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Mathematics Education for Sustainability: A Bibliometric Analysis of Global Research Trends

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ABSTRACT

The growing urgency of global environmental and social challenges has highlighted the role of education in supporting sustainable development, particularly under Sustainable Development Goal 4 (Quality Education). Although mathematics education is increasingly recognised as a tool for developing sustainability literacy, research in this area remains fragmented and lacks a comprehensive global synthesis. This study addresses this gap through a bibliometric analysis of Scopus-indexed publications from 2000 to 2024. Using VOSviewer, the study maps publication trends, prolific authors, contributing institutions, leading journals, country distribution, subject areas, keyword co-occurrence, and citation networks. The findings show a notable increase in publications after 2015 following the adoption of the SDGs, with dominant themes including STEM integration, environmental literacy, curriculum innovation, and sustainability pedagogy. The results also reveal that research contributions are largely concentrated in developed countries, indicating geographic disparities in the field. Overall, the study highlights the interdisciplinary growth of mathematics education for sustainability and emphasises the need for more inclusive and practice-oriented research to strengthen its role in addressing real-world sustainability challenges.

1. INTRODUCTION

Across the globe, education systems are being reshaped by the urgency of addressing environmental crises, social inequalities, and economic instability. The role of education is increasingly critical in addressing these complex global challenges. The Sustainable Development Goals (SDGs), particularly SDG 4 on Quality Education, call for transformative, inclusive, and future-ready learning experiences (UNESCO, 2017; United Nations, 2015). Mathematics education, traditionally perceived as abstract or technical, is now being reimagined as a vital platform for sustainability education (Skovsmose, 2020; Jablonka, 2021). Integrating sustainability into mathematics enables learners to apply mathematical thinking to real-world challenges such as climate change, energy consumption, and social equity (Boaler, 2016; Roth, 2009).

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Although interest in mathematics education for sustainability is increasing, the research remains fragmented across disciplines and often limited to isolated case studies or conceptual discussions. There is a lack of comprehensive global mapping of publication trends, thematic evolution, and collaboration patterns, particularly in relation to sustainability-focused mathematics learning approaches that prepare students for real-world challenges. This gap highlights the need for a bibliometric analysis to provide a structured synthesis of the field (Arikan & Unal, 2020; Figueiredo, Lopes, & Silva, 2022).

This study explores the role of mathematics education in advancing sustainability through a bibliometric network analysis of global research trends. Mathematics is increasingly viewed not only as a technical discipline but also as a tool for critical thinking, civic responsibility, and real-world problem-solving (Jablonka, 2021; Roth, 2009; Sharma, 2021). Using Scopus data and visualisation tools like VOSviewer (Van Eck & Waltman, 2010), supported by bibliometric methodologies (Godin, 2006; Zupancic & Grm, 2022), the study maps key contributors, institutions, thematic clusters, and emerging keywords, highlighting its interdisciplinary nature and alignment with the Sustainable Development Goals (United Nations, 2015; Figueiredo, Lopes, & Silva, 2022) and transdisciplinary education approaches (Nicolescu, 2002).

Despite growing interest, gaps remain in geographic representation and classroom implementation (Arikan & Unal, 2020; Figueiredo et al., 2022). By identifying trends in publications, authorship, institutions, keywords, and citation networks for Scopus-indexed articles from 2000–2024, the study provides a macro-level synthesis of the field. Mathematics education supports sustainable development by fostering critical thinking, quantitative reasoning, modeling, and data literacy, equipping learners to address complex 21st-century challenges.

This study focuses exclusively on peer-reviewed journal articles indexed in the Scopus database. It examines global publication trends, research networks, thematic clusters, and citation structures related to mathematics education and sustainability. While the study does not evaluate the effectiveness of specific classroom interventions, it provides a macro-level overview of how the field has evolved. The scope aligns with the research questions by systematically analysing bibliometric indicators that reveal the intellectual and collaborative structure of the field.

