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A Systematic Review of Trend STEM Education Research on Physics Learning in Indonesia

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Abstract

STEM education can contribute to the achievement of students' thinking skills, such as 21st-century learning skills (critical thinking, creative thinking, collaboration, communication), literacy, and numeracy, which are crucial to develop in every school learning activity, especially in physics learning. These skills are essential for students to prepare a resilient generation to face global challenges related to rapid technological advances, the Industrial Revolution 4.0, socio-cultural shifts, environmental changes, and future world differences. This research study aimed to systematically analyze trends of STEM Education research on physics learning in Indonesia based on articles published in national journals (SINTA). Fifty-four articles were collected from Physics Education journals in Indonesia between 2019 and 2024, with STEM Physics learning as the main point of this research. The current study revealed that STEM Physics research publications had improved annually for the past 5 years. The types and designs mostly used are Research and Development (RnD). Senior High School is the most researched subject. The physics topics mainly researched are Wave and Heat & Temperature. The most dominant treatments in STEM Physics research are Project-Based Learning (PjBL). The most dominant part of skill aspects researched is creative thinking. In addition, the most common data analysis used in STEM Physics research is N-Gain. Several recommendations have been made for future research, including increasing the diversity of research types, choosing more appropriate physics learning techniques, and aiming for relevant skills for the students. By mapping trends in research focus, methods, and skills targeted, this study helps identify gaps and opportunities for innovation in teaching practices. Teachers can use the findings to design learning models that are more diverse, relevant, and engaging, while policymakers can use the evidence to formulate educational policies that strengthen 21st-century competencies. This study's findings should be a reference for the development of innovative and inclusive educational regulations and teaching approaches for a better future generation.

Keywords: STEM, literature review, research trend, physics learning.

INTRODUCTION

The Fourth Industrial Revolution, promoting artificial intelligence (AI), robotics, and the Internet of Things (IoT), shows how new technologies are changing industries, jobs, societies, and governments, aiming for a future centred on people (Dalenogare, Benitez, Ayala, & Frank, 2018; Philbeck & Davis, 2018). It brings both social and economic chances and challenges, requiring government support for societal change (Bloem et al., 2014; Manda & Ben Dhaou, 2019). In developed countries, mastering technology is one of the main keys to advancing the efficiency and productivity of society; technology plays a significant role in the nation's progress (Dahlman, Mealy, & Wermelinger, 2016).

Applying scientific principles, particularly physics, is inextricably linked to technological advancements. Including all the modern technology, such as the creation of artificial intelligence (AI), machine learning (ML), Internet of Things (IoT), and quantum computing, which is directly tied to physics principles (Carleo et al., 2019; Dunjko & Briegel, 2018). Thus, understanding physics is essential for the younger generation to improve their cognitive abilities and change the way they think, which will help them use technology more effectively and protect them from the negative effects of modern technologies (Dori & Belcher, 2005). This goal can be easily achieved using a learning strategy based on relevant technological advancements, such as STEM-based learning.

STEM, referred to as Science, Technology, Engineering, and Mathematics, covers a wide range of fields necessary to comprehend and deal with the complexity of the contemporary world (Bybee, 2010). By encouraging critical thinking, problem-solving, and creativity, STEM education seeks to provide students with the ability to solve real-life problems (Yulianti, Wiyanto, Rusilowati, & Nugroho, 2020). For instance, STEM projects are crucial to providing knowledge, promoting positive attitudes, and changing students' behaviour (Nguyen, Nguyen, & Tran, 2020). Besides enhancing learning results, the STEM education program seeks to develop students into capable persons who can handle challenges worldwide, including in Indonesia.

STEM learning development in Indonesia started in 2014 with the 2013 curriculum (Nugroho, Permanasari, & Firman, 2019). STEM research grew each year, peaking in 2019 before the Covid-19 pandemic. Due to the pandemic, all learning activities shifted to virtual learning. Since then, STEM research has decreased as the pandemic spreads (Farwati et al., 2021). Fortunately, learning has resumed, typically now that the pandemic has ended. However, most Indonesian students experienced learning loss because of the pandemic. In most cases, learning loss happens in practically every subject, including physics (Hadi, 2022; Restu, Suryana, Herman, & Mulyati, 2023).

STEM education has been proven to empirically enhance physics learning outcomes through active learning activities and develop student soft skills such as higher-order thinking skills (HOTS), problem-solving, critical, creative thinking, reasoning, and decision-making (Isnaeni, Rudyatmi, Ridlo, Ingesti, & Adiani, 2021; Widyawati, Kuswanto, & Suyanto, 2024; Yulianti & Handayani, 2021). This occurs due to the integration of STEM with various approaches, including ethnoscience, local wisdom, inquiry-based learning, problem-based learning (PBL), project-based learning (PjBL), and other methods. The STEM approach allows students to contribute to the quickly evolving fields of science, industry, and technology by giving them opportunities to learn through hands-on, applied experiences (Stephens, 2017). In the context of teaching physics, STEM education is crucial. Integrating science, technology, engineering, and mathematics prepares students for an era of innovation and technology (Mcdonald, 2016). Critical thinking, teamwork, communication, and creativity are 21st-century learning qualities that students can acquire (Birzina, Cedere, & Kalnina, 2023; Yulianti, Sugianto, & Ngafidin, 2022). Through appropriate, engaging, and beneficial learning, the STEM approach to physics lessons also contributes to students' interest in science and technology (Ibáñez & Delgado-Kloos, 2018). Enhancing the students' curiosity and enthusiasm in studying science and technology in this modern era.

