Global trend of STEM Education for the SDGs of the last decade: A bibliometric analysis

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Abstract. STEM (Science, Technology, Engineering, and Mathematics) can help achieve the Sustainable Development Goals (SDGs) by fostering the development of 21st-century skills. It sparked a significant advancement in research on science education within the STEM field. This research intends to explore trends in STEM education for the SDGs by conducting a bibliometric analysis using the extensive Scopus databases. A total of 58 papers were reviewed from Scopus databases. A descriptive study method was employed to analyze the data. This study found that the number of STEM education and SDGs programs has increased over the past decade (2013-2023). The most prolific authors according to Scopus are seven authors. Over the past decade, Sustainability Switzerland has been the most significant source of documents on STEM education and SDGs. The VosViewer showcases six clusters associated with STEM Education and SDGs: Sustainable development goal, engineering education, science technology, quality education, stem education, and physics.

1 Introduction

In 2016, the United Nations Development Program (UNDP) launched the 2030 Sustainable Development Goals (SDGs). It pertains to the sustainable development plan which includes 17 goals and 169 targets. These objectives synchronize development needs with social, economic, and environmental factors to enhance the quality of life in marginalized communities. Education plays a crucial and transformative role in achieving the 2030 Sustainable Development Goals. This issue emerges not solely due to the direct inclusion of education in the 4th SDG (Quality Education), but due to its critical role in improving literacy to advance all SDG objectives [1]. Education plays a direct role in reducing poverty and addressing inequalities in human rights, health and nutrition, the environment, economic development, and labor productivity [2]. These objectives can be achieved if the population possesses pertinent 21st-century competencies, especially in STEM literacy and skills.

STEM education fosters literacy and proficiency in science, technology, engineering, and mathematics by integrating these disciplines to tackle real-world challenges [3]. This interdisciplinary approach equips students with the skills necessary to navigate a

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technologically advanced society, enabling informed decision-making across domains such as health, energy efficiency, environmental sustainability, resource management, and national security [4, 5]. Empirical evidence supports that STEM learning enhances critical soft skills essential for STEM careers, including higher-order thinking, problem-solving, collaboration, creativity, reasoning, and decision-making [6-10]. Additionally, STEM education contributes to the development of self-efficacy, learning motivation, and positive attitudes towards learning [11, 12]. The growing recognition of the economic importance of STEM skills has led to increased emphasis on STEM education reforms globally [13].

Countries like the United States, through initiatives like the Next Generation Science Standards (NGSS), and Ireland, with its STEM education policy, have prioritized integrating science, engineering practices, and inquiry-based learning to enhance STEM education quality [14, 15]. Similarly, South Korea has embedded STEAM education into its national agenda to promote comprehensive educational development [5]. STEM research, characterized by its novelty, innovation, and potential to bridge theoretical gaps, can be facilitated through the identification of existing research trends in the field. Thus, there is a pressing need for a systematic investigation to analyze these trends within the global context. Systematic reviews, which explore the current status and emerging patterns within specific themes, have become increasingly prevalent in educational research. For instance, systematic literature reviews like those on STEM research trends in the International Journal of STEM Education (IJ-STEM) by [16], inquiry-based learning trends by [17], scientific literacy research trends in Indonesia by [18], and meta-analyses such as the study on the impact of STEM on learning achievement by [19] exemplify this trend.

Based on the latest research by Jamali et al. [20], a bibliometric analysis reveals the significant role of STEM education in enhancing the quality of education, aligning with Goal 4 of the Sustainable Development Goals (SDGs). This prompts the question: what are the prevailing trends in STEM education research aimed at achieving the SDGs over the past decade (2013-2023)? Addressing this question will deepen our understanding of the integration of STEM education in improving educational quality and will support future efforts in this field. This study refers to the 2023 research conducted by [21] about the role of STEM Education in improving the quality of education: a bibliometric study. The primary distinction between this study and the previous research lies in its focus on a bibliometric analysis of STEM education, specifically in relation to the Sustainable Development Goals (SDGs). This is evident in the search criteria, which require the inclusion of the terms 'SDGs' or 'Sustainable Development Goals,' unlike the previous research which did not.

