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Inclusive STEM Education: Bibliometric Analysis and Recommendations for Implementation in Indonesia's Diverse Context

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Abstract. Research on inclusive Science, Technology, Engineering, and Mathematics (STEM) education has advanced significantly in developed countries, but remains limited in developing countries such as Indonesia. This study aims to explore the global trends in inclusive STEM education and to provide recommendations for its application in the Indonesian context. The research combines bibliometric analysis and an integrative review guided by the PRISMA Framework. Data analysis uses both quantitative and qualitative methods, including coding and co-occurrence network analysis for trend visualization. Findings indicate that, based on the 20 papers most frequently cited, the main contributors to this field of research are from the Americas, with the university level being the most researched. The most frequently recommended strategies include the fostering of learning that strengthens students' sense of belonging to STEM, high-intensity active learning, and personalized learning that provides more inclusive support, especially for minority groups. We recommend several essential factors of inclusive STEM education in the Indonesian context, including: 1) interdisciplinary STEM education; 2) cultural relevance; 3) collaboration; and 4) the use of digital technology. The implications of this research are encapsulated in the provision of an overview of the essential aspects of inclusive STEM education, which can be applied not only to developed countries but also to developing countries with a highly diverse context, such as Indonesia.

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Therefore, this research represents an invaluable contribution toward achieving Sustainable Development Goal 4, ensuring quality education for all.

Keywords: Inclusive; STEM education; culture; collaboration; digital technology

1. Introduction

A critical issue in education today is the challenge of regulating the system to turn diversity challenges into strengths for building a more sustainable and inclusive society for the future. Massive global changes have heightened diversity, including demographic, ethnic, socioeconomic, and national minorities, often widening inequality and creating further barriers to inclusion. Diversity often harms minorities, resulting in their needs being neglected, their inability to reap maximum benefits, and a higher potential for failure in the learning process (Whitcomb & Singh, 2021).

Therefore, the existing education system must adapt to promote inclusive education for all students (Cerna et al., 2021). Concrete steps towards educational transformation are needed to support the achievement of Sustainable Development Goal (SDG) 4, which aims to provide quality education that is inclusive and equitable for all. In addition to inclusive education, the implementation and development of Science, Technology, Engineering, and Mathematics (STEM) education continues to attract global attention, as a nation's STEM capacity is believed to be an indicator of its progress (Niancai et al., 2024). Unfortunately, there remains a dearth of opportunities in STEM fields, particularly for underserved children (Clements et al., 2021).

Compared to developing countries, including Indonesia, developed countries are further down the path to providing inclusive STEM education. According to a search of the Scopus database using the keywords 'Inclusive+STEM+Education', research publications on inclusive STEM education have significantly increased in a global context; however, research on this topic has not been widely explored, especially in developing countries such as Indonesia. In the United States, for example, high school programs have been explicitly designed for developing STEM skills and increasing inclusivity; these are sometimes known as Inclusive STEM high schools (ISHSs) (Means et al., 2017).

In addition, the Universal Design for Learning (UDL) framework offers an inclusive STEM education that can be accessed by all students, including those with disabilities (Schreffler et al., 2019). In the UK, research has sought to identify the potential for the use of games as pedagogical tools to promote STEM learning spaces that can mitigate gender differences (Rushton & King, 2020). Another study focuses on ethnic minorities in the UK and explores the factors that influence their sense of belonging, which can support or provide targeted inclusive education (Chiu et al., 2025).

As the fourth most populous country in the world, Indonesia has a high level of diversity. Through education, the Indonesian government has been focusing more on developing STEM talents to realize sustainable development. The Ministry of Primary and Secondary Education of the Republic of Indonesia has also created various programs to improve STEM education in Indonesia; for example, through the Kihajar STEM Competition (Ministry of Primary and Secondary Education of the Republic of Indonesia, 2024); the launch of the Smart Indonesia STEM Movement 2025-2027 (Ministry of Primary and Secondary Education of the Republic of Indonesia, 2025b); and emphasizing that STEM mastery must be inclusive (Ministry of Primary and Secondary Education of the Republic of Indonesia, 2025a).

Learning designs that can accommodate the diversity of learning abilities, cultures, ethnicities, religions, and economic levels that characterize Indonesia's population are urgently needed. STEM education can provide learning that trains students to review and solve problems from multiple perspectives by integrating STEM disciplines (Nugraha et al., 2024). Such diversity of viewpoints and experiences can be a considerable asset for creating sustainable solutions (Maulucci et al., 2023). However, even though STEM education continues to grow (Lisa & Efwinda, 2024; Nugraha et al., 2024), integrating diversity in STEM learning requires approaches that can accommodate these differences effectively. Therefore, establishing an inclusive STEM learning environment has become a priority (Kewalramani et al., 2024), and the first step is to conduct mapping and an integrative literature review to determine the kind of inclusive STEM education that is needed.

Mapping research and literature reviews are common as initial studies to map and identify trends, explore research gaps, and provide strong scientific evidence. For example, systematic reviews have explored inclusive education for students with developmental disabilities in sub-Saharan Africa (Genovesi et al., 2022). Another study systematically reviewed the literature on inclusive pedagogy in higher education (Stentiford & Koutsouris, 2021). Although research on inclusive STEM education has significantly increased in developed countries, it remains limited in developing countries such as Indonesia. Of the existing literature review studies to date, none has yet provided a thorough understanding of inclusive STEM education. This research is essential to explore the strategies that are recommended to facilitate inclusive STEM learning, not only globally but especially in the local and highly diverse context of Indonesia.