Nationally, the current state of STEM education trend research has been well documented in the previous literature. For example, Farwati et al., (2021) identified a trend implementation of STEM research in 154 articles published between 2015-2020, revealing how STEM learning was conducted in 19 provinces in Indonesia. Then, Ardwiyanti, Prasetyo, & Wilujeng, (2021) systematically analyze STEM research trends based on articles in national and international journals, identifying 50 articles published between 2001-2020, scoping how STEM research integration patterns were conducted. In addition, Parameswari, Sutoyo, & Azizah (2023) used a literature review to describe how STEM strategy is usually conducted in science learning, and identified 45 articles published in Sinta and Copernicus between 2018-2022 related to critical thinking and concept mastery skills. Most recently, Cahyanti et al., (2024) evaluated the implementation of STEM education in high schools to reveal opportunities, challenges, and policy recommendations. However, it's important to note that none of the studies referenced above have conducted a comprehensive review of the implementation of STEM in physics learning research in Indonesia.

Based on that, this gap reveals an opportunity to examine a comprehensive analysis of the implementation of STEM education within the context of physics learning in Indonesia. The result of this study will be set as a reference and may assist educational practitioners and government policy regarding effective strategies, innovative teaching methods, and potential challenges, ultimately contributing to improving education, especially in physics, to develop resilient and well-being human beings. This study aims to gather information on various research projects focusing on the application of STEM in physics learning by using content analysis of several papers about physics education journals published in Indonesia (SINTA) between 2019 and 2024. This investigation seeks to gain comprehensive insight comprehensively about STEM research in physics learning in Indonesia. By conducting these present studies, they may assist in the development of innovative and inclusive educational regulations and teaching approaches in guiding future studies.

Research Question

The questions of this current study were proposed as follows:

1. What are the trends of STEM research elaboration in physics learning in Indonesia?
2. What are the most used integration physics learning approaches in STEM research in Indonesia?
3. What are the potential research topics that integrate specific STEM components and address specific challenges in physics learning in Indonesia?

METHOD

Research Design

The research method used is a systematic literature review. A systematic literature review is a type of secondary research that occurs where the results from several primary sources are gathered to examine an issue for investigation (Snyder, 2019). To find answers to research questions, it also collects and evaluates data. The review applied systematic methods to examine and synthesized all relevant original scientific studies related to the defined research questions, and by employing methodical and explicit approaches to analyze research papers to obtain accurate findings that could be used as a framework for an evaluation (Xiao & Watson, 2019). By using this method, the study expects to gather data from multiple sources to provide an unbiased perspective to address the research question and support the practical application of STEM, especially in physics education. This method guarantees that the results are representative and based on accurate, relevant data that is particularly appropriate for the educational setting of Indonesian schools.

Search Strategy

The literature search was driven through electronic searches in the nationally identified Garuda. Garuda is an Indonesian database that indexes scientific references and publications from Indonesian researchers and academics. Garuda is known to provide high-quality, peer-reviewed, indexed articles and is the foremost reference for access to national scientific information. Keywords used in the search included: "STEM education," "STEM physics," and "STEM physics learning," and

their synonyms, along with appropriate variations aligned with the focus of the study. This strategy was designed to reach publications across relevant physics research nationally in the past 5 years to provide a diversity of viewpoints in the discussion of STEM implementation in physics learning. Each article found will be screened to give its relevance to the study focus, and only those fitting the inclusion criteria will proceed to further evaluation. The relevance of recent literature in this study could be examined how literature published between 2019 and 2024 has shaped current research trends across various fields. In addition, the evaluation is only on the literature published in Sinta 1 and Sinta 2 because it is based on the higher significance and influence of the local Indonesian research. This study aims to evaluate several relevant, credible, and significant findings to answer various learning problems and innovative improvements in the quality of education in Indonesia.

Eligibility Criteria

The eligibility criteria in this study are relevant literature on implementing STEM education at every school level, focusing on physics learning in the local Indonesian context. Studies that meet the eligibility criteria must provide in-depth insights about objectives and purposes, treatment approach, research methods, participants, results, and conclusions.

Study Selection

The article selection process is carried out in two stages: (1) First stage is screening articles based on the title and abstract to ensure that the article discusses the implementation of STEM in physics learning. (2) The second stage is evaluation, full reading of the articles to verify relevance and research quality.