1.1 Research Aims

i. What are the research trends in Mathematics education for sustainability according to the year of publication?
ii. Who are the most prolific authors in the field of Mathematics education for sustainability?
iii. Which institutions contribute the most to Mathematics education for sustainability?
iv. What are the leading journals publishing on Mathematics education for sustainability?
v. Which country/territory contributes the most to Mathematics education for sustainability?
vi. What is the dominant subject area published in Mathematics education for sustainability?
vii. What are the most frequently used keywords in research on Mathematics education for sustainability?
viii. What are the main citation clusters of Mathematics education for sustainability?

2. METHODOLOGY

This section describes the bibliometric procedures used to analyse research trends in mathematics education for sustainability, including the data source, search strategy, selection criteria, and analytical techniques.

2.1 Research Design

This study adopts a bibliometric research design to systematically analyse scientific publications related to mathematics education for sustainability. Bibliometric analysis is a quantitative approach used to examine research productivity, intellectual structure, collaboration networks, and thematic development within a

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specific field. In this study, bibliometric mapping techniques were applied to investigate global publication trends linking mathematics education with sustainability, the Sustainable Development Goals (SDGs), and Education for Sustainable Development (ESD). By analysing publication growth, authorship patterns, institutional productivity, country contributions, keyword co-occurrence, and citation networks, the study provides a structured overview of how mathematics education contributes to sustainability discourse and how the field has evolved over time.

2.2 Literature Search

The study relied on the Scopus database, one of the largest abstract and citation databases of peer-reviewed literature, indexing approximately 22,800 active journals from more than 5,000 publishers worldwide. Scopus was selected due to its extensive coverage across education, mathematics, environmental science, and social science disciplines, making it suitable for capturing interdisciplinary research related to sustainability. The literature search was conducted on 5 March 2025 and covered publications from 2000 to 2024, allowing the inclusion of early foundational studies as well as the significant increase in research following the adoption of the Sustainable Development Goals in 2015. Only English-language, peer-reviewed journal articles were included, while conference proceedings, book chapters, editorials, and non-English publications were excluded to ensure consistency and maintain a focused dataset.

2.3 Search Term

The search was conducted in the Scopus database across relevant subject areas, including Social Sciences, Education, Mathematics, and Environmental Science. The search terms were selected to capture research linking mathematics education with sustainability. Keywords were conceptually grouped to represent both the educational and sustainability dimensions of the field. The Boolean search string used in the systematic retrieval process was:

(TITLE-ABS-KEY ("mathematics education" OR "mathematics teaching" OR "math education")) AND (TITLE-ABS-KEY ("sustainability" OR "sustainable development" OR "SDGs" OR "education for sustainable development"))

This search strategy ensured comprehensive coverage of studies on mathematics education within sustainability-related contexts while maintaining relevance to the research objectives. After applying the inclusion and exclusion criteria, the final dataset was exported in CSV format for bibliometric analysis. The data were analysed using VOSviewer to generate network visualisations of co-authorship, institutional collaboration, keyword co-occurrence, and citation patterns. Threshold values were applied to improve cluster clarity, and full counting methods were used to ensure consistency in bibliometric measurement, enhancing the transparency and reliability of the analysis.

3. RESULTS AND DISCUSSION

This section presents the bibliometric findings alongside analytical interpretation. The results highlight significant growth trends, dominant contributors, thematic evolution, and structural patterns shaping mathematics education for sustainability research.

3.1 Results

RQ1: What are the research trends in Mathematics education for sustainability according to the year of publication?

