



Trends in STEM education from 2020 to 2023: A critical review in selected academic publications

Tren pendidikan STEM dari tahun 2020 hingga 2023: Tinjauan kritis dalam publikasi akademis terpilih

Naufal Rabah Wahidin^{1*}, Diana Rochintaniawati¹, Rika Rafikah Agustin¹

¹ Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia

*naufalrabah@upi.edu

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Abstract: The numerous amounts of research regarding STEM education in the last five years indicate that every country put their eyes on the development of STEM education itself. In the school settings, the STEM education rises starting from middle school to higher education. There is a need in reviewing the articles of STEM education for middle school students. By selecting 17 articles indexed by Scopus and has a grade of Q1 from 2020 to 2023, this study guarantees the maintenance of quality in the selected articles. The results of this critical review shows that the majority of articles can be divided into big three themes; the integration of STEM education with other instructional approaches, STEM and gender, and professional development in STEM education. This study implies that various instructional approaches can maximize STEM education to foster students' learning output. There is also no correlation between gender and their cognitive skills while learning a STEM subject. The most important thing, STEM education can be more successful if the teachers get proper professional development.

Keywords: STEM, gender, approaches, professional development.

Abstrak: Banyaknya penelitian mengenai pendidikan STEM dalam lima tahun terakhir menunjukkan bahwa setiap negara menaruh perhatiannya terhadap perkembangan pendidikan STEM itu sendiri. Di lingkungan sekolah, pendidikan STEM meningkat mulai dari sekolah menengah pertama hingga pendidikan tinggi. Perlu adanya kajian terhadap artikel-artikel pendidikan STEM untuk siswa sekolah menengah. Dengan memilih 17 artikel yang terindeks Scopus Q1 dari tahun 2020 sampai 2023, penelitian ini menjamin terjaganya kualitas artikel yang dipilih. Hasil tinjauan kritis ini menunjukkan bahwa mayoritas artikel dapat dibagi menjadi tiga tema besar; integrasi pendidikan STEM dengan pendekatan pembelajaran lainnya, STEM dan gender, dan pengembangan profesional dalam pendidikan STEM. Penelitian ini mengindikasikan bahwa berbagai pendekatan pembelajaran dapat memaksimalkan pendidikan STEM untuk mendorong hasil belajar siswa. Juga tidak terdapat korelasi antara gender dengan keterampilan kognitif mereka saat mempelajari mata pelajaran STEM. Yang terpenting, pendidikan STEM bisa lebih sukses jika para guru mendapat pengembangan profesional yang tepat.

Kata kunci: STEM, gender, pendekatan pembelajaran, pengembangan profesional

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a) Introduction

The numerous issues in our rapidly shifting world have heightened the demand for creative and inventive solutions. There is a dire need for professionals with essential 21st-century skills and competences to address many complicated real-world afflictions. These abilities are critical for tackling current and potential global problems, including those related to energy, climate, the environment, and health, among others. Science, technology, engineering, and mathematics (STEM) have taken center stage in educational and policy circles more than ever before as viable tools for addressing these concerns (Eroğlu & Bektaş, 2022; Han et al., 2021; Hiğde & Aktamış, 2022; Sellami et al., 2023; Shahbazloo & Abdullah Mirzaie, 2023). STEM education, as outlined by Tsai, Chung, and Lou (2018), stands out as one of the most widely employed learning methodologies in many countries today. Moreover, the STEM approach has infiltrated various industries and subjects, with a particular impact on science education.

STEM education is considered a viable alternative for enhancing pupils' test scores, which are still perceived as low in PISA and TIMSS (Pimthong & Williams, 2020). The way STEM can tackle those concerns is through hands-on activity. STEM education is mostly related to hands-on activities. It has been found that hands-on activities can make the learning process more meaningful for students (Hiğde & Aktamış, 2022; Hsiao et al., 2023; Knezek & Christensen, 2020; Tan et al., 2023; Tsinajinie et al., 2021; Wilson, 2021). The learning process in STEM education indicates that students and teachers to collaborate together to make it successful (Eroğlu & Bektaş, 2022; Flegr et al., 2023; Han et al., 2021, 2023; Sellami et al., 2023; Wilson, 2021). With a variety of instructional models and approaches, teachers need to explore the most suitable ones for teaching STEM, not only to make the learning process more meaningful but also to improve students' learning outcomes (Eroğlu & Bektaş, 2022; Hsiao et al., 2023; Knezek & Christensen, 2020; Shahbazloo & Abdullah Mirzaie, 2023; Simeon et al., 2022; Wilson, 2021).

