.

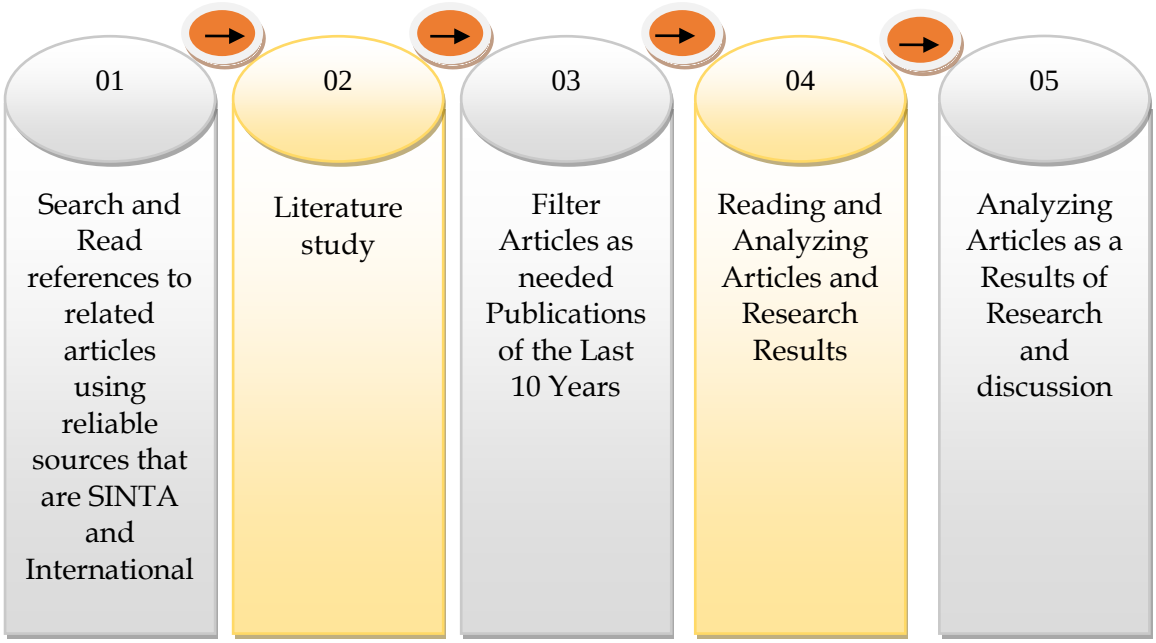

Figure 1. Flow of research methods

The article analysis method used content analysis (Barnard et al., 2022), which was modified for the suitability of research objectives (Marin et al., 2018). Modifications are made by synthesizing and replicating the three methods, namely by analyzing the year of publication, type of research, research subject, research instrument, learning model, effort developed, research results, and research suggestions used in the scientific article (Marvin et al., 2018). In this study, looking for reference data sources for related articles were obtained from 40 journals. After that, filtering articles obtained 21 articles considered relevant to the topic studied by the year of publication. From the selected articles, various information related to the contribution of authors and journals was obtained, including the material used in the article, the feasibility level of the Innovative approach developed, level n, and the number of article citations. This information is strengthened by analyzing each article to explain the purpose of the study.

RESULTS AND DISCUSSION

Results

Based on the results of the analysis conducted, the Innovative approach is one-way teachers can further activate the learning minds of their students when the teaching and learning process takes place in the classroom is to apply the STEAM approach. The STEAM approach is a learning model that helps teachers connect the material taught with students' real-life situations, allowing students to relate their knowledge by applying it in life as families and citizens (Rahma & Isralidin, 2022). The following is a grouping Table 1 from various sources of Innovative Approaches to Learning Physics through steam learning: The result of the study is that the construction of a STEAM

learning model based on Design Thinking on renewable energy materials requires learning media that accommodates every stage of thinking in solving a problem, which includes (1) Empathy; (2) Define; (3) Ideate; (4) Prototyping; (5) Test. Through STEAM City learning media, students are expected to be able to understand renewable energy materials applicatively in a miniature city with a continuous scope of material between force, motion, and energy.