Therefore, this study highlights the research directions in STEM education and SDGs from 2013 to 2023, focusing on seven key research questions:

a. What has been the outcome of research publications on STEM education and SDGs over the past decade?
b. How extensively have papers on STEM education and SDGs been disseminated globally among nations and organizations?
c. Who was the initial author to introduce STEM education and SDGs globally?
d. What publication trends exist in STEM education and SDGs based on the title of the source?
e. How does the author engage with current trends in STEM education and SDGs studies?
f. What methods can be used to illustrate trends in research on STEM education and SDGs?

These inquiries aid us in examining patterns in STEM education and SDGs research by conducting bibliometric analysis using the extensive Scopus database.

2 Method

A new predefined search query for the "UN Sustainable Development Goals" (SDGs) has been introduced in the SCOPUS database, comprising 16 distinct pre-generated search queries. Consequently, data were extracted from SCOPUS, which offers extensive coverage in social sciences compared to WoS [22]. The data collection took place on July 10, 2024, covering the period from January 1, 2013, to December 31, 2023. Data from 2024 were incomplete and thus excluded from the dataset. Relevant documents about the "Sustainable Development Goals" or "SDGs" were retrieved by searching within document titles, abstracts, and keywords, referred to as set #1. Similarly, documents related to "STEM education" were collected using the same search criteria, referred to as set #2. The search strategy followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram [23], as illustrated in Fig. 1. The datasets for this study comprised documents on the "Sustainable Development Goals," "STEM education," and the combination of both search terms #1 and #2, totaling 46,062, 7,199, and 72 documents, respectively. The data were collected on July 10, 2024, hence, the data for the year 2024 were incomplete and excluded from the study.

The analysis includes terms, keyword frequencies, citation counts and distributions, and other bibliometric impact indicators such as the h-index. Structural analysis encompasses word dendrograms, co-occurrence networks, thematic maps, and collaboration and co-citation networks. The dynamics and structural analysis of bibliometric data were conducted using the "visualization of similarities" (VOS) Viewer software [24, 25] and the R-Tool from the Bibliometrix package, which is specifically designed for quantitative bibliometric research [26].

The approach employed in this study involves conducting a bibliometric literature review, which gathers pertinent books and library resources related to the research questions and objectives [27]. Bibliometric analysis involves studying the development of research fields, such as subjects and authors, by analyzing the social, intellectual, and conceptual framework within disciplines [28]. Bibliometric analysis, widely employed across scientific fields, involves quantitatively studying journal papers, books, or other forms of written communication [29]. The study utilized bibliometric analysis by defining search terms, examining search outcomes, and analyzing the collected data.

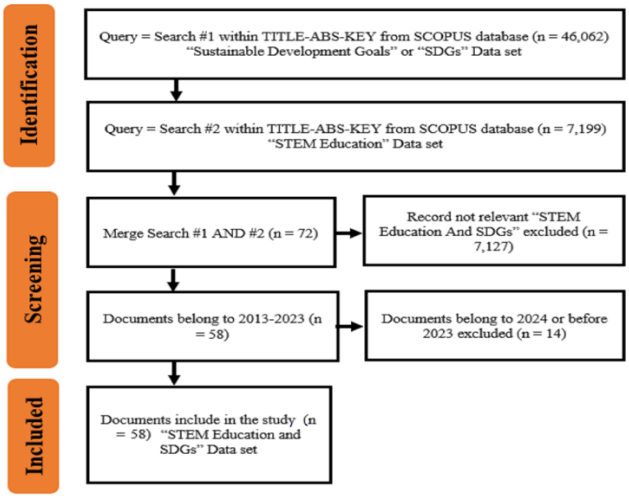

Fig 1. The Research Stages of Bibliometric Analysis

3 Result and Discussion

3.1 Year-wise Distribution

Figure 2 displays the quantity of studies concerning STEM education for SDGs according to Scopus databases spanning from 2013 to 2023.