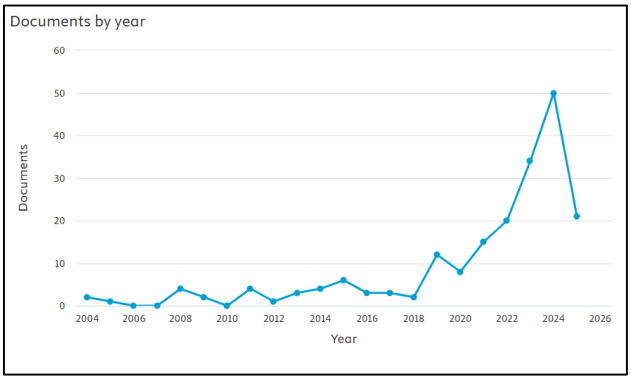

Fig. 1. Publication trends over time in Mathematics education for sustainability

Fig. 1 illustrates the annual distribution of publications in mathematics education for sustainability. The data show a gradual but consistent increase in scholarly output, particularly after 2015, coinciding with the global adoption of the Sustainable Development Goals (SDGs), especially SDG 4 Quality Education. The highest number of publications occurred in 2024, reaching 50 documents, representing a 150% increase from 2022, which had 20 documents. This sharp rise reflects growing global attention to the intersections of mathematics education and sustainability, likely driven by curriculum reforms, increased research funding, and international education initiatives. The trend suggests that mathematics education is increasingly recognised as a key tool for promoting sustainability literacy, equipping learners with critical thinking, quantitative reasoning, and problem-solving skills to address complex environmental, social, and economic challenges.

RQ2: Who are the most prolific authors in the field of Mathematics education for sustainability?

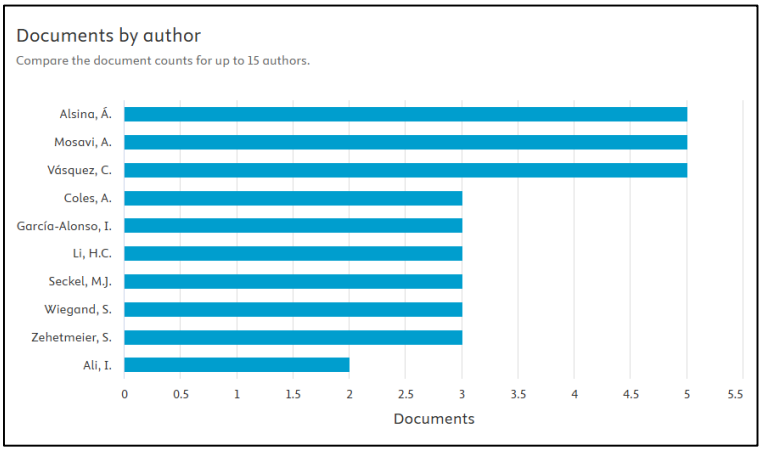

Fig. 2. List of prolific authors in Mathematics education for sustainability with publication counts and total publications

Fig. 2 presents the most prolific authors in the domain based on publication counts. Á. Alsina, A. Mosavi, and C. Vásquez are the leading contributors, each with 5 publications. Their research mainly focuses on areas such as sustainability-oriented mathematics education, mathematical modelling, and the integration of environmental and sustainability concepts into teaching and learning. Other notable authors, including A. Coles, I. García-Alonso, H.C. Li, M.J. Seckel, S. Wiegand, and S. Zehetmeier, each contribute 3 publications, addressing topics such as sustainability literacy, curriculum integration, and innovative pedagogical approaches in mathematics education. I. Ali follows with 2 publications, contributing to related discussions on mathematics education and sustainability.

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RQ3: Which institutions contribute the most to Mathematics education for sustainability?