Table 1. Selected journal articles focusing on Innovative Approaches to Physics Learning Through STEAM Learning

No	Title (Researcher, Year published)	Purpose	Method	Result
1.	Research development of steam approach on learning (Fitria et al., 2022)	The purpose of this study is to review the development of STEAM approach research on physics learning in Indonesia.	Systematic literature review research with the content analysis method is used to review articles published from 2018-2022. The analysis techniques carried out are identification, screening and analysis	The results of the study are the most widely used type of experimental research, the subject of research is at the junior high school level students grade VII and VIII with a sample number of 20-45 students. Test research instruments are widely used by examining light and optical materials. The variable that is often measured is creative thinking skills. Learning media integrated with the PjBL-STEAM model is the most widely used option. Therefore, the research variables that have not been measured are representation skills and higher-order thinking skills aspects of problem solving and material physics that have never been used for testing are rigid body equilibrium, representation skills and higher-order thinking skills aspects of problem solving and material physics that have never been used for testing are rigid body equilibrium,
2.	Development of STEAM-based physics e-module learning media	The purpose of this study is to develop a STEAM-based e-module of physics in	The method used in this study is research and development with a 4D development	Based on the results of validation analysis from experts, it gets quite good results, based on effectiveness tests it gets a

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	to improve students' critical thinking skills (Written by the Wizard of the Philippines, 2023)	improving students' critical thinking with sound material, testing the feasibility of e-STEAM-based physics module to improve students' critical thinking with sound material as well as testing the feasibility of e-STEAM-based physics modules to Improve students' critical thinking.	model consisting of define, design, develop, and disseminate stages. The data collection method in this study is by analyzing student responses to e-modules in learning and teacher questionnaires regarding the effectiveness of using e-module-based STEAM pada pembelajaran.	percentage score of 58.26% which means it is quite effective. Based on these results, it is known that the development of STEAM-based e-modules to improve skills berpikir kritis pada The subject matter of sound can be implemented in learning
3.	STEAM approach to physics learning for inclusive schools (Nur et al., 2023)	This research aims to integrate five disciplines to improve students' critical thinking, problem-solving, and creativity skills.	This research uses the method of literature study. The literature study method is a research approach that aims to investigate and analyze literature or pre-existing written works to understand and compile understanding of a research topic	The results showed a positive impact on the creativity and learning outcomes of students. This literature study explores the definition of STEAM, its benefits, and effective approaches to creating an inclusive environment in physics learning. The challenges teachers face are acknowledged, but interest in STEAM is increasing, reflecting the growing interest in this method in physics education in Indonesia.
4.	Steam approach can improve critical thinking (Martha, 2021)	The purpose of this study is to develop the learning process using metode pembelajaran STEAM dan loose part based learning.	The research used is classroom action research which aims to improve or improve the quality of the implementation process pembelajaran pada media loose parts. The research	The result of this study is that through an approach through STEAM-charged activities, there is an increase in critical thinking skills in anak The result of this study is that through an approach through STEAM-charged activities, there is an increase in critical thinking skills IN is

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			procedure uses the Kemmis and MC Taggart model (In Patmono, 2010. Includes the following stages: (a) action plan, (b) acting, (c) observation and (d) reflecting.	getting better, satisfactory and has achieved action success indicators where the classical gain of 93.3% with the criteria is developing very well.
5.	STEAM Learning as Innovative Learning (Darmadi et al., 2022)	The purpose of this study is to obtain STEAM-based learning tools such as RPP, LKPD, PPT / Video, learning instruments to be able to become models in the development of STEAM-based learning. In addition, the purpose of this study is to determine the position of STEAM-based learning with pembelajaran pembelajaran inovatif menurut ahli atau orang yang dianggap ahli.	The research method uses qualitative research. The subject of research is an expert or a person who is considered an expert. Data collection using in-depth interviews	The results showed that videos related to learning with the STEAM approach are still theoretical and have not yet entered practical, so it is necessary to develop videos and learning tools that can be used as learning models with the STEAM approach. In addition, STEAM learning includes innovative learning and in STEAM learning reflection and more knowledge are needed to optimize success in achieving learning goals.
6.	Critical Thinking Skills of Vocational Students in ESD-Oriented IPAS Project Learning and STEAM Approach (Muntamah et al., 2024)	This study aims to determine the effect of learning ESD-oriented IPAS Project with the STEAM approach on improving critical thinking skills of vocational students.	This research uses a quantitative approach with a research design, namely Quasi Experimental Design. The design used is Non-equivalent Control Group Design. The instrument used is	The results showed that the results of the t-test were obtained t-count > t-table (9.320 > 1.995) with a significance of 0.00, while the N-gain test was 73.75%, so it can be concluded that there is an increase in critical thinking skills in learning ESD-oriented IPAS projects and the