(1) Screening

A diagram of the screening process can be seen in Fig. 1. To select studies for inclusion, the following criteria were used sequentially against article abstracts:

1. Study published between 2019 and 2024.
2. Study published in a physics journal accredited in SINTA 1 & SINTA 2 and can be accessed openly and legally.
3. The study discusses about implementation of STEM in physics learning.
4. The study discusses STEM in the local Indonesian context.
5. Study is empirical (qualitative, quantitative, mixed methods, or meta-analyses).

(2) Evaluation

In order to evaluate the content of each article, the criteria of evaluation must provide insights about objectives and purposes, treatment approach, research methods, participants, results, and conclusions. Those criteria were used against the full-text contents to gain the data extracted in further evaluation. After assessing the content of each article, three were excluded and 54 retained. To prevent bias, the second author also evaluates all the articles.

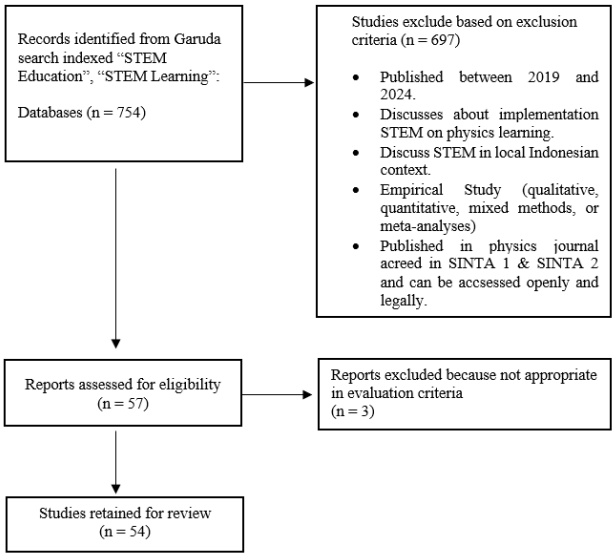

Figure 1. Article Selection Used in SLR Using the PRISMA Model

Data Analysis

The data obtained from the articles that meet the inclusion criteria will be analyzed using thematic analysis. Thematic analysis is a method used to analyze qualitative data by identifying, analyzing, and reporting patterns (themes) within the literature being reviewed by researcher systematically

organize and interprets the data to uncover key themes and concepts that emerge across the studies included in the review. The analysis process involves identifying key themes based on the formula proposed by Susetyarini & Fauzi, (2020) collected data related to the implementation of STEM in physics learning contexts, such as objective and purpose, treatment approach, research methods, participants, results, and conclusions. The findings will be grouped into relevant categories, such as educational policies, teacher training, and technology use. The current analysis findings seek to develop references for innovation and improvement of education in Indonesia.

RESULT AND DISCUSSION

This section presents the main conclusions drawn from a systematic review of STEM education implementation in the context of physics in Indonesia. The research findings are organised around key themes identified during the analysis. This discussion aims to provide new insights that can help advance STEM education at the multi-level of school, clarify the relationships among the studies reviewed, and interpret the results in the context of existing literature. Therefore, in addition to reporting the findings, this section also contextualizes them to offer practical insights and recommendations.

The trends of STEM research elaboration in physics learning in Indonesia (RQ 1)

a. Overview of Papers per Year

The quantity of article publications indicates the frequency of research conducted over a time period. Based on the bar chart shown in Figure 2., between 2019 and 2024, the number of publications on STEM-Physics learning research has increased. The number of publications increased gradually, with 2024 seeing the highest improvement. The trend of publications research on STEM-based physics learning has been increasing, suggesting that more academics are realizing how crucial it is by utilizing technology through STEM to enhance the quality of physics learning in the classroom.

One of the most researched is conducted based on observations about the problems around them, specifically in school education. The most frequently discussed issue recently is the low level of thinking skills among Indonesian students. As a result, many research procedures are conducted as the most effective way to find a solution and solve the problem. Through research, researchers can determine the most effective way for learning design or media that can accommodate students' learning needs in the best possible way.

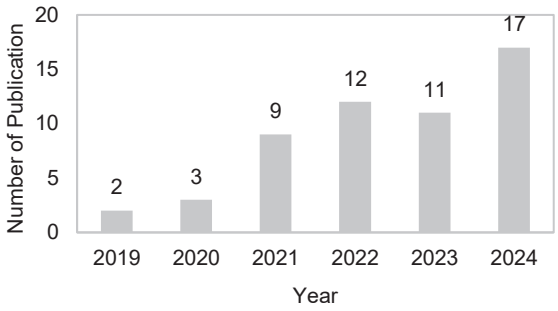

Figure 2. STEM-Physics Publication Research per Year 2019-2024

Based on the findings of numerous studies, it is generally accepted that STEM-based physics learning enhances students' thinking skills, in addition, other soft skills are improved, like active learning, communication, teamwork, literacy, and numeracy (Anugrah, Herlina, & Suyatna, 2023; Khaeruddin & Bancong, 2022; Listiana, Abdurrahman, Suyatna, & Nuangchalerm, 2019; Syukri, Rahmi, Saminan, Artika, & Subramaniam, 2022). As a result, research about STEM applied to physics learning has increased annually shown in Figure. 2, to solve problems and improve the quality of physics learning. These results are aligned with Li, Wang, Xiao, & Froyd (2020) who evaluated 798 articles of STEM education published between 2000 - 2018, discovering that research in STEM education is increasingly important globally. This result also aligned with research conducted by Chiu, Li, Ding, Hallström, & Koretsky (2025) who examined 400 articles published in the International Journal of STEM Education between 2014 and 2023, and found that STEM research grows on average by 20% annually. This growth indicates the rapid expansion of STEM education not only in

Indonesia but also in majors internationally. In addition, these findings indicate increasing awareness of the importance of STEM applied to school education, especially in Indonesia.