Thus, the research aims to map the development of inclusive STEM education globally and explore how inclusive STEM education is implemented, as well as providing recommendations for its application in the Indonesian context. Therefore, the research is guided by the following questions:

RQ1: What are the trends in inclusive STEM education research around the world?

RQ2: What are the trends in inclusive STEM education research in Indonesia?

RQ3: How is inclusive STEM education implemented according to the top 20 citations worldwide?

RQ4: What suggestions can be made, based on a review of the existing literature?

This study informs international readers about the trends and gaps in inclusive STEM education research, both globally and locally (in Indonesia). It further proposes how inclusive STEM education can be implemented in a highly diverse country such as Indonesia.

2. Methods

2.1 Research Design

This research design adapts previous research, which combines bibliometric analysis and an integrative review guided by the PRISMA Framework (Nugraha et al., 2023). Bibliometric analysis is a suitable research technique through which to map and explore research trends, , as well as identifying research gaps in the topic under study (Suhaimi & Mahmud, 2022). Furthermore, bibliometric analysis can also be used to determine other statistics related to the topic, including growth rates, top contributing countries, most popularly cited journals, and most frequently cited articles, as well as analyzing the most significant global research aspects of the focus topic (Phuong et al., 2023).

Although it can track trends, it depends solely on a quantitative approach, which may lack clarity in terms of understanding the meaning behind the numbers. Therefore, we combine the bibliometric analysis with an integrative review. Integrative review research is conducted by reviewing various types of research in previous studies to help formulate recommendations on the problem or topic under study (Alshammari et al., 2018).

2.2 Data Sources, Identifications, and Screening

This study collected research data from the international Scopus database. Search strings used were as follows for articles and documents, respectively: "Article title, abstract, keywords" and "Inclusive+STEM+Education". In order to find relevant data to answer RQ1, no filters were used in the first step. Next, the documents were limited to "article and conference paper" and reviewed, among other items, 1) contributors by country; and 2) co-occurrence maps or visualization. To answer RQ2, the country was limited to "Indonesia" in the initial identification data. This search yielded eight publications, only six of which were relevant to the topic of inclusive STEM education.

In answering RQ3, several documents that appeared in the search (global context) were then categorized based on the 20 highest numbers of citations. The reason for selecting this criterion was that, generally, a higher number of citations indicates that a publication is frequently referred to by many other researchers who are conducting research and publishing works in similar fields. In addition, it was agreed that the 20 publications with the most citations would be sufficient to provide a comprehensive overview, while still allowing for more in-depth analysis. A summary of the process used for obtaining 20 reviewed articles is presented in Figure 1.

The data used to answer RQ4 were the synthesized results of the data used in RQs 1 to 3. In this research, the process of identifying and screening the data was complemented by the method of monitoring and synthesizing it; these stages were adapted from the work of Tejera et al. (2025). This study focuses on the

Scopus database and includes only English-language publications, which may cause bias or limitations in the research, including the potential for the results to underrepresent local perspectives because relevant publications in national journals were not analyzed.

The process of selecting data sources with which to answer RQ1 and RQ3 (Figure 1) and RQ 2 (Figure 2) is based on the PRISMA Framework and consists of the three consecutive steps of identification, screening, and inclusion criteria.

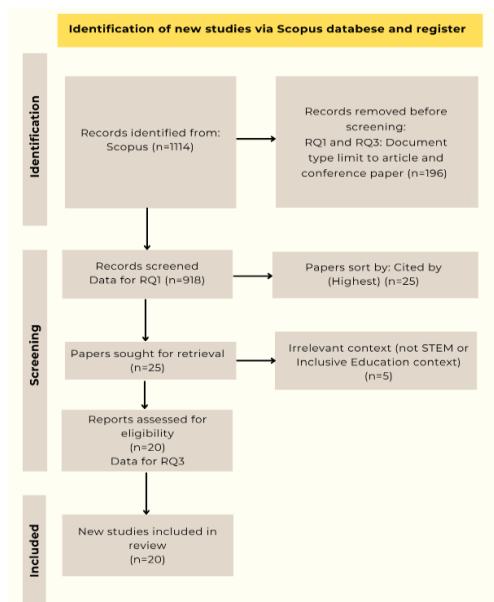


Figure 1: Data identification and screening process for RQ1 and RQ3

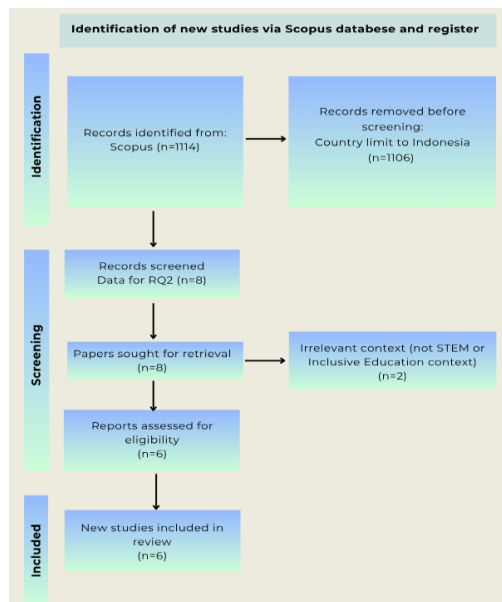


Figure 2: Data identification and screening process for RQ2

2.3 Data Monitoring and Synthesis

After the initial steps of identifying and screening the results, the first author thoroughly monitored and analyzed the documents for the integrative review process. A total of 26 papers resulted, of which 20 (global context) and six (Indonesian context) were further analyzed.