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			a test developed based on indicators of critical thinking skills. Statistical tests carried out in the form of t-tests and N-gain tests.	STEAM approach with quite effective criteria. The results of this research contribute to the implementation of ESD-oriented IPAS projects and STEAM approaches. The results of this study are expected to be an alternative in efforts to improve critical thinking skills, especially students in SMK.
7.	Integration of independent learning and physics innovation in STEAM-based renewable energy education to improve critical thinking skills in the era of Society 5.0 for Sustainable Development Goals (SDGs) 2030 (Dwi et al., 2023)	This research aims to integrate Independent Learning and Physics Innovation in STEAM-based Renewable Energy Education to improve critical thinking skills in the Society 5.0 Era to achieve the 2030 Sustainable Development Goals (SDGs).	This study used a literature review method that collects and analyzes related articles.	The results showed that integrating Independent Learning and Physics Innovation in STEAM-based Renewable Energy Education is an effective approach to improve students' critical thinking skills. Renewable energy education is a relevant and important topic in SDG 2030, and the STEAM approach helps students understand and overcome these challenges. The era of Society 5.0 emphasizes the integration of technology, so the educational approach must continue to be updated and adapted to the times. The results of this literature review can help educators, policy makers, and researchers in developing aligned Education Strategies with the needs of the times.
8.	Analysis of constructivism principles in physics learning based on Science, Technology,	This study aims to analyze the application of constructivism learning theory in physics-based learning Science,	Research data collection is carried out through observation techniques, interviews, and open	. The results of the analysis show that STEAM-based learning carried out has applied the principles of constructivism such as using problems in everyday life to stimulate

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	Engineering, Art, and Mathematics (STEAM) (Ika et al., 2023)	Technology, Engineering, Art, and Mathematics (STEAM).	questionnaires, where the three data collection techniques are also triangulated to check the validity of the data collected. The research data was analyzed using interactive analysis techniques developed by Miles and Huberman whose stages are data collection, data reduction, data presentation, and conclusion drawing	the learning process, the existence of an inquiry process through assessment and experimentation, there is an encouragement to ask questions and interact with lecturers, to provide opportunities for students to find new knowledge. STEAM learning contributes greatly to the development of students' thinking skills, including mengaktifkan mahasiswa, meningkatkan kemampuan komunikasi dan kerja sama, meningkatkan the ability to think at a higher level, as well as develop students' scientific attitudes. Even so, STEAM learning also has obstacles, including requiring a long learning time
9.	Increasing creative thinking of students by learning organization with steam education (Ahmad et al., 2021)	The purpose of this study was to analyze the changes in learning between learning before using the STEAM method and learning after using the STEAM method	Researchers use an assessment score reference instrument, where the assessment of the final product is assessed by course lecturers, learning media experts, and linguistics (language) lecturers. To find out whether there is a change in the ability to think creatively in each learning process before and after learning, researchers use a hypothesis test using a t test.	The results of the analysis test explain that the learning method using the STEAM method in learning has a positive impact on learning where students experience a significant average increase before and after being given learning using the STEAM method by providing direct experience through the project work process.

No	Title (Researcher, Year published)	Purpose	Method	Result
10.	Literature Research: The Use of Science, Technology, Engineering and Math (STEM) In Physics Learning (Norlaili, 2022)	This study aims to determine the advantages of STEM approaches and obstacles in physics learning	The method used to achieve this goal is literature research. The study reviewed various STEM research journals of physics studies published in the last ten years which were indexed in Sinta or National Proceedings	The results showed that the use of STEM has the greatest advantage in improving student learning outcomes, while the biggest obstacle in STEM learning is learning adjustment STEM dengan kurikulum dan perlunya manajemen waktu which is good. The results of this study can be used as input for physics teachers to apply STEM approaches in the physics learning process in the classroom.
11.	STEAM Approach to Improve Environmental Education Innovation and Literacy in Waste Management: Bibliometric Research (Syahmani et al., 2021)	This research aims to improve innovation and literacy Pendidikan Environment in waste management	This research is a bibliometric literature review that using systematically explicit methods	After managing the database, this study classifies and visualize the database using VOS software "STEAM", and "waste management" is used to search for relevant journal articles published on the three concepts, indexed in Google Scholar from 1969 to 2020. The study only found a total of 163 results from the Google Scholar Index. Further refinement of the results shows that published research has been scarce in the last 51 years and requires further study to substantiate the concept. The author also discusses some suggestions on how STEAM can be considered as a way to develop students' Environmental Literacy in waste management
12.	STEAM Learning Against Science Process Skills	This research aims to stimulate students to improve their	Research design using One Group Pretest-Posttest Design. The	The results found that there is an influence of STEAM learning on students' SPS and there are differences in