The research about STEM education nowadays has become abundant. It is also noticed by the amount of research regarding critical review of STEM education. The study by Rottinghaus (2018) focused on the critical review of STEM career assessment, another study by Takeuchi (2020) focused on the critical review of transdisciplinary in STEM education, meanwhile a study from Winberg (2019) focused on critical review of STEM discipline in higher education. However, there is still a gap in the study of critical reviews focusing on middle school students. This research aims to address this gap and conduct a critical review of selected articles related to STEM education for middle school students over the last 5 years.

b) Method

The method in this study is critical review of academic publications. The article chosen has met the predetermined criteria, which is indexed by Scopus (Q1), written

in English, the theme is STEM education, not an article review, published in the last 5 years, and focusing on middle school students. In this study, the authors chose 17 articles from reputable international journals indexed by Scopus (Q1) from 2020 to 2023. Initially, over 30 articles related to STEM were collected. However, they exhibited variations in index grade, with many being article reviews, a type of publication authors avoid. A summary of the journals can be seen in table 1.

Table 1. Summary of Journal for Critical Review

No	Name of Journal	f	Indexed By
1	Journal of Science Education and Technology	1	Scopus (Q1)
2	Education and Information Technologies	1	Scopus (Q1)
3	Thinking Skills and Creativity	3	Scopus (Q1)
4	Heliyon	1	Scopus (Q1)
5	International Journal of Technology and Design Education	4	Scopus (Q1)
6	International Journal of Science and Mathematics Education	1	Scopus (Q1)
7	Educational Technology Research and Development	1	Scopus (Q1)
8	Journal for STEM Education Research	1	Scopus (Q1)
9	International Journal of STEM Education	1	Scopus (Q1)
10	Learning and Instruction	1	Scopus (Q1)
11	Science & Education	1	Scopus (Q1)
12	Learning and Individual Differences	1	Scopus (Q1)
	Total	17	

1. Data Analysis

This study analyzes the main problems in each article and explains the results descriptively. In the results and discussion section, three main themes will emerge based on the analyzed articles. These three main themes will include the integration of STEM education with various instructional approaches, STEM and gender, and professional development in STEM education.

2. Research Procedure

The authors adopted the research procedure from Winarno, Rusdiana, Samsudin, Susilowati, Ahmad & Afifah (2020) studies. There are five stages in making this critical review. The stage can be seen in figure 1.

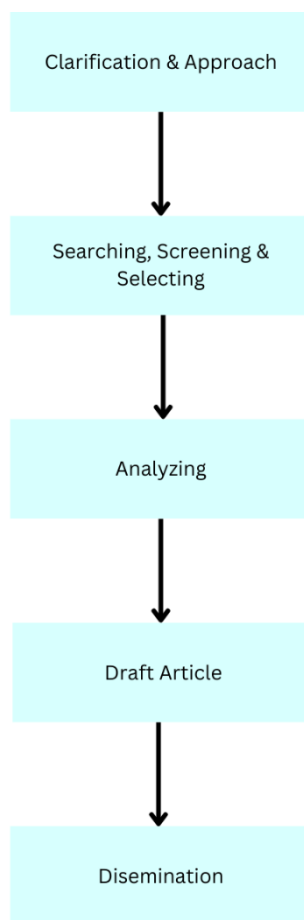


Figure 1. Research Procedure

In the first stage, the authors initiate an investigation into the need for reviewing articles related to STEM education. During the second stage, the authors focus on searching for articles pertaining to STEM education, emphasizing specificity and consistency by selecting articles indexed only by Scopus with categories limited to Q1. Although there are more than 30 articles available, the authors choose to analyze only 17. In the third stage, the authors delve into reading each selected article, conducting a thorough analysis of the methods, problems addressed, instruments used, results obtained, implications, as well as both strengths and weaknesses. Subsequently, the authors proceed to draft an article encompassing the critical review, intending to publish it in a SINTA-indexed journal.