The research team, consisting of seven authors, conducted an integrative review by creating a spreadsheet in which to collect key data from each article. The integrative review process consisted of several stages. First, all authors agreed to develop a spreadsheet consisting of several sheets, including the main sheet, the first author's review results sheet, the second author's review results sheet, and so on, up to the sixth author.

The sheets in the spreadsheet were blank tables with columns for filling in 1) the title of the article and authors of the reviewed article; 2) Objectives; 3) Participants' levels and/or focus areas on STEM –for instance, levels are coded by determining whether the research focus is on primary, secondary, tertiary or further education levels. STEM focus coding relates to whether the inclusive education research in question focuses on the integration of STEM fields or only one field within STEM– 4) Methods (e.g. qualitative, quantitative or mixed-

methods); 5) Results (key findings from the research that are relevant to the research objectives) and 6) Types of inclusion researched (minority groups, gender, social, economic, cultural, etc.).

Second, before filling in the key data fields on the main sheet, the first author conducted an integrative review of all the articles that had been selected and filled in the table fields on the sheet for the results of the first author's review. Third, to test the suitability and consistency of the integrative review process conducted by the first author, the second to sixth authors randomly selected two articles to review and filled in the other sheets. Fourth, the first to sixth authors then held a face-to-face meeting to discuss and compare the results for the keyword table entries to be written on the main sheet.

Fifth, after reaching a common perception, the columns in the table on the main sheet were filled in based on the results of the perception alignment agreed upon by the six authors. Sixth, after the six authors reached an agreement, the results were then consulted with the seventh author to reach a final agreement. This process was repeated until an agreement was reached for all integrative review results. Contributions or recommendations are finally examined.

Data analysis was conducted systematically to respond to the four research questions, as follows.

To respond to RQ1, data sources were analyzed through frequency and percentage calculations using Microsoft Excel software. VOSviewer software was also used to visualize co-occurrence maps based on text data. For RQ2, the steps were similar to those undertaken in answering RQ1, but they were supplemented with an overview of the results of the integrative review, including a synthesis of six selected articles, based on the PRISMA Framework.

Content analysis was performed in response to RQ3, assisted by a spreadsheet that included citations, objectives, STEM focus, methods, results and/or contributions, and inclusive types. In addition, the tendency for inclusive kinds was also analyzed and visualized with the help of KH Coder software. RQ4 was answered by analyzing the answers to RQ1 and RQ3 and identifying gaps to propose recommendations for implementing inclusive STEM education in the Indonesian context.

3. Results

3.1 Trends in Inclusive STEM Education Research Around the World

Globally, based on a search of the Scopus database, inclusive STEM education research has been published since 1991. The trend in the number of publications on this research topic is presented in Figure 3.

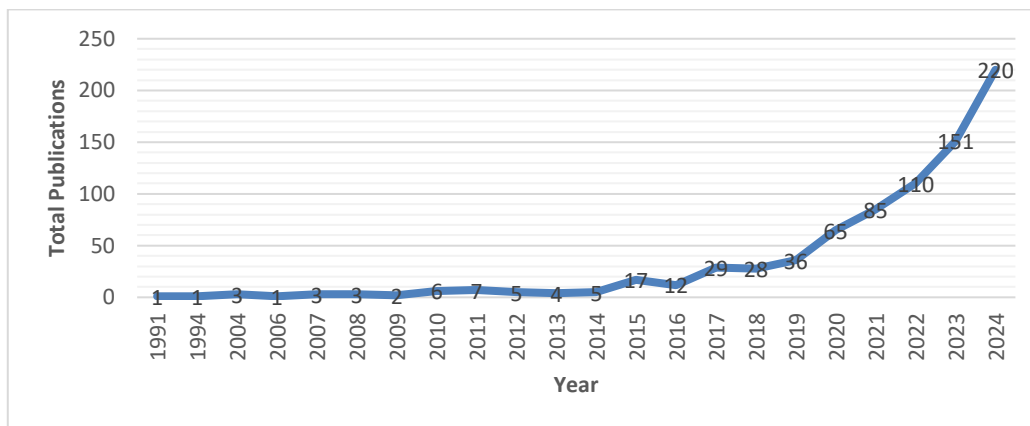


Figure 3: Trend in the number of publications on "Inclusive+STEM+Education" (in a global context, Scopus database)

Figure 3 shows that the trend of publications on inclusive STEM education continues to increase significantly from year to year. Over the course of approximately 34 years, the number of publications on this topic has increased rapidly, from only one publication in 1991 to 230 publications in 2024.

Specifically, to answer RQ1, the development of research on inclusive STEM education worldwide was identified based on Scopus database data up to June 2025. Through a search within: Article title, abstract, keywords, and search documents with "Inclusive+STEM+Education," without any filters, 1,114 papers were obtained. The author then limited the search results to articles and conference papers only, resulting in 918 papers. The data from the 918 identified papers were then filtered by country. The main contributors to research on this topic, based on Scopus Data within search TITLE-ABS-KEY: "Inclusive+STEM+Education", based on continent and country, are presented in Figure 4.