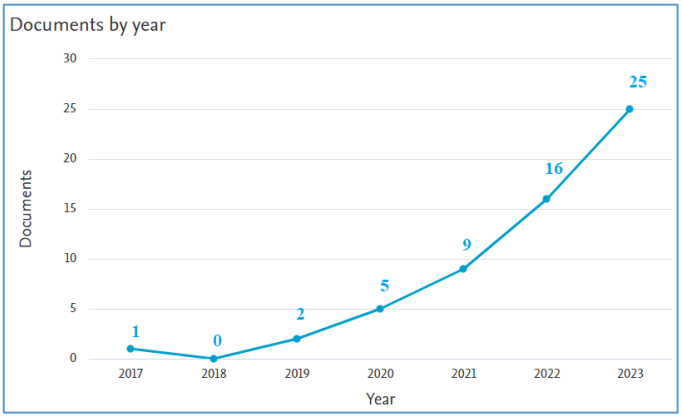

Fig 2. Trend Publication in 2013-2023

In total, 58 Scopus search documents on STEM education for SDGs were found throughout the year, accessible widely and openly through the Scopus database using the Publish or Perish tool. According to Scopus databases, the number of STEM education publications from 2013 to 2023 has risen. Based on the data trend shown in Figure 2, we also can anticipate that the total number of STEM education documents found in the Scopus database will continue to rise over the next three years.

3.2 The Top Productive Authors

Table 1 displays the leading ten authors ranked by document count in Scopus globally spanning from 2013 to 2023. Note that in 2013-2016 the total of publication is 0.

Table 1. Leading 10 productive authors based on the Scopus database

Author	Country	Doc.	Author	Country	Doc.
Campbell, C.	Australia	2	Rodrigo, M.M.T.	Philippines	2
Kewalramani, S.	Australia	2	Speldewinde, C.	Australia	2
Kidman, G.	Australia	2	Abhijith, K.V.	UK	1
Nagatomo, D.	Taiwan	2	Agirre-Basurko, E.	Spain	1
Nguyen, T.P.L.	Thailand	2	Akhlag, S.B.	Australia	1

According to data from the Scopus database (refer to Table 1), seven authors have 2 publications. The seven authors are Campbell from Australia, Kewalramani from Australia, Kidman from Australia, Nagatomo from Taiwan, Nguyen from Thailand, Rodrigo from the Philippines, Speldewinde from Australia, Abhijith from the UK, Agirre-Basurko from Spain, and Akhlag from Australia. These are nominal maximal documents in this research topic.

3.3 The Most Productive Affiliation and Region

Table 2. Top 10 Affiliations authors based on the Scopus database

Affiliation	Country	Doc	Affiliation	Country	Doc
Tecnológico de Monterrey	Mexico	2	Universidad del Pais Vasco	Spain	2
University of Florida	USA	2	Swinburne University of Technology	Australia	2
Deakin University	Australia	2	Ateneo de Manila University	Philippines	2
Monash University	Australia	2	Universitas Pendidikan Indonesia	Indonesia	2
National Taiwan Normal University	Taiwan	2	Ministry of Education	Iran	1

The top ten affiliations in STEM education research topics are shown in Table 2. The most contributor affiliations in this research area are from Technologico de Monterrey, University of Florida, Deakin University, Monash University, National Taiwan Normal University, Universidad del Pais Vasco, Swinburne University of Technology, Ateneo de Manila University, Universitas Pendidikan Indonesia. The nine universities each have 2 documents.