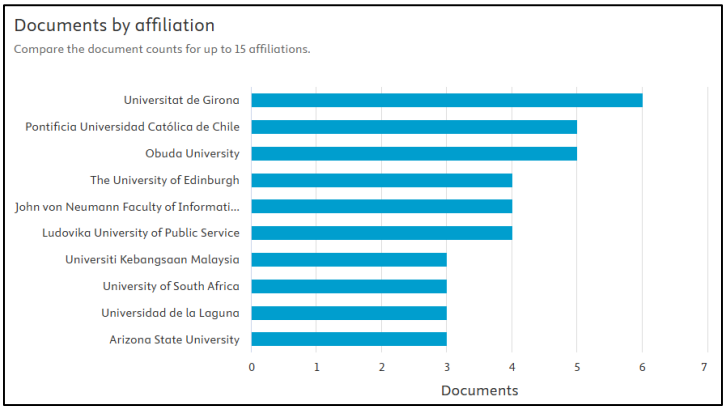

Fig. 3. Top contributing institutions in Mathematics education for sustainability with publication counts.

Fig. 3 shows the top academic institutions contributing to the literature on mathematics education for sustainability. Leading contributors include Universitat de Girona (Spain), Pontificia Universidad Católica de Chile (Chile), and Óbuda University (Hungary), each with five or more publications. The distribution indicates participation from institutions across Europe, South America, Africa, Asia, and North America. However, many of the leading institutions are in relatively developed or research-intensive countries, which aligns with the broader pattern observed in the country analysis where research output is dominated by wealthier nations. This suggests that while the field demonstrates global interest, research productivity is still concentrated in regions with stronger research infrastructure and funding support.

RQ4: What are the leading journals publishing on Mathematics education for sustainability?

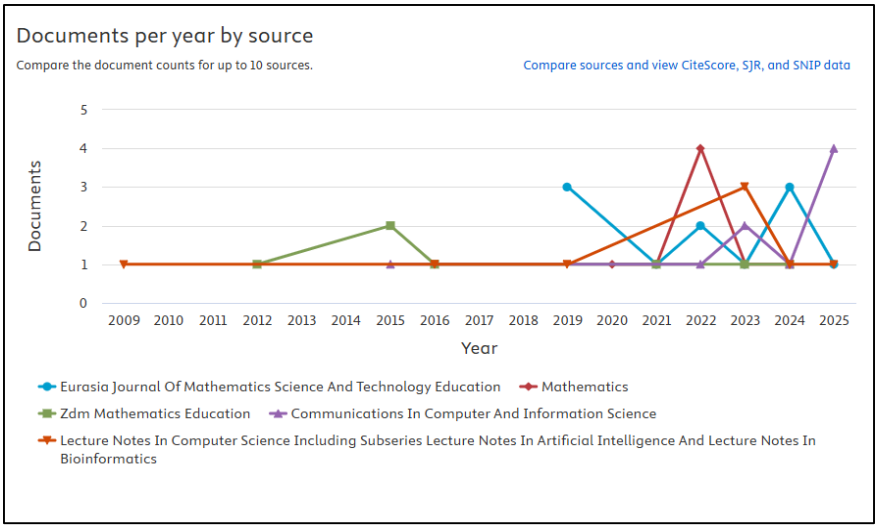

Fig. 4. Top journals in Mathematics education for sustainability with publication counts and years

Fig. 4 identifies the leading journals publishing research on mathematics education for sustainability. Mathematics records the highest number of publications in a single year with four documents in 2022, while Communications in Computer and Information Science also shows four publications in 2025. Other journals, including Eurasia Journal of Mathematics, Science and Technology Education, ZDM Mathematics Education, and Lecture Notes in Computer Science, contribute between one and three

publications across different years. This distribution indicates that research on mathematics education for sustainability is spread across both specialised mathematics education journals and broader interdisciplinary outlets.

RQ5: Which country/territory contributes the most to Mathematics education for sustainability?