There are some insights gained from the increasing quantity of research on STEM-based physics learning. The most important ones are educational offerings that are better linked with the integration of STEM into physics learning. The information obtained from the research findings will have more credibility as additional findings are obtained. As educational practitioners, teachers can use these findings as an inspiration or insight for the learning process they will implement. Teachers will have more options for references before integrating STEM-based physics lessons in the classroom based on their learning needs. In addition, it will increase awareness of the importance of creating an interactive and collaborative learning environment and provide examples of effective teaching practices that promote student-centred learning in physics.

b. Popular Type STEM-Physics Research

The aims to be achieved by the research are determined by the type and design of the research. The most common design employed by researchers to figure out STEM-based physics education is experimental and RnD (Research and Development), shown in Figure 3. The substantial amount of experimental and development as quantitative research on STEM-based physics education suggests that researchers are aware of the need to raise the standard quality of learning in school. Researchers can determine the elements that affect STEM learning quality through experimental research and RnD, which raises the possibility of creating a variety of solutions to address issues. These findings align with research conducted by Bozkurt, Ucar, Durak, & Idin (2019) who identified research trends and patterns in articles published between 2014 and 2016 and examined 258 articles from Scopus, revealing that almost 40% of the 258 articles were quantitative research. These findings also align with Irwanto, Saputro, Widiyanti, Ramadhan, & Lukman (2022) who examined 336 studies of research trends in STEM education between 2011 and late 2020, revealing that quantitative research designs have been the most popular design over the past 10 years among STEM scholars.

In addition, Figure 3. shows data nearly 80% of STEM research in physics education is experimentation and development. It happened because, according to several research findings, development research focuses more on finding creative, useful, and innovative solutions to problems, whereas experimental research enables researchers to assess research variables and their impact on outcomes. (Okpatrioka, 2023; Pinasthika & Kaltsum, 2022; Setyanto, 2013). That is the cause of the imbalance between quantitative and qualitative types of research.

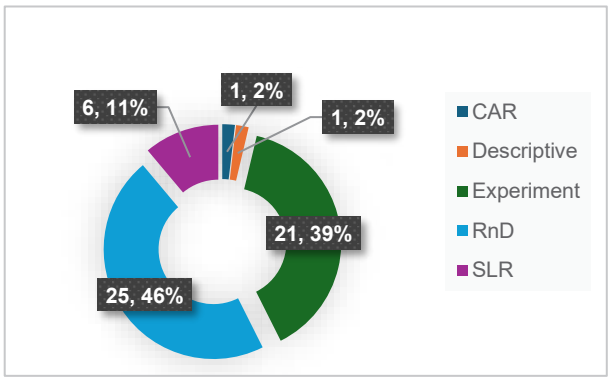

Figure 3. Type Research of STEM-Based Physics Learning

However, it has been discovered that the trend of STEM research on physics learning in qualitative research (descriptive & SLR) is still relatively small (see Figure 3). However, primarily, qualitative research can define a phenomenon in detail and comprehensively (Aspers & Corte, 2019; Yilmaz, 2013). Based on this, due to a lack of information about qualitative research, future researchers can use qualitative designs and concentrate their studies on STEM-based physics learning. This suggestion may assist in how qualitative research methods, such as interviews and observations, provide in-depth insights into comprehensive findings and bring more complexity to STEM in Indonesia's physics learning context. It could analyze specific case studies where qualitative research has uncovered complex social

phenomena that quantitative approaches may neglect in the diversity of STEM research.

c. Most used Subject Research for STEM-Physics

The issues that occur are closely tied to the research subject. Based on data research shown in Figure 4, it is proven that researchers most frequently use experimental and development designs. In order to test their hypotheses, researchers need research volunteers. This suggests that, mostly, researchers aim to compare and create some of the best instructional strategies for solving problems that occur, particularly related to STEM-based physics learning.