c) Results and Discussion

1. General Characteristics of Articles

From the 17 articles, the general characteristics have been analyzed based on its type of publications, research design, and year of publication.

a) Articles characteristics based on type of publications

The type of academic publications includes journals, books, proceedings, and etc. Table 2 shows the characteristics of 17 articles based on type of publication

Table 2. Type of Publications

No	Type of Publications	Number of Articles (f)	%
1	Journal	17	100
2	Book, Proceeding	0	0
	Total	17	100

All selected academic publications are from journals, not books or proceedings. This ensures that the chosen articles can be maintained in terms of quality. Out of the 17 articles, all are sourced from reputable international journals.

b) Articles characteristics based on research design

In general, research design consists of three types: quantitative, qualitative, and mixed-methods. Among the 17 articles analyzed, the research designs vary. Table 3 displays a summary of the research designs.

Table 3. Research Design

No	Research Design	Number of Articles (f)	%
1	Quantitative	11	64.7
2	Qualitative	4	23.5
3	Mixed-methods	2	11.8
	Total	17	100

c) Articles characteristics based on year of publication

Based on predetermined criteria, the authors have decided to analyze articles published no more than 5 years ago. The distribution of articles based on the year of publication is shown in Table 4.

Table 4. Year of Publication

No	Year of Publication	Number of Articles (f)	%
1	2019	0	0
2	2020	4	23.5
3	2021	2	11.8
4	2022	4	23.5
5	2023	7	41.2
	Total	17	100

2. STEM Integrated with Various Instructional Approaches

One of the instructional approaches that has been related to STEM education very often is project-based learning (PBL). From the 17 articles, the study by Tsinajinie, Kirboyun & Hong (2021) is very interesting to analyze. They investigate the roles of students with visual impairment (VI) in a STEM education program and explore effective strategies for implementing outdoor STEM education activities tailored to students with VI. The Academy proved to be beneficial in fostering science awareness among students with VI. The activities incorporated various accessible elements, and technology options were employed efficiently. Studies focusing on special needs students are notably scarce, especially in STEM education.

The study from Wilson (2021) also focuses on the integration of PBL and STEM learning in the school that has socio-economic disadvantages. The study identified three defining characteristics—establishing a culture, fostering active learning, and utilizing multidimensional assessment—that can contribute to the successful implementation of STEM PBL in schools facing disadvantages. Additionally, it suggests that school leaders play a crucial role in actively promoting an environment where teachers are encouraged to experiment with new pedagogical approaches and where students feel motivated and confident to engage in STEM learning.

A study by Yahaya (2022) is integrating STEM education with environmental interactive based education called PRInK. The PRInK model and the prototype enhance society's awareness of environmental issues, commencing from middle school. They not only boost STEM interest but also contribute to an enhanced overall quality of life by fostering a shared understanding for future generations.

It is also found that 5E-based STEM education is popular in the last 5 years. The study from Shahbaz Loo & Mirzaie (2023) and Eroğlu & Bektaş (2022) shows that 5E-based STEM education can be an interesting way to improve the quality of science education and can lead to effective science learning while stimulating creativity. The 5E-based STEM education can foster students' academic achievements, creativity, and views on the nature of science.

The STEM activity-based education program presented by Hiçde & Aktamış (2022) is intriguing for analysis. Their aim is to determine the impact of STEM activities on the science process skills, motivation, career interests, academic achievements, and views towards STEM education among seventh-grade students. The study encompasses numerous variables, providing a more in-depth discussion compared to other research. The findings reveal that students derive the most benefit from STEM activities in areas such as designing for daily life, acquiring daily life skills, and developing STEM products. However, students faced challenges, including a lack of task sharing, scheduling difficulties, insufficient dexterity, disagreements, and failures in the design process.

The study about design thinking approaches integrated with STEM education arises in the last 5 years. The study was conducted by Hsiao (2023) and Wingard (2022). The integration of the design thinking approach in STEM learning emphasizes that students should offer real-world solutions to the community. The study revealed that the design thinking approach also encourages students to be actively engaged in the learning process, involving activities such as asking questions, proposing solutions, planning, and redesigning. Design thinking aids students in developing an intuitive understanding by observing problems and synthesizing information from various perspectives. The primary goal of the design thinking approach is to uncover solutions for the challenges faced by society.