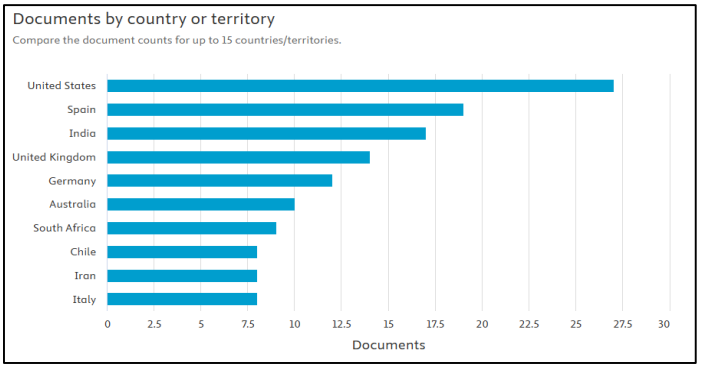

Fig. 5. Top contributing country/territory in Mathematics education for sustainability with publication counts

Fig. 5 displays the countries and territories most actively publishing in this field. The analysis reveals that countries such as the United States, Spain, and India are leading contributors, with the United Kingdom and Australia also featuring prominently. This distribution underscores the influence of both developed and emerging economies in shaping the discourse on mathematics education for sustainability. The presence of countries like South Africa, Chile, and Iran further reflects a growing global commitment to integrating sustainability into educational practices, highlighting the inclusive and worldwide nature of this research area.

RQ6: What is the dominant subject area published in Mathematics education for sustainability?

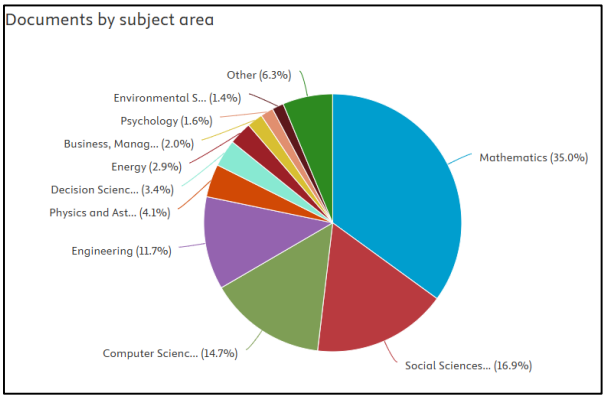

Fig. 6. List of subject areas in Mathematics education for sustainability

Fig. 6 categorises the retrieved publications by subject area, highlighting the interdisciplinary nature of research on mathematics education for sustainability. Mathematics represents the largest share with 35.0% of the publications, followed by Social Sciences (16.9%), Computer Science (14.7%), Engineering (11.7%), and Physics and Astronomy (4.1%). Smaller contributions are observed in Decision Sciences, Energy, Business and Management, Psychology, and Environmental Science. The dominance of mathematics and social sciences reflects the strong pedagogical and theoretical focus of the field, while the presence of computer science and engineering indicates growing integration with technology and applied problem-solving. Future research could further explore interdisciplinary collaboration, particularly within

environmental science and sustainability-related fields, to strengthen the practical application of mathematics education in addressing real-world sustainability challenges.

RQ7: What are the most frequently used keywords in research on Mathematics education for sustainability?