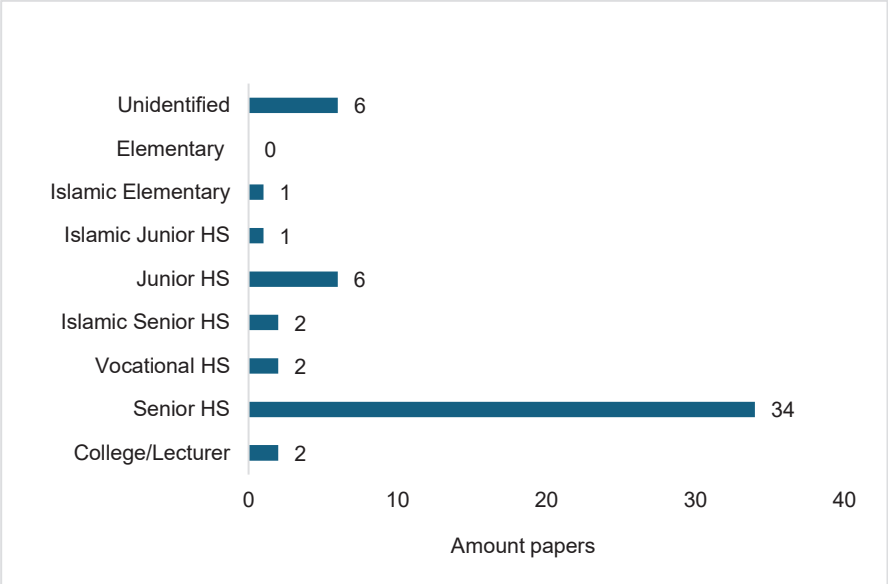

Figure 4. Subject Research Physics STEM-Based Learning

Figure 4 shows that, with 68% of the total research, high school students were the most commonly chosen subjects for the study. These findings are consistent with several studies which suggest high school students have a foundational understanding of various areas, including science, technology, and mathematics. This sets them up for higher-level research and study, like that which might take place at a university. Moreover, groups with educational systems are realizing the value of STEM education increasingly, and they are promoting it through a variety of programs, including research projects and extracurricular activities for high school students. (Dewi & Jauhariyah, 2021; English, 2016; Martín-Páez, Aguilera, Perales-Palacios, & Vílchez-González, 2019; Nurhasnah, Festiyed, & Yerimadesi, 2023).

However, it should be crucial to conduct STEM research in lower education levels, such as middle and elementary schools. Middle school STEM research is crucial for preparing students with a variety of future-relevant abilities. Junior high STEM education can help students develop 21st-century abilities like critical, creative, cooperative, and communicative thinking (Nurhayati, Pramono, & Farida, 2024; Yani & Putra, 2023). Accordingly, it is crucial to investigate STEM-based physics education in an attempt to get young students ready for future research.

d. Most Analysis Data used in STEM-Physics Research

The amount of validity of a study will depend on how well the methods for data analysis are chosen. According to Table 1, N-Gain is the data analysis technique utilized most frequently, by using STEM research on physics learning, which is employed in 30 papers. According to these findings, researchers frequently compare initial and final results using the N-gain test to determine how much students' comprehension of their learning has

improved. Additionally, the N-Gain test can demonstrate how well learning is utilized in research (Isdianti, Nasrudin, & Erman, 2021). This supports several studies that indicate STEM research in physics education has a significant impact on student learning outcomes and boosts student engagement during the learning process, moreover, it can increase student collaboration activity (Ratnasari, Doyan, & Makhrus, 2023; Yulianti et al., 2022).

Table 1. Most Popular Analysis Used in STEM-Physics Research

Analysis Used	Amount
N-Gain	30
Validity	26
Anova	14
Descriptive	7

Based on Figure 5, Descriptive analysis has quite a low frequency of use. This is directly related to the research design in Figure 3, which shows that there is very little qualitative research compared to quantitative research. So, this is an opportunity for researchers to be able to apply qualitative research with a complete and comprehensive discussion to enrich information about STEM research in physics learning.

Figure 5. Word Cloud of Data Analysis Research STEM-Based Physics Learning

Based on Figure 5, Descriptive analysis has quite a low frequency of use. This is directly related to the research design in Figure 3, which shows that there is very little qualitative research compared to quantitative research. So, this is an opportunity for researchers to be able to apply qualitative research with a complete and comprehensive discussion to enrich information about STEM research in physics learning.

e. Popular Topic used for STEM-Physics Research

Most students believe that physics is a science subject that covers a wide range of topics and is very tough (Ady & Warliani, 2022). According to Table 1, wave and temperature & heat are two of the most frequently selected STEM research topics in physics education. This is due to the fact that Wave and Temperature & Heat are very easily applied to STEM-based learning and provide more chances to develop online modules and virtual practicums, and it is related to students' everyday lives. Aligned with research Ratnasari et al., (2023) who suggested that the development of research modules on heat and temperature may improve the usefulness of physics education. The results of this study are also in line with research Chania, Medriati, & Mayub (2020) which suggests that the development of teaching materials on work and energy increases the effectiveness of physics learning in the classroom. Thus, these topics are often chosen in STEM research on physics learning.

Referring to Table 2, it can be seen that a physics topic that is rarely researched is electric matter. In fact, based on several studies, it is stated that on the topic of electricity, more students experience misconceptions and a lack of understanding of the concepts. This is confirmed by the opinion of several studies, which suggest that the majority of students experience misconceptions about dynamic electricity material (Didik, Wahyudi, & Kafrawi, 2020; Hidayatulloh, Humairoh, Wachidah, Iswati, & Suliyanah, 2015).