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	Viewed from the Scientific Attitude of Students in the Vocational Physics Study Course (Halimatus et al., 2022)	skills through the application of the STEAM learning approach	instruments used are tests to observe SPS variables and non-tests to observe scientific attitudes. Research hypothesis analysis using one-way ANOVA analysis	SPS students who have high, medium, and low scientific attitudes.
13.	STEAM teaching professional development works: effects on students' creativity and motivation (Catherine & Franz, 2020)	This research aims at a professional development path that lies not only in the introduction of creativity with its social skills but not only in cognitive learning ,The materials provided ensure teachers to work regularly with STEAM and as teachers involved are supposed to recapitulate and consolidate STEAM skills	Test Design using pre test and post test with questionnaire, using analisis satistik distribusi Test Design using pre test and post test with questionnaire, using	The structural equation model (SEM) confirms that model of creativity with STEAM memiliki efek positif pada Motivation: Long-term PD integrated into school life is the right entry point to socio-cultural sustainability to encourage creativity in the classroom. Through creativity, it turns out that students' self-efficacy increases. Conclusion Motivation: Long-term PD integrated into school life is the right entry point to socio-cultural sustainability to encourage creativity in the classroom. Through creativity, it turns out that students' self-efficacy increases. Conclusion
14.	STEM vs. STEAM Education and Student Creativity: A Systematic Literature Review (David & Jairo, 2021)	This study aims to characterize didactic interventions intended to follow a STEM or STEAM educational approach and, on the other hand, to evaluate their impact on student creativity	A systematic literature review is presented in this study, given that the selection of jobs has been carried out based on inclusion criteria that are clearly defined and explained. In addition, the selection process was designed in accordance with	The results show that STEM and STEAM education do not have a clear conceptual framework with broad consensus in the scientific-educational community. In this regard, the likelihood of applying this approach in practice is diminishing, as is the rigorous evaluation of potensi pendidikannya. Selain itu, hal ini highlights the obligation of the scientific

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			the PRISMA Declaration	community to increase the number of studies that are experimental in nature to determine whether STEM and STEAM education have the ability to develop student creativity.
15.	Students' Perspectives about Science Technology Engineering Art and Math in Application to Physics Measurement Equipment Projects (Nadiah ,2023)	This study aims to describe students' views on STEAM in the application for the Measurement Physics Measuring Instrument Project.	This study used quantitative qualitative descriptive methods and used the Likert scale to conduct the survey.	Based on the results, projects were directly described for the science component (= 4.47, 5D 0.07), the technology component (E=422, SD=0.300), the engineering component (4.19, SD = 0.011, the art component (=403, SD- 031), and the mathematical component (3440 SD 0.15) In conclusion, five projects were strongly approved as constructive projects with the STEAM application
16.	The Development of Teaching Material Based on Science, Technology, Engineering, and Mathematics (STEM) (Abdul et al., 2021)	This research is a development research that aims to describe the valid profile of STEM-based teaching material development, analyze student responses terhadap pengembangan bahan ajar dan menganalisis the effectiveness of STEM-based teaching materials to test creative thinking skills.	This research is called research and development (R&D). This research learning development procedure adapts the development of the ADDIE model. Research on the design and development of STEM-based teaching materials carried out refer to the development of the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation)	The results showed the practicality of STEM practice-based physics teaching materials. This can be seen from the results of student responses and teacher responses that are in the very good category. Learning using STEM-based teaching materials efektif dan can make students think creatively. This is shown in the fluent thinking indicator with a percentage of 74.58%, flexible thinking indicator 71.25%, original thinking indicator 81.56%, and elaborative thinking indicator 82.03%, with an average percentage of 77.36% being in the creative category.
17.	The effect of	This quantitative	This study used a	The results of the analysis