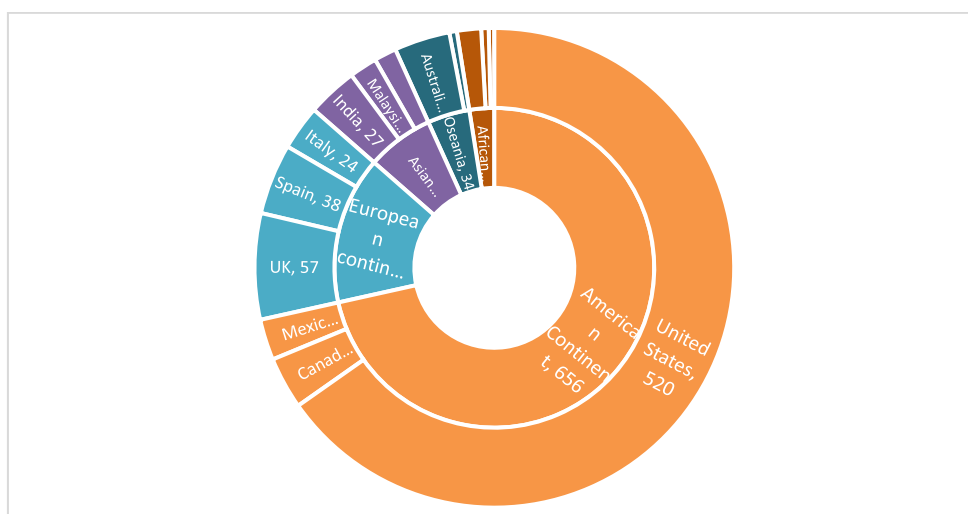


Figure 4: Trends in contributing countries (by continent and major contributing countries) in inclusive STEM education publications

Figure 4 shows that the Americas, specifically the United States, is the primary contributor to this field of research, with 520 publications out of 998 papers. The results of the co-occurrence maps based on text data (on networks) are presented in Figure 5.

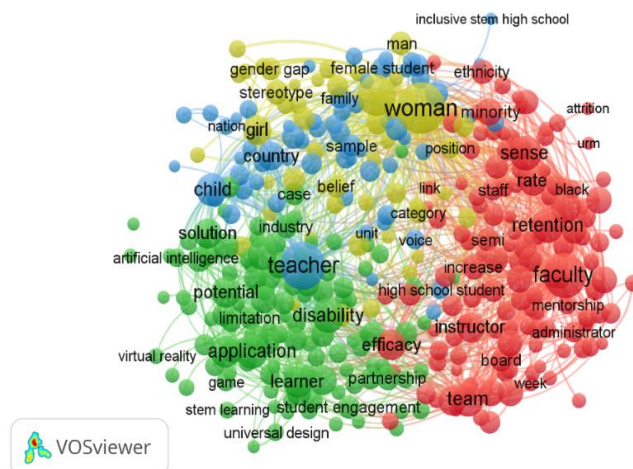


Figure 5: Visualization of co-occurrence maps based on text data (on networks) from the "Inclusive+STEM+Education" study

Figure 5 shows four different colors representing four thematic groups from the analysis of co-occurrence maps based on text data (on networks). Co-occurrence maps based on text data are also visualized using an overlay and presented in Figure 6.

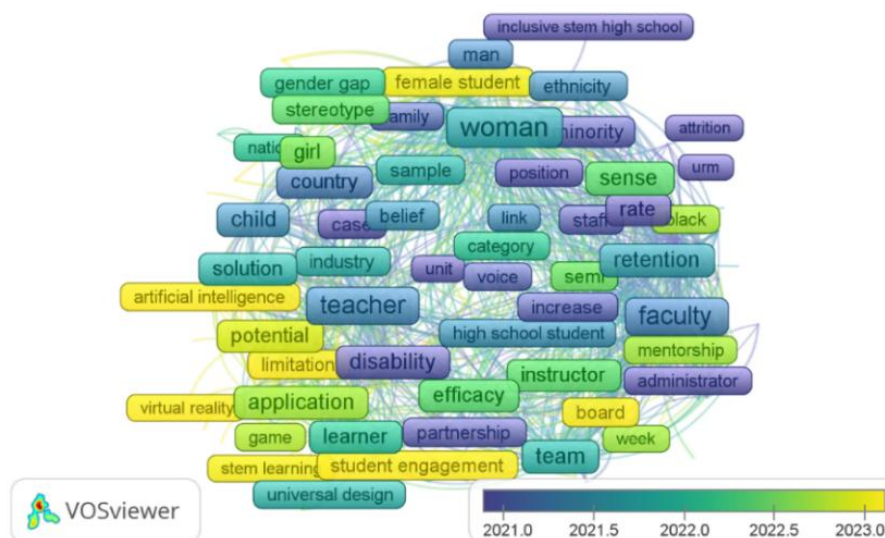


Figure 6: Visualization of co-occurrence maps based on text data (on overlay) from the "Inclusive+STEM+Education" study

Figure 6 shows emerging trends, marked by dark purple, beginning around 2021, such as inclusive STEM high schools and partnerships in bridging inclusive STEM

education. Yellow marks more recent trends, occurring around 2023 and beyond, including the use of digital technology as a bridge for inclusive STEM education, such as virtual reality and artificial intelligence.