Table 2. Most Used Topic Research STEM-Physics

Topic Research	Amount
Energy	6
Fluid	5
Wave	7
Environment	5
Electric	3
Optic	3
Heat and Temperature	7

Based on that, it is very important to carry out research on this topic in an effort to increase understanding of concepts and reduce student misconceptions, especially the application of STEM to classroom learning. Based on this, STEM research on the topic of electrical materials needs to be encouraged to provide more information.

f. Result of Tren STEM Research on Physics Learning in Indonesia

An evaluation has been conducted on 54 articles from SINTA 1 & SINTA 2 indexed physics journals; based on several analyses that have been presented, it can be stated that the trend of STEM research development in the context of physics learning in Indonesian research is getting bigger every year between 2019 - 2024, with a peak in 2024. RnD is a popular research model, followed by Experiments, with a percentage of quantitative research of 80% of the total articles. Senior high school is the most popular subject participant, and “wave” and “Heat & Temperature” are the most frequent topics in STEM physics research. In addition, N-Gain is the most used analysis data.

These findings aligned with Asbanu (2023) who conducted a content analysis of articles published in physics education journals across Indonesia from 2017 to 2022, focusing on critical thinking skills. The study revealed an increase in the number of publications related to critical thinking skills each year. The most commonly used research design was quantitative, with high school students as the primary research subjects. The most frequently employed analysis methods were N-Gain and the T-test. Furthermore, these findings are consistent with Ha et al., (2020) who identified 175 STEM education research articles across ASEAN between 2000 and 2019, revealed that STEM education has experienced significant growth in the past three years and aims to develop various relevant skills.

Several findings reveal that STEM education is crucial in developing high school students. Research on STEM education indicates that the awareness of educational practitioners is widely open. Promoting effective STEM education and the workforce could improve students' critical thinking skills, problem-solving abilities, and academics. These findings not only happen in local Indonesian communities but also globally, such as research conducted by Rafanan, De Guzman, and Rogayan, (2020) who identify STEM implementation in the Philippines, in line with research conducted by Jakubowski & Piotrowski, (2020) who identify STEM Education in Poland, and also Aslam et al., (2022) conducted STEM research on Pakistan. In addition, research shows that BRICS countries (Brazil, Russia, India, China, and South Africa) play a significant role in STEM education. China has the most prominent highest activity in STEM according to Fayzullina et al., (2024). Based on these findings, STEM education is fundamental to preparing future generations to navigate an increasingly complex and dynamic world. Generations build resilience with the necessary skills to confront and overcome future challenges, which is very important. Consequently, investing in STEM education represents a strategic commitment to human development and well-being, much like approaches led by other leading countries.

The trends of STEM research integration approach on physics learning in Indonesia (RQ 2)

a. Treatment STEM-Physics Research

Treatment aims to determine the significance of specific conditions on the parameters under study or to evaluate the researcher's hypothesis. According to Table 3, the most popular approach in STEM research on physics education is Project-Based Learning (PjBL). PjBL has been used in 14 publications. This is a result of a strong connection between STEM and project-based learning. Students can more easily apply STEM principles comprehensively using the applied project-based learning (PjBL) approach. This method successfully integrates science, math, engineering, and technology as students undergo several iterative processes to create a project-related result. Students can apply scientific and mathematical knowledge in designing and constructing engineering solutions while utilizing technology as a critical tool to support the process. As a result, PjBL offers a structured environment in which students can actively apply interdisciplinary concepts to real-world challenges. The results of this research are in line with the findings research by Roslina, Samsudin, and Liliawati (2022) who stated that the relevance of implementing the PjBL STEM model in the context of physics learning is dominated by learning tools and skills. So it is not surprising that PjBL-STEM occupies the largest research treatment.

Table 3. Most Treatment Used for Research

Treatment Used	Amount
PjBL	14
Module	9
Worksheet	7
Inquiry	4
EDP	3
Virtual Lab	3

The second most common treatment after PjBL is Module. The module is the second most popular treatment, behind PjBL, shown in Figure 5. In some cases, the way STEM learning modules are applied can immediately impact how effectively students utilize STEM principles to enhance their learning process, thereby maximizing their understanding of physics. Educational modules can affect students' thinking abilities. This activity facilitates students' deep comprehension of physics concepts and fosters analytical skills. This aligns with research findings by Nazifah and Asrizal, (2022), which showed that the STEM module in physics instruction could greatly improve learning activity optimization.