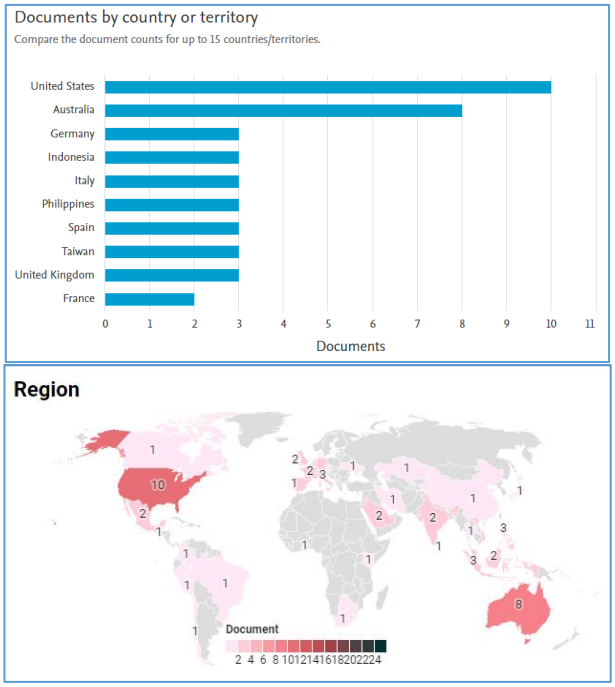

Fig 3. Top Five Countries in Publication About STEM Education

According to Figure 3, the USA authored the highest number of STEM education-related articles at 10, followed by Australia with 8 articles, and Indonesia-UK with 3 articles. Referring to Table 2, Universitas Pendidikan Indonesia emerged as the leading contributor of STEM education articles in Indonesia. In Figure 4, the majority of research on STEM education was presented in the Article. Out of 29 papers, 16 were published in conference papers, with journals being preferred by researchers for their quicker and more dependable

publication process compared to conference papers. Most of the articles appear in the Sustainability Switzerland with 11 papers.

3.4 Type of Research Document

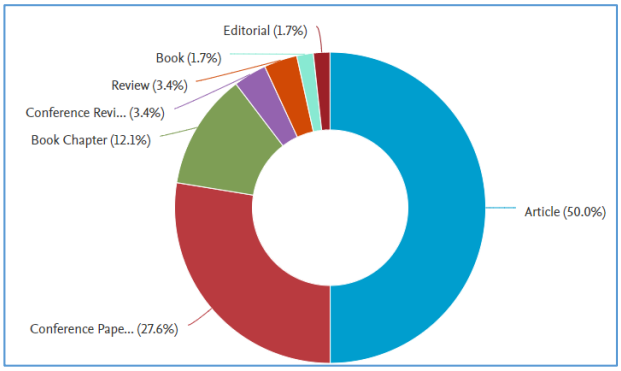

Fig 4. The Research Stages of Bibliometric Analysis

3.5 Application STEM Education for SDGs

VOSViewer was employed to examine 58 documents on STEM education research from the Scopus database. It visualized a map of keywords and their correlations, revealing research novelty. This analysis highlighted key parameters and relationships within STEM education and related variables. Keywords in titles and abstracts were represented by colored circles, with circle size indicating frequency of appearance—larger circles denoting more frequent keyword usage.

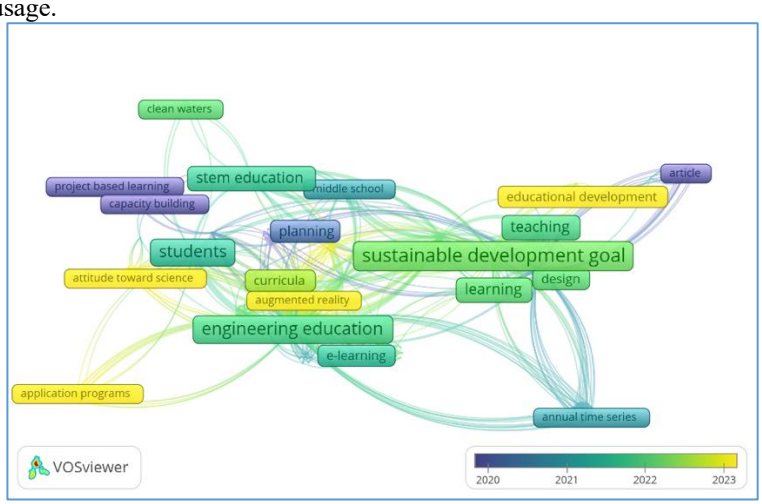

Fig 5. The Research Stages of Bibliometric Analysis

From Figure 4, an interesting thing is obtained, in the last decade, there are several keywords from the development of STEM education for SDGs that have only become popular in recent years, namely: augmented reality, application programs, attitude toward science, and educational development. And of course, the keywords that are most associated with researchers are of course SDGs and STEM Education.