3.2. Trends for Inclusive STEM Education Research in Indonesia

The development of research on inclusive STEM education in Indonesia (Figure 7) shows that the number of publications continues to fluctuate (rising and falling). This contrasts sharply with the global trend, which continues to experience significant growth.

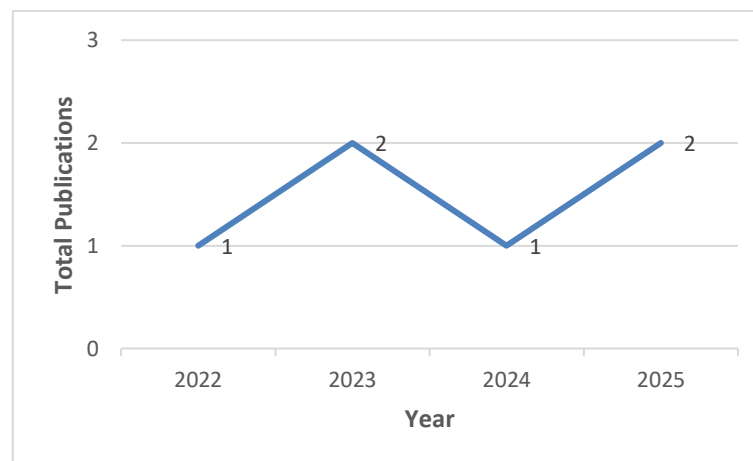


Figure 7: Trend in the number of publications on "Inclusive+STEM+Education" (in the context of Indonesia, Scopus database)

As can be seen in Figure 7, the first publications related to this topic in Indonesia began in 2022, before increasing in 2023, decreasing in 2024, and increasing again in 2025. Therefore, we recommend that research on the topic of inclusive STEM education in Indonesia should receive greater attention, as it remains underexplored.

Through a search within: Article title, abstract, keywords, and search documents with "Inclusive+STEM+Education", with a limitation of country to Indonesia, eight papers were identified. However, before conducting further analysis, we screened the eight papers to identify those that were relevant to science, technology, engineering, mathematics, or integrated STEM. As a result of this screening process, six relevant papers were selected for further analysis.

We also identified emerging trends in these papers by analyzing co-occurrence maps based on text data using VOSviewer. The analysis results, in the form of network visualizations, can help provide an overview of research conducted on inclusive STEM education in Indonesia and identify gaps that can help determine what research is required. The results of the co-occurrence maps, based on text data (on networks), are presented in Figure 8.

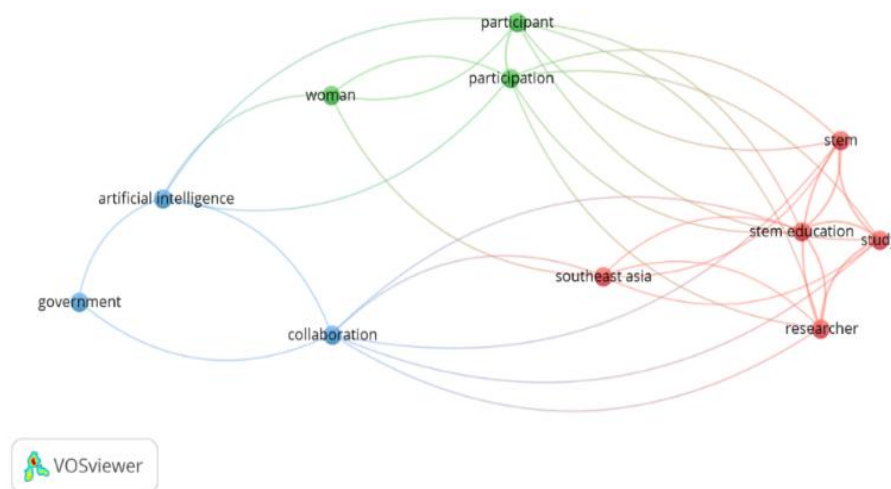


Figure 8. Visualization of co-occurrence maps based on text data (on networks) from the "Inclusive+STEM+Education" research, limited to Indonesia

As Figure 8 shows, three different color groups exist in the context of the six papers reviewed. These color groups include red, green, and blue. Words or terms that are interconnected within the same color group indicate a strong relationship between those words or terms.

3.3 Implemented Inclusive STEM Education based on the Top 20 Citations Worldwide

In this section, we aim to explore the examples of inclusive STEM education that have been implemented or researched globally. We selected 20 papers with the highest numbers of citations worldwide (presented in Figure 9) for an integrative review based on the Scopus database.