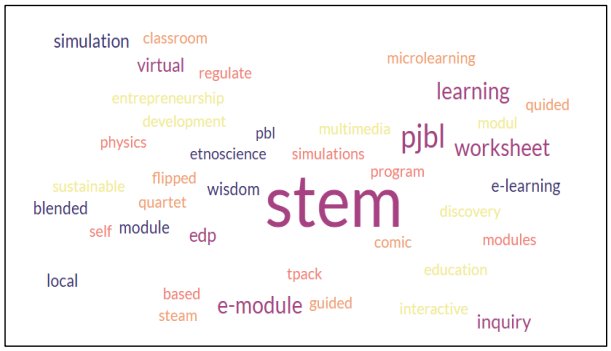

Figure 6. Word Cloud of Treatment Integrated with STEM-Based Physics Learning

Based on Figure 6, Problem-Based Learning (PBL) and Inquiry-Based Learning are among the least commonly employed approaches in STEM-based physics education research. However, despite relatively low usage, these methods are crucial to addressing key educational issues, such as problem-solving, character development, student literacy, and critical thinking skills (Isdianti et al., 2021; Kong, Matore, & Effendi, 2020). Therefore, future research holds significant potential to advance knowledge of STEM-based physics education by thoroughly examining the integration of STEM-PBL and STEM inquiry. More exploration of these approaches may assist and offer valuable insights into STEM-Physics within the context of physics learning by enhancing the effectiveness of student engagement, problem-solving abilities, and the development of critical thinking skills.

b. Most Aspects Aims for STEM-Physics Research

Students' skills have a significant influence on the demands of changing times. Preparing students' skills is crucial for them to live in a complex and ever-developing society. Based on Table 4, creative thinking is the most researched skill aspect in STEM-based physics learning. Referring to Table 4 is closely related to STEM, which requires students to think creatively in engineering a phenomenon or product to create valuable innovations. The findings of this study align with several studies that state that students' creative thinking skills need to be improved, and STEM has been proven to significantly enhance students' creative thinking skills (Anugrah et al., 2023; Khoiri, Ristanto, & Kurniawan, 2023).

Table 4. Most Aspect Aims at STEM-Physics Research

Research Aims	Amount
Creative Thinking	10
Critical Thinking	6
Problem Solving	6
Validity	5
HOTS	4
Learning Outcomes	4

STEM education has been demonstrated to significantly promote the development of creative thinking in students. By involving in real problems, students are encouraged by active learning to enable students to cultivate progressive problem-solving competencies, which are crucial to fostering creativity and identifying multiple solutions to complex issues (Putri, Krisnaningsih, Suprapro, Deta, & Dwikoranto, 2021). STEM education not only enhances critical thinking but also supports the expansion of multiple skill aspects through its emphasis on interdisciplinary learning and practical application in the context of physics, as shown in Figure 7.

Figure 7. Word Cloud of Skill Aspect Research on STEM-Based Physics Learning

In addition to creative thinking, 21st-century skills are essential for students. The 21st-century skills comprehensively cover the 4C skills (Creative, Critical, Communicative, and Collaborative), making it very important for education practitioners to equip students with these skills. However, based on Figure 6, the 21st-century skills are relatively rare in these findings compared to other competencies. This result suggests a gap in the current research landscape and a need for further investigation about the integration of STEM in the context of physics education, particularly about the development of 21st-century skills. More comprehensive studies are necessary to explore how STEM practices in physics learning can be leveraged to cultivate better skills, such as critical thinking, collaboration, communication, and technological literacy, which are essential for preparing students for the challenges of the modern world.

c. Result of Trend STEM Research Approach Integration on Physics Learning in Indonesia

In general, the treatment used in research is very closely linked to the aspect that aims to be developed. As an example, treatment PjBL is linked to Creative thinking as shown in this current study. The treatment aligns with the specific aspects of the population, and by using appropriate treatment, could enhance the effectiveness of the result (Feldstein & Glasgow, 2008). Based on the evaluation conducted on 54 articles from SINTA 1 & SINTA 2 indexed physics journals, based on several analyses that have been presented, it can be stated that the trend of STEM research approach integration in the context of physics learning in Indonesia is that Project-Based Learning (PjBL) is the most popular treatment used, the second is Module. In addition, creativity is the most frequent aspect aimed to be developed by STEM Research.

These findings are aligned with research conducted by Roslina et al., (2022) Identifying 36 articles from reputable international journals, such as those indexed by Scopus, Web of Science (WoS) and SINTA, reveals that research on PjBL in physics learning has significantly grown over the 8 years (2015 to 2018). The results show that by using STEM-PjBL on physics learning, it not only develops skills aspects, but also has a positive impact on students. Moreover, several study shows that PjBL is related to Creative Thinking ability the same as shown in Table 3 & Table 4. These findings are in line with the study conducted by Rohmatika, Yuliani, & Annovasho (2024) who examined 28 articles of PjBL-STEM from 2014 to 2024 from Google Scholar. Their findings reveal that PjBL has an 85% impact on students' creative thinking skills.

Based on the findings shown in Figure 6, the 21st-century skills quietly small compared to Creative, Critical, and Communication. However, in century learning, the four skills, e.g. creative thinking, communication, collaboration, and critical thinking, are already covered. STEM researchers should be concerned about the importance of 21st-century abilities, particularly in physics education, as they are highly relevant to the requirements of the world today and in the future. According to Newton & Newton, (2014) claim that, in a highly interconnected 21st-century world, viewing creativity only from one perspective is not enough. Students need to learn how to communicate and elaborate on their creative or critical ideas (Higgins, Flower, & Petraglia, 1992). Communication and elaboration might lead to more innovative solutions, and be able to involve ideas through teamwork (Thornhill-Miller et al., 2023). 21st-century skills are a complete package for students in the future world that provides innovative ideas and how to execute them based on teamwork. Therefore, these findings suggest that educational practitioners to develop 21st-century skills in their learning systems, not only in physics but also in every subject, especially in science education progress.