The combination of virtual and video experiments in STEM education was conducted by Flegr, Kuhn & Scheiter (2023). The data was taken during covid-19 pandemic. The study indicates that either virtual experiments alone or combinations of virtual and video experiments can effectively enhance students' conceptual understanding if appropriately guided. With well-designed instruction, inquiry learning in various experimentation settings becomes feasible even in remote schooling situations.

STEM Problem Solving conducted by Tan, Ong, Ng & Tan (2023) provides something interesting too. In this study, Dewey's concept of practical and scientific inquiry and Bereiter's notions of referent-centered and problem-centered knowledge were employed to analyze six lessons where students participated in integrated STEM problem-solving. The findings suggest that an integrated approach to STEM problem-solving, which underscores the link between scientific knowledge and practical reasoning, can enhance the learning experience and the quality of student solutions.

Lastly, the comparison between web-based and classroom-based STEM learning has been conducted by Lin, Yu, Hsiao, Chang & Chien (2020). The study suggests that Web-based collaborative problem-solving systems, when accompanied by teacher guidance, can be employed to enhance the collaborative problem-solving skills of junior high students in STEM education.

3. STEM and Gender

Gender is one of the most frequently considered variables in relation to STEM education (Knezek & Christensen, 2020; Sellami et al., 2023; Simeon et al., 2022; Wang

et al., 2023). The research regarding gender in STEM interest and career inspiration has been conducted by Sellami (2023). Results indicated that whereas students' interest in mathematics and science subjects were aligned with their likelihood to pursue STEM careers, however, their interest in engineering and technology doesn't line up with their STEM career aspirations. Female students exhibited higher STEM interests than their male counterparts, while especially expatriates were more inclined toward STEM than Qatari nationals.

The study conducted by Knezek & Christensen (2020) aimed to investigate the dispositions of middle school students toward STEM subjects and assess the influence of a hands-on project on students' STEM content knowledge. The results revealed notable differences in STEM dispositions but minimal differences in content knowledge when comparing males to females.

Another study regarding gender and STEM education was conducted by Wang, Tan, Zhou, Liu, Zeng & Xiang (2023). The study sought to examine gender disparities and investigate the primary factors influencing students' interest in STEM careers. According to the findings, male students scored significantly higher than their female counterparts in all constructs, except for STEM career perception, where no significant gender difference was observed.

The final article that discusses gender and STEM education is the study conducted by Simeon, Samsudin & Yakob (2022). They also employed a design thinking approach, similar to the previous study. The findings indicate that the utilization of the developed STEM-design thinking instructional module for learning selected physics concepts was effective in improving the achievements of both male and female students. This study also suggests that cognitive abilities of male and female students are not determined by genetic differences between them.

4. Professional Development in STEM Education

Implementation of STEM education cannot be succeeded if it's relied on students only. Teachers who participate in a STEM professional development program before they teach the lesson to students can help STEM education to be well-implemented (Han et al., 2021, 2023; Wilson, 2021). The research by Han, Kelley & Knowles in (2021) and (2023) focusing on professional development for teachers to teach STEM in middle school level. The objective of these two studies is to examine the impact of the STEM class following the conclusion of the Teachers and Researchers Advancing Integrated Lessons in STEM (TRAILS) project. Researchers seek to understand whether it has an influence on students' academic achievements and the development of twenty-first-century skills. The study demonstrates that the proficiency of teachers in delivering STEM-integrated lessons plays a crucial role in students' academic achievements and enhances their confidence in developing 21st-century skills. It is supported by research from Nazifah & Asrizal (2022), which suggests that teachers' proficiency in utilizing STEM-based modules with electronic learning materials can positively impact student knowledge and 21st-century skills in science and physics learning.

D. Conclusion

The research on STEM education through a review of 17 articles indexed in Scopus (Q1) over the past five years has highlighted several key areas of focus. Upon critically reviewing selected articles from reputable international journals, it becomes evident that STEM education has primarily emphasized integration with other learning approaches, gender-related investigations, and the professional development of teachers. This study suggests that future research can employ a similar critical review method, but the scope of STEM education needs to be more specific.

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