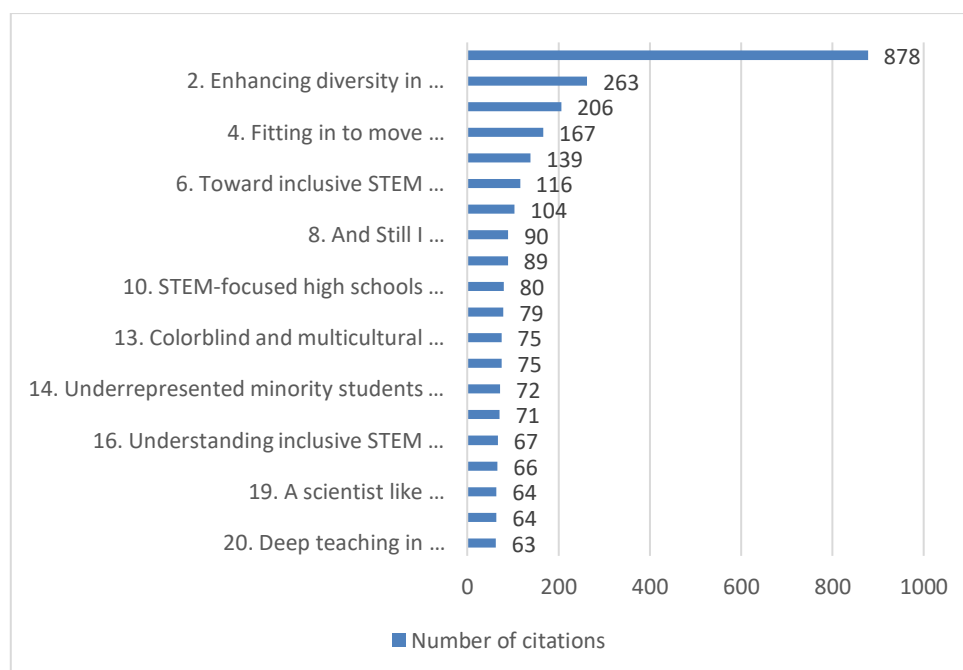


Figure 9: Topic and number of citations of the 20 most cited references

As shown in Figure 9, in addition to active learning, other types of learning that have the potential to facilitate inclusive STEM education, based on the 20 documents reviewed, are also disclosed and presented in Table 1.

Table 1: Recommended Learning Methods for Inclusive STEM Education

No	Learning Recommendations	References	Frequency
1	Learning that fosters a sense of belonging to STEM	(Ballen et al., 2017; Dewsbury & Brame, 2019; LaForce et al., 2016; Lewis et al., 2017; Miles et al., 2020)	5
2	Active learning	(Theobald et al., 2020) (Ballen et al., 2017; Borda et al., 2020; Dewsbury & Brame, 2019)	4
3	Inclusive STEM schools	(Eisenhart et al., 2015; LaForce et al., 2016; Lynch et al., 2018; Means et al., 2016)	4
4	A more inclusive learning environment	(Dewsbury, 2020; Killpack & Melón, 2016; Lynch et al., 2018; Whitcomb & Singh, 2021)	4
5	A more personalized approach	(Aragón et al., 2017; Killpack & Melón, 2016; LaForce et al., 2016)	3
6	Problem-based learning	(Laforce et al., 2017; LaForce et al., 2016)	2
7	Project-based learning	(Laforce et al., 2017)	1
8	Special support for minority groups	(Lynch et al., 2018)	1
9	Deep teaching	(Dewsbury, 2020)	1
10	Student-centered learning	(Borda et al., 2020)	1
11	Use of ChatGPT	(Rejeb et al., 2024)	1

As revealed in Table 1, another decisive factor in the decision to remain in STEM fields, apart from active learning, is a sense of belonging (Ballen et al., 2017; Dewsbury & Brame, 2019; LaForce et al., 2016; Lewis et al., 2017; Miles et al., 2020). Other factors that are also considered important for improving inclusive STEM education are presented in Table 2.

Table 2: Other Determining Factors in the Effectiveness of Inclusive STEM Education

No	Aspects	References	Frequency
1	STEM educators who are reflective and trained	(Borda et al., 2020; Dewsbury, 2020; Killpack & Melón, 2016; Lynch et al., 2018)	4
2	Guidelines, workshops or training for STEM educators	(Dewsbury & Brame, 2019; O'Leary et al., 2020)	2
3	Education policy documents	(Basile & Lopez, 2015)	1

Table 2 shows that, in addition to focusing on appropriate learning methods or approaches, the skills and experience of the educators who will implement

As Figure 10 reveals, the words “STEM” and “student” are in the largest circle, indicating the highest frequency of occurrence and the strongest relevance in the analyzed literature. Seven different colors represent seven interconnected concept groups.

3.4 Suggestions based on the Literature Review

Based on the review of existing literature, we propose several aspects that are essential for inclusive STEM education in the Indonesian context. These aspects include: 1) interdisciplinary STEM education (Deehan et al., 2025; García-Ramírez, 2025; Gutierrez-Berraondo et al., 2025; Hakim et al., 2023; Kelley & Knowles, 2016; Nugraha et al., 2024; Purwaningsih et al., 2020); 2) cultural relevance (Matindike & Ramdhany, 2024); 3) collaboration (Killpack & Melón, 2016; Sheherazade et al., 2022); and 4) the use of digital technology (Maullyda et al., 2024; Rejeb et al., 2024; Vasconcelos & dos Santos, 2023). Each aspect and its relevance to the results of the review of existing literature will be further discussed in the following section.