The potential STEM research integration on physics learning to address resilient generation in Indonesia (RQ 3)

Several discussions have been presented previously regarding STEM research trends in physics learning in Indonesia. Integrating STEM into various approaches could enhance better concepts and develop many skills, such as creative thinking, critical thinking, and more, as shown in Figure 5, but not all those skills play a significant role in developing a resilient generation that could face any challenges and adapt to the complexity of the future world. There are several factors that can encourage the formation of a resilient generation, one of which is an educational strategy. Clauss-Ehlers & Wibrowski, (2007) reveal that educators should gain a greater understanding of the processes that promote resilience in youth. In addition, educators need to explore not only how students perform during and after college, but also what can be done to forge success while students actively participate in the educational process. This aligned with many studies that promote active learning participation among the students, known as “student-centred learning” and in line with the STEM Education process. Implementing STEM in learning progress could promote effective learning, a better learning environment, and innovative teaching strategies (Banks-Hunt, Adams, Ganter, & Bohorquez, 2016; Benabentos et al., 2021). Therefore, the implementation of STEM in any educational process may assist the development of a resilient generation, especially in Indonesia.

Based on the current study findings show that most of the researchers' STEM in Physics learning across Indonesia aims to develop creative thinking by using Project-Based Learning treatment. There is nothing wrong with this treatment, but researchers should be aware of developing aspects of 21st-century learning skills, which already include 4 types of skills, such as: Critical, Creative, Communication, and Collaboration. This happens because 21st-century learning skills hold crucial opportunities to develop well-being and human ability skills to adapt complexity of global challenges. Many leading countries around the world have developed STEM in their educational programs, such as BRICS nations, the United States, Australia, and other developed countries, which mostly aim to create a workforce that is ready to face the challenges, especially in technology-oriented challenges (Li, 2021). Treatments that suggest enhancing 21st century skills are learning approaches which involve active thinking, communication, and collaboration, such as Project-Based Learning (PjBL), Problem-Based Learning (PBL), Research approach, and Guided inquiry learning. Based on the lack of evidence for a research-based learning approach, it is highly recommended that STEM integration with a research-based learning approach be examined.

According to several discussions presented, it is highly recommended that STEM research in Indonesia should examine more deeply how STEM implementation uses appropriate methods, treatments, and approaches to improve the 21st-century skills of the young generation, these findings can be a reference for educational policy makers regarding the advancement of education in Indonesia. In addition, educational practitioners can get innovative teaching methods on every subject level, such as in elementary school or junior high school, which is very important for 21st-century learning skills to be developed.

Limitations of the Study

This search strategy for systematic analysis has certain limitations. Although it is acknowledged that not all written publications are available in the databases we used, we made an effort to compile all of the Indonesian literature. Our search was limited to articles indexed in SINTA 1 and SINTA 2, so papers that did not contain Indonesia or any Indonesian location as keywords or in their abstracts were excluded during the identification process. The STEM research trend in Indonesian physics education was identified by the systematic review. In addition, studies documenting STEM education policy in Indonesia are quite low. Recommendations include:

1. Firstly, in contrast to further studies, we suggest that one not only use the “Garuda”

search but also another indexed search and double-check the article in SINTA databases.
2. Researchers must examine Indonesian teachers' views and existing awareness of STEM education, not only in physics.
3. This study only limited to papers published in Physics Journal indexed higher SINTA, and articles published in Science Journal are excluded.
4. Future research could discuss the trends in STEM implementation in physics compared to other countries comprehensively.

CONCLUSION

This study looked at STEM-based physics education articles published in Indonesian physics education journals from 2019 to 2024. It showed a steady increase in the number of research papers, with the highest number in 2024. The analysis found that Research and Development (RnD) was the most common type of study, followed by experimental studies. Most of the research used quantitative methods, making up about 80% of all the studies. The main group studied was senior high school students, and the physics topics most often explored were waves and heat and temperature. N-Gain analysis was the most widely used method for analyzing data. In terms of teaching methods, Project-Based Learning (PjBL) was the most used, followed using modules. Creative thinking was the main skill that researchers aimed to develop. These results show that the studies align with the goals of building 21st-century skills like creativity, critical thinking, collaboration, and communication, which are important for students to handle global challenges. The growing number of studies shows that educators are becoming more aware of the importance of integrating STEM in teaching to improve critical skills, problem-solving, and academic success. The study suggests that future research should use a wider range of STEM-based teaching methods, such as PjBL, Problem-Based Learning (PBL), guided inquiry, and research-based approaches to better develop 21st-century skills. The findings offer valuable insights for researchers, teachers, and policymakers in creating new and inclusive physics learning methods and in making educational policies that help build a generation that is resilient, creative, and critical.

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