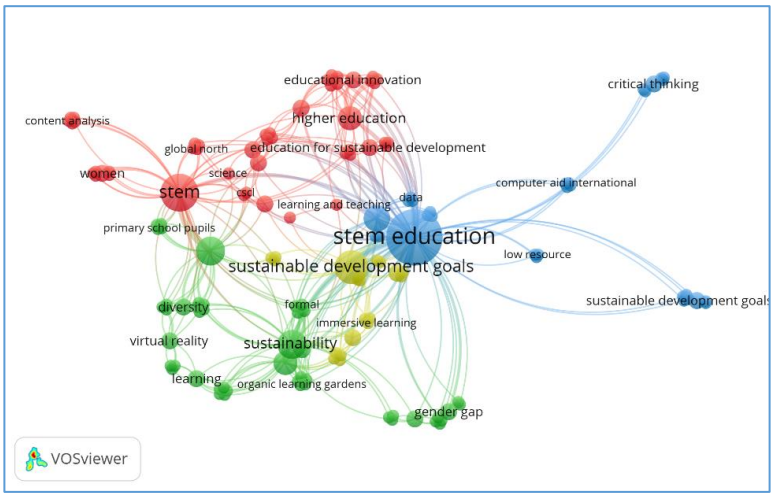

Fig 6. Network Visualization of Author Keyword of STEM Education and SDGs.

The trend analysis using the Bibliometrix package [26] indicates that "computing education" has emerged as a more recent topic in the SCOPUS "Author Keywords" compared to "circular design", which has lower word frequencies. The distribution of "Author Keywords" reflects the popular research topics, as illustrated in Fig. 7. In addition to "STEM education," "early childhood education" is experiencing significant growth within the "SDGs and STEM education" research area. The trend demonstrates that "early childhood education" and "education technology" have become more recent focal points in the "Author Keywords."

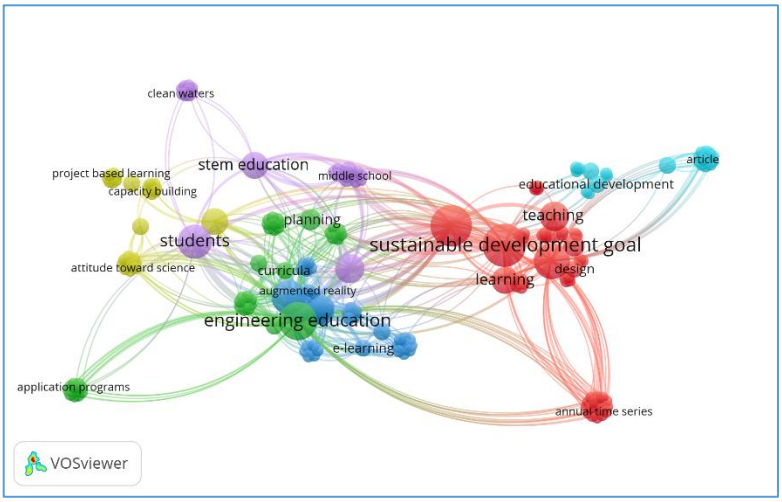

Fig 7. Network Visualization of Index Keyword of STEM Education and SDGs.

The results from the Density Visualization tool VOSviewer depicted in Figure 7 illustrate the concentration of research themes. There are six clusters representing the interrelation of these keywords: Cluster 1 centers on "Sustainable development goal" (red), Cluster 2 centers on "engineering education" (green), Cluster 3 centers on "science technology" (blue), Cluster 4 centers on "quality education" (yellow), Cluster 5 centers on "stem education" (purple), and Cluster 6 centers on "physics" (cyan) The results of this study are in line with the findings of

other studies [41-47] that research using bibliometric analysis can be a valuable way to strengthen current research and contribute positively to strategic policymaking.

4 Conclusion

The study investigates the current trajectory of STEM education within the framework of STEM education for SDGs. Using bibliometric analysis spanning from 2013 to 2023, the research reveals a consistent annual increase in research activity, despite minimal exploration of local knowledge over the past decade. The bibliometric mapping identified 6 distinct clusters—red, green, blue, yellow, purple, and cyan—highlighting dominant themes such as engineering and mathematics, sustainable development goals, STEM education, and climate change. Notably, Australian authors dominate the top 10 contributors, whereas institutions based in the USA lead among the top 10 affiliations.

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