4. Discussion

4.1 Trends in Inclusive STEM Education Research Around the World

In relation to RQ1 regarding global trends in inclusive STEM education research, it was found that research on inclusive STEM education has increased significantly (Figure 3). This is relevant to systematic reviews (Kurniati et al., 2022; Nugraha et al., 2023) which have shown that STEM education research has become increasingly popular. To obtain a comprehensive overview of the trends in this topic, we also explored which continents and countries had contributed to the topic of inclusive STEM education research; these results were presented in Figure 4. The main contributor to research publications on this topic is the Americas, and the leading contributing country is the United States. Perhaps this is not surprising, as the term STEM first appeared in the United States (Dillon & Wong, 2025).

Furthermore, in relation to RQ1, visualization via VOSviewer (Figures 5 and 6) identified that minority (Lynch et al., 2018), ethnicity (Chiu et al., 2025), and gender (Mwajabu & Joseph, 2017; Rushton & King, 2020) are the most frequently appearing words in the reviewed articles. Meanwhile, the visualization of trends based on the year of research shows a shift in trends around 2021, when researchers tended to implement special programs or schools (Eisenhart et al., 2015; LaForce et al., 2016; Lynch et al., 2018; Means et al., 2016) and partnerships to bridge inclusive STEM education (Dewsbury, 2020; Killpack & Melón, 2016; Lynch et al., 2018; Whitcomb & Singh, 2021). Then, around 2023, in line with the development of digital technology, the trend changed again, with digital technology integration becoming the most frequently mentioned term in the review results (Rejeb et al., 2024).

4.2 Trends for Inclusive STEM Education Research in Indonesia

Given Indonesia's high level of diversity, inclusive STEM education is crucial, as it goes beyond the provision of quality education for all. Demographic diversity can generate diverse perspectives, leading to diverse ideas that are essential for a nation's progress. Therefore, varied and inclusive teaching strategies are needed

to create a more diverse STEM workforce (Ballen et al., 2017). Addressing RQ2, Figure 7 shows that research on inclusive STEM education in Indonesia remains minimal and underexplored. However, such research is essential because Indonesia is the fourth most populous country in the world, with more than 300 ethnic groups and diverse languages, religions, cultures, and social backgrounds (Mariyono, 2024).

Figure 10 shows that the types of inclusivity identified as the focus in this literature include underrepresented groups (minorities, low income, access), social identity (economic-social status, low academic achievement), race, ethnicity, culture, and gender identity. In its commitment to conducting quality research for all, the Indonesian education system must also consider Indonesia's high level of diversity. This demonstrates the urgent need for further research into learning strategies to facilitate inclusive STEM education so that every child can successfully access the same quality education, regardless of their background.

Words or terms that are interconnected within the same color group in Figure 8 indicate a strong relationship between those words or terms. The red network demonstrates that the reviewed papers are related to STEM education research in "Southeast Asia". The study in question explores the kinds of mentoring that can support women's careers in STEM, particularly in conservation in Southeast Asia (Sheherazade et al., 2022).

The research team applied a mentoring approach based on their experiences in Indonesia, where gender equality issues are similar to those experienced by Southeast Asian participants. The female participants received emotional and mental support as well as role models through female leadership. Results showed that these women were able to support one another, and this approach has the potential to change existing social norms, whereby women are not asked for their input or even acknowledged, especially in subjects such as conservation.

The green network indicates that "women" represent the most prominent focus of gender-inclusive initiatives (Falak et al., 2023; Maulyda et al., 2024; Sheherazade et al., 2022), as shown in the visualization. One of the papers reviewed revealed that participants (prospective student teachers) with left-brain dominance are more proficient in artificial intelligence (AI) (Maulyda et al., 2024). Therefore, educational programs ensuring all students receive comprehensive and balanced training, specifically for women, are urgently needed. Another study explores the challenges that hinder or limit women's involvement in data science and STEM fields (Falak et al., 2023). The research findings reveal that the barriers to participating in STEM fields faced by Asian women—including those from Indonesia—include financial constraints, lack of information, and parental skepticism.

The blue network can be interpreted as the "role" group of the terms or words "artificial intelligence," "collaboration," and "government," indicating that the papers analyzed in this study focus on the role of these three terms in STEM education. One of the reviewed papers conducted an integrative review and

mapping, with the results showing that the implementation of the STEM approach in Indonesia was carried out collaboratively and inclusively, as affirmed by the diversity of research participants, including disciplinary backgrounds and universities throughout Indonesia (Nugraha et al., 2023). Other studies encourage high-quality STEAM education for all children, considering their needs and interests regardless of their background, social status, economic conditions, or academic abilities (Asrifan et al., 2025). Artificial Intelligence-Based Teaching Assistants can be used as an innovative alternative solution in Indonesia, particularly in the field of STEM, offering personalized learning facilitation, real-time feedback, and task automation that can promote more inclusive learning (Winandri et al., 2025).

4.3 Examples of Inclusive STEM Education in Practice, based on the Top 20 Citations Worldwide

Concerning RQ3, Figure 9 shows that the most cited paper on inclusive STEM education, with over 850 citations, is the research on active learning from the United States (Theobald et al., 2020). The study successfully demonstrated that implementing active learning, which facilitates the integration of deliberate practice and inclusive teaching, can reduce gaps or inequalities in test scores and graduation rates among students. The most effective inclusive learning occurs when academic experiences are based on relationships and dialogue (Dewsbury & Brame, 2019).