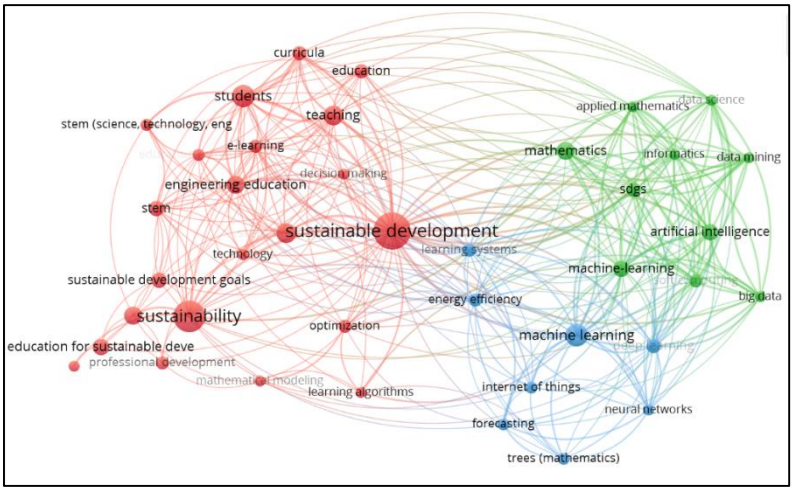

Fig. 7. Network visualisation map of keywords co-occurrence

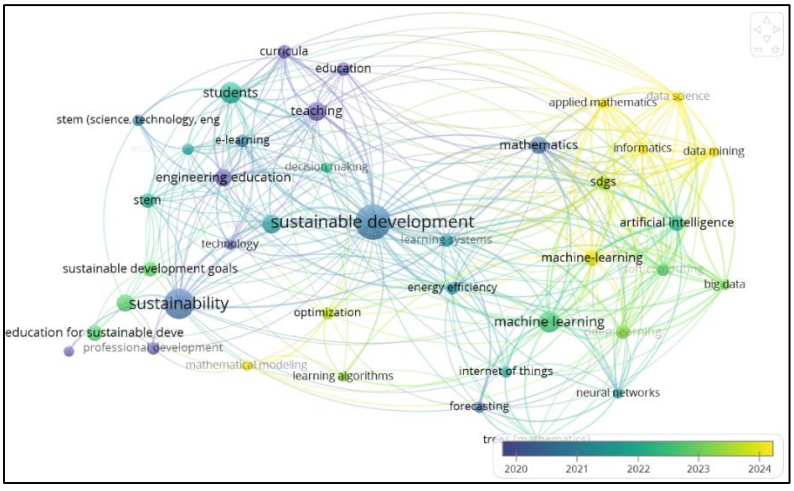

Fig. 8. Keywords co-occurrence overlay visualisation map according to year

Fig. 7 presents a network visualisation of frequently co-occurring keywords in literature. The clusters formed within the network reveal dominant research themes such as STEM education, curriculum development, environmental literacy, and sustainability pedagogy. The size and proximity of nodes suggest both the frequency of keyword usage and their conceptual interrelatedness, offering insights into how various subtopics within the field are interlinked. Fig. 8 provides an overlay visualisation of keyword co-occurrence based on the year of publication. This temporal perspective highlights the evolution of research interests, showing the transition from foundational themes such as “curriculum” and “teaching strategies” to more contemporary focuses like “climate change,” “green education,” and “technology-enhanced learning.” The overlay adds depth to the bibliometric analysis by indicating emerging research trends over time.

RQ8: What are the main citation clusters of Mathematics education for sustainability?

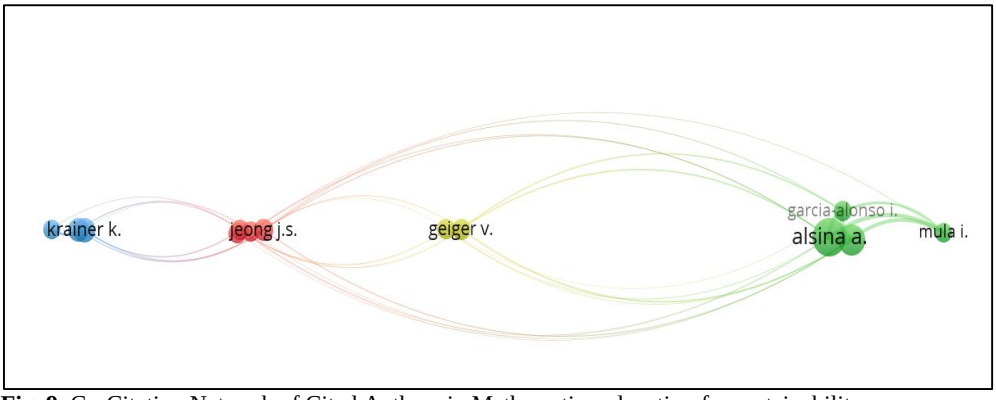

Fig. 9. Co-Citation Network of Cited Authors in Mathematics education for sustainability

Fig. 9 depicts the co-citation network of authors, illustrating the intellectual structure underpinning mathematics education for sustainability. Authors who are frequently cited together are grouped into clusters, signifying shared conceptual or methodological approaches. This network not only identifies key influencers in the field but also reveals the foundational literature that informs current research practices. It serves as a valuable resource for new researchers seeking to understand the theoretical and empirical underpinnings of the domain.