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	project-based learning model on students' critical and creative thinking skills in the ecosystem concept (Feselmi, 2023)	research aims to determine the influence of the PjBL model on students' critical thinking and creative thinking skills on ecosystem concepts.	quasi-experimental design with the matching posttest-only control group design and the population of all classes. The sample was determined using purposive sampling techniques with various considerations The research instrument used 15 critical thinking skills questions and 12 creative thinking questions. The collected data is then analyzed using a one-way ANOVA test.	show that the PjBL model has a significant effect on students' critical and creative thinking skills on the ecosystem concept (P0.000 < 0.05) Thus, the PjBL model can be used as an alternative learning to empower 21st century skills.
18.	The Impact of (STEAM) Approach on the Innovative Thinking and Academic Achievement of the Educational Robot Subject among Eighth Grade Students in Jordan (Jawhara et al., 2022)	This study aims to identify the effect of STEAM-based learning approach in teaching educational robot subjects on academic achievement and creative thinking in grade VIII students in Jordan.	This research as a quasi-experimental study (designing unequal groups in pre and post-sale). It is used to design two groups: learning based on integrative and traditional approaches education with Torrance Test of Creative Thinking (Form B). A	The results showed statistically significant differences between the experimental and control groups in academic achievement and creative thinking. In conclusion, the STEAM-based learning approach significantly improves students' academic achievement and creative thinking skills
19.	The effect of applying the Steam approach to static fluid matter on understanding Concept of	The study aims to determine the application of the STEAM approach to static fluid materials Pemahaman Konsep Siswa	The approach used in research is a quantitative approach. While the type of research is experimental. The place where this research was	The results of the research that has been carried out have obtained that tcount> ttable, which is 3.154 > 2.021, it can disimpulkan bahwa the null hypothesis (H0) is rejected and the working hypothesis (H1) is

No	Title (Researcher, Year published)	Purpose	Method	Result
	Class Xi Students of State High School 1 Term (Rauzatul et al., 2022)	Kelas XI SMA Negeri 1 Jangka	carried out was at SMA Negeri 1 Masa This research was to test the research hypothesis or t test.	accepted. This means that there is an influence of STEAM Learning on students' understanding of concepts in static fluid material in class XI of SMA Negeri 1 Jangka.
20.	The effect of applying the Steam integrated project based learning model on creative thinking is seen from the understanding of high school students' physics concepts on rotational dynamics material (Abd et al., 2021)	The purpose of this study is to describe the effect of applying the STEAM integrated Project Based Learning model on creative thinking in terms of understanding the concept of high school students on rotational dynamics material	The research method used is pre-experiment with one group pretest-posttest design. The population is the entire class XI of science odd semester SMA Bustanul Mubtadiin Pangorayan Proppo Pamekasan. A sample of one class is selected by purposive sampling. The research instruments used are concept comprehension tests and creative thinking tests	The results showed that there was a significant influence on the STEAM-integrated PjBL model on creative thinking skills in grade XI science students in high school (Fhit = 131.231 α=0.000
21.	Construction of STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning models with a design thinking approach on renewable energy materials (Devie ,2022)	This study aims to reconstruct the STEAM learning model with a combination of design thinking approaches on renewable energy learning materials.	This study used a descriptive qualitative approach with data sources from the literature. The analysis tool used is the Miles and Huberman interactive model data analysis.	The result of the study is the construction of a STEAM learning model based on Design Thinking pada materi energi Renewable requires learning media that accommodates every stage of thinking in solving a problem, which includes (1) empathy; (2) define; (3) ideate; (4) prototyping; (5) test. Through learning media STEAM City students are expected to be

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				able to understand renewable energy materials applicatively in a miniature city with a continuous scope of material between force, motion, and energy.