Active learning, emphasizing interaction and a sense of togetherness, can facilitate inclusive teaching and provide a supportive classroom environment. In turn, this can be beneficial in strengthening students' sense of belonging in the face of stereotypes or discrimination (Ballen et al., 2017; Theobald et al., 2020). Integrating active learning and inclusive teaching can make students feel supported by lecturers, and lecturers' efforts to provide education that meets their needs will motivate students to work harder.

Several other studies (from among the 20 most frequently cited articles) also tested or proposed active learning to facilitate inclusive STEM education (Ballen et al., 2017; Borda et al., 2020; Dewsbury & Brame, 2019). Intensive and structured active learning activities can provide sufficient practice or learning time for students, including underrepresented students who require more time and a more in-depth approach due to their limited prior experience in quality STEM education (Theobald et al., 2020).

An active classroom with structured group activities can increase students' self-efficacy and mediate knowledge acquisition (Ballen et al., 2017). However, guidance, workshops, and training are needed to strengthen the skills and experience of educators (Dewsbury & Brame, 2019; O'Leary et al., 2020). In addition, education policy documents also need to explicitly outline support and facilitation for minority groups (Basile & Lopez, 2015), thereby reinforcing the mandate to provide quality education for all.

4.4 Suggestions based on the Review of Existing Literature

Addressing RQ4, we recommend four aspects that should be integral to inclusive STEM education, as follows: 1) interdisciplinary STEM education; 2) cultural relevance; 3) collaboration; and 4) use of digital technology.

4.4.1 *Interdisciplinary STEM education*

Interdisciplinary STEM education is an approach that integrates knowledge and skills in science, technology, engineering, and mathematics (Kelley & Knowles, 2016; Nugraha et al., 2024). It is relevant to the reviewed literature because it offers a student-centered approach (Deehan et al., 2025) and accommodates active learning, problem-based, and project-based learning (Gutierrez-Berraondo et al., 2025; Hakim et al., 2023; Purwaningsih et al., 2020); furthermore, it provides academic experiences with planned and structured group activities (García-Ramírez, 2025). Therefore, interdisciplinary STEM education is in line with the learning approaches recommended by the previous inclusive STEM education (see Table 1).

4.4.2 *Cultural Relevance*

Because Indonesia is known for its rich cultural diversity, integrating the cultural diversity of students (both majority and minority groups) can make learning more personalized, as it becomes more meaningful, relevant, and closely connected to students' lives when integrated with students' culture (Matindike & Ramdhany, 2024). Presumably, this can also foster a stronger sense of belonging among students toward their learning. A sense of belonging is vital in inclusive STEM education because it relates to a person's motivation and resilience in engaging with STEM (see Table 1).

4.4.3 *Collaboration*

Collaboration is proposed to enhance learning. According to the VOSviewer visualizations, there is a trend related to "partnership" (Figure 6) and "collaboration" (Figure 8). It can be interpreted as indicating that partnership or collaborative activities play a significant potential role in promoting inclusive STEM education; for example, by enabling students to interact or collaborate directly with scientists, practitioners or other external parties that are relevant to the learning topic.

This aligns with Social Constructivism Theory, which views knowledge development as being built through social interaction between individuals in contextual learning (Toma et al., 2024). The external parties involved are those who are not only capable but also share similar identities or social, cultural, and other backgrounds with the students (Sheherazade et al., 2022). Alternatively, they may showcase capable scientists, experts, or figures from minority or marginalized groups (Killpack & Melón, 2016).

4.4.4 *The use of digital technology*

The current trend in inclusive STEM education relates to technological developments (Maulyda et al., 2024; Rejeb et al., 2024; Vasconcelos & dos Santos, 2023), marked by the emergence of "artificial intelligence" in both visualizations (Figures 6 and 8). The use of artificial intelligence has rapidly become an essential

element of education that can be beneficial not only for students but also for teachers (Rejeb et al., 2024) in terms of understanding and exploring concepts in STEM education (Vasconcelos & dos Santos, 2023).

5. Conclusion

This study revealed that although the trend of publications on this research topic has significantly increased around the world, this research remains underexplored in the Indonesian context, with only six articles having been identified in the Scopus database. We recommend the following essential factors for inclusion in inclusive STEM education in the Indonesian context: 1) interdisciplinary STEM education; 2) cultural relevance; 3) collaboration; and 4) the use of digital technology.

The theoretical implication of this study is to combine the essential aspects of inclusive education with an integrated STEM approach that can be adapted to the local context, making it relevant for implementation in both developed countries and developing countries with high diversity, such as Indonesia. The practical implication is that teacher education institutions and prospective teachers should adopt the aspects identified in this study as part of their curriculum or teaching strategies to facilitate inclusive STEM education. From a policy perspective, the findings of this study provide an overview of techniques that can be developed to support the government's commitment to providing inclusive education while developing STEM talent.

Ultimately, we recommend that future research should examine the most highly cited publications and those from recent years to explore the latest trends in this field. Furthermore, the aspects we have proposed for enhancing inclusive STEM education still require more in-depth research regarding their relevance, particularly concerning the specific framework needed to integrate these aspects and how to instill global insight in the local Indonesian context. Additionally, we recommend the development of an inclusive STEM education framework that includes the abovementioned aspects. More serious attention to inclusive STEM education is needed from researchers, especially in Indonesia, in order to achieve Sustainable Development Goal 4 by providing an inclusive, equitable, and quality education for all.

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