3.2 Discussion

The findings highlight the growing importance of mathematics education in supporting sustainable development. The increasing number of publications, particularly after the adoption of the Sustainable Development Goals (SDGs) in 2015, reflects rising academic interest in integrating sustainability into mathematics education. This shift suggests a move beyond procedural learning toward mathematics as a tool for critical thinking, problem-solving, and addressing real-world challenges (Jablonka, 2021; Roth, 2009; Sharma, 2021; Skovsmose, 2020).

The results also demonstrate the interdisciplinary nature of the field. Contributions from mathematics, social sciences, computer science, and engineering indicate that sustainability-oriented mathematics education increasingly involves collaboration across disciplines. Emerging research themes such as environmental literacy, sustainability pedagogy, and technology integration further highlight this evolving direction (Boström et al., 2018; Öhman & Sund, 2021; Sterling, 2010).

However, the analysis reveals that research output is largely concentrated in wealthier countries, potentially limiting perspectives from regions facing pressing sustainability challenges (Arikan & Unal, 2020; Figueiredo et al., 2022). Expanding global participation and incorporating indigenous knowledge and local contexts could enhance the inclusiveness and relevance of mathematics education for sustainability (Barton & Frank, 2001; Gerdes, 1998).

Another key challenge is the gap between theoretical discussions and classroom implementation. Future research should prioritise practical approaches that enable students to apply mathematical concepts to real-world sustainability issues, such as climate data analysis and environmental modelling (Sharma, 2021).

Overall, the findings suggest that mathematics education has significant potential to contribute to sustainable development. Strengthening interdisciplinary collaboration, expanding global research participation, and promoting practice-oriented approaches will be essential to realise this potential.

4. CONCLUSION

This study aimed to map global research trends in mathematics education for sustainability using a bibliometric analysis of Scopus-indexed publications from 2000 to 2024. Using VOSviewer, the analysis examined publication growth, key contributors, institutions, journals, country distribution, subject areas, keyword co-occurrence, and citation networks. The findings reveal a notable increase in research activity after the adoption of the Sustainable Development Goals (SDGs) in 2015, highlighting growing academic interest in integrating sustainability into mathematics education. The results also show that the field is increasingly interdisciplinary, with contributions from mathematics, social sciences, computer science, and engineering. However, research output remains concentrated in wealthier countries, and a gap persists between theoretical discussions and practical classroom implementation.

Future research should focus on strengthening the practical integration of sustainability into mathematics education, particularly within local educational contexts such as Malaysia. Studies could explore how sustainability-related topics such as climate data analysis, resource management, and community-based problem solving can be incorporated into school and university mathematics curricula. Supporting teachers through professional development and providing appropriate teaching resources will also be essential for implementing sustainability-oriented mathematics instruction. Greater collaboration among educators, researchers, and policymakers can further help develop context-sensitive frameworks that prepare students to use mathematics as a tool for addressing real-world sustainability challenges.

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CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

Noor Halimatus Sa'diah Ismail contributed to the conceptualisation, methodology design, formal analysis, supervision, and led the writing of the original draft. Nur Dalila Norshahidi was responsible for data curation, software use (including bibliometric tools), visualisation, and contributed to writing—review and editing. Nur Fatihah Haron and Fadila Amira Razali supported the investigation, validation of results, and writing—review and editing. All authors have read and approved the final manuscript.

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