Discussion

Table 1 contains 21 selected journal articles focusing on innovative approaches to Teaching Physics Through STEAM Learning. From the effectiveness and practicality testing of the 21 articles, it can be seen that the STEAM-based Innovative Approach they developed is valid and practical, including the criteria of "good" to "excellent." The four articles tested for feasibility only concluded that all STEAM-based e-modules developed fall into the feasible category with appropriate appearance, content, and practicality criteria. Innovative Approaches in Teaching Physics through STEAM Learning" highlights various approaches and methods in integrating STEAM (Science, Technology, Engineering, Arts, and Mathematics) elements into physics education. This approach aims to improve 21st-century skills, such as critical thinking, creativity, collaboration, and problem-solving. STEAM learning encourages students to apply science and technology in real-world contexts. For example, in the engineering component, students learn theory and do hands-on practice, such as building structure projects, to understand fundamental physics and engineering concepts. This process starts with problem identification, then designing and testing solutions, which teaches students the importance of iterations and failures as part of the learning process.

Integrating art in STEAM is also important, as it helps students express their ideas through various art forms, which can enhance their fine motor skills and creativity. This approach ensures more thorough and interdisciplinary learning so that students understand physics concepts theoretically and apply them in various contexts. In addition, the implementation of STEAM also pays attention to social context and real-world relevance, ensuring that learning is always linked to situations that students face daily. This increases learning motivation and makes the material easier to understand. Learning physics with the STEAM approach can improve students' science literacy and critical thinking skills, preparing them to face real-world challenges in creative and innovative ways.

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach has recently been widely discussed as an educational innovation. The evaluation of various articles shows that this approach has many benefits, challenges, and significant impacts on learning, including in physics subjects. One of the benefits is to foster 21st-century creativity and skills. STEAM allows students to develop creativity, critical thinking, and problem-solving skills by incorporating art into STEM subjects. This approach helps students understand abstract concepts in physics classes through creative projects, such as designing simple tools to understand the material. In addition, STEAM meets real-world demands because it teaches students the connections between

different fields and real-life applications. Additionally, because STEAM-based learning involves hands-on, exploratory, and fun activities, students tend to be more engaged.

However, the implementation of STEAM, including in physics classes, also faces many challenges. One of them is the lack of teacher training, which often results in the implementation of this approach being less than optimal. Physics teachers may find it challenging to integrate artistic elements into teaching more technical physics concepts. Limited resources such as laboratories, technical equipment, and art materials are also an obstacle, especially in remote areas. Furthermore, the rigid curriculum structure makes it difficult to achieve integration between subjects, which is at the core of the STEAM approach. Nonetheless, STEAM has a significant positive impact on physics learning. Several studies have shown that this approach improves student learning, especially in understanding abstract physics concepts such as mechanics, thermodynamics, and wave motion. Additionally, this approach encourages students to work in teams, which helps develop interpersonal skills. In physics classes, STEAM-based projects, such as designing miniature bridges using force principles or creating kinetic art to understand energy, provide a more immersive learning experience. This approach can also break gender stereotypes in STEM subjects by incorporating the arts as a creative component that appeals to all students. Several strategic steps are needed to improve the implementation of STEAM in physics education, including providing intensive training to physics teachers to understand the approach thoroughly, investing in facilities to support cross-disciplinary experiments and projects, and making the curriculum more adaptable. With the right support, STEAM can be a solution to improve the overall quality of physics education while preparing students for the challenges of the 21st century.

CONCLUSION

Fundamental Finding: The STEAM-based learning approach has a significant positive impact on multiple aspects of physics education, such as enhancing creativity, conceptual understanding, critical thinking skills, and overall learning outcomes. Additionally, the approach fosters positive scientific attitudes and greater motivation among students, with observable differences based on their initial scientific disposition. **Implication:** These findings support the integration of STEAM into the physics curriculum as a means to modernize learning experiences and develop 21st-century competencies. The results reinforce STEAM as a viable and innovative pedagogical approach that can bridge traditional science instruction with interdisciplinary and real-world applications. **Limitation:** Despite its potential, STEAM implementation faces challenges, including limited alignment with current curriculum structures, insufficient teacher training, and time constraints during lesson planning and delivery. The review is also limited by its reliance on secondary data from Indonesian journal articles, which may affect the generalizability of the results. **Future Research:** Future studies should explore the long-term impact of STEAM-based learning on student achievement across various education levels and subject areas. Experimental designs with larger and more diverse populations, as well as cross-country comparisons, are recommended to validate and expand the findings. Further research into teacher readiness, curriculum

design, and digital integration in STEAM is also essential for sustainable implementation.

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