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Mapping global trends and collaboration in mathematics education research: A Temporal and geographical analysis (2014–2024)

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Abstract:
This study analyzes global trends and collaboration in mathematics education research from 2014 to 2024 using a bibliometric approach. The findings reveal a significant rise in publication numbers, peaking in 2020 before stabilizing in recent years. Indonesia and Malaysia are leading contributors, with increasing involvement from countries such as Turkey, Iran, and Saudi Arabia. International collaboration has expanded, supported by influential institutions like Universitas Pendidikan Indonesia (UPI) and Universitas Syiah Kuala. Thematic shifts are evident, moving from traditional pedagogical methods toward integration with STEM, technology, and international assessments such as PISA and TIMSS. The collaborative network analysis highlights key contributors like S. Huda and M. Broer as influential figures in the research community. These results emphasize the importance of cross-border and interdisciplinary collaboration in advancing global innovation and effectiveness in mathematics education, providing valuable insights for academics, policymakers, and practitioners in shaping more inclusive and sustainable teaching and research strategies.

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INTRODUCTION

Mathematics education plays a vital role in supporting global development, yet research trends and dynamics in this field reveal significant challenges (Arifurrohman & Crismono, 2025; Crismono, 2017; Ouvry & Furtado, 2019; Waite, 2020). Despite the increase in publications and international collaboration between 2014 and 2024, the diversity of geographical and institutional contributions remains an issue. This raises questions about how temporal patterns in research output and the geographical distribution of contributions reflect the evolving global needs for mathematics education. Furthermore, although cross-national and institutional collaboration networks have expanded, their influence on the relevance and impact of research remains insufficiently understood. This study also needs to explore the extent to which the diversity of participating institutions affects the inclusivity of research networks and the innovations they generate.

Furthermore, mathematics education is increasingly integrated with interdisciplinary approaches such as STEM, technology, and contextual values like religion and culture. However, the impact of this integration on curriculum innovation and instructional strategies remains an open

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question (Crismono, Maghfiroh, et al., 2025; Ingram, 2024; Kurniawan, 2021; Li et al., 2021). At the same time, international assessments such as PISA and TIMSS have become essential tools for evaluating the global quality of mathematics education, yet their connection to research trends and author contributions has not been comprehensively mapped. Additionally, patterns of author collaboration, which reflect thematic focuses and research subtopics, require further analysis to uncover their contributions to the transformation of mathematics education (Baiduri et al., 2020; Country Participation in TIMSS 2019 and in Earlier TIMSS Assessments, 2019; Crismono et al., 2025; Dian, 2022; Kemendikbud, 2019; Mullis et al., 2019; OCDE, 2023).

This study aims to identify key patterns within the global network of mathematics education research, evaluate their impact on educational innovation, and offer practical recommendations for strengthening cross-national and institutional collaboration. Accordingly, the study is not only relevant to mathematics education but also encompasses sociological dimensions, educational management, and technological applications, making it significant for a range of related fields. In a global context marked by challenges such as pandemics, technological innovation, and cross-cultural educational needs, this research serves as a critical step toward addressing knowledge gaps concerning the sustainability and relevance of international collaboration in mathematics education.
Research Questions:

1. What are the trends in the number of research publications during the period from 2014 to 2024?
2. What are the trends in the diversity of countries involved in mathematics education research?
3. How have the patterns of country contributions to research collaboration evolved annually?
4. How is the geographical distribution of research contributions mapped globally?
5. How does the diversity of institutions involved in this research affect the inclusivity of the research network and its impact on research outcomes?
6. How does the network of mathematics education research reflect interdisciplinary and methodological approaches, and how do these influence curriculum development and teaching strategies?
7. How are citations and author contributions distributed within the research network?
8. How do patterns of author relationships reflect specific thematic focuses or subtopics within the research?
9. How does the temporal development of mathematics education research from 2018 to 2023 reflect shifts in focus and emerging trends in the field?

METHOD

This study employs an exploratory design using both quantitative and qualitative approaches to map trends, collaboration patterns, and the geographical distribution of research in mathematics education during the period 2014–2024. The quantitative approach is applied through bibliometric data analysis, while the qualitative approach is used to thematically interpret the findings. Research data were obtained from the Scopus academic database, with metadata coverage including titles, abstracts, keywords, author information (affiliations, countries of origin, collaboration networks), citation indices, and publication years (Donthu et al., 2021; Gao et al., 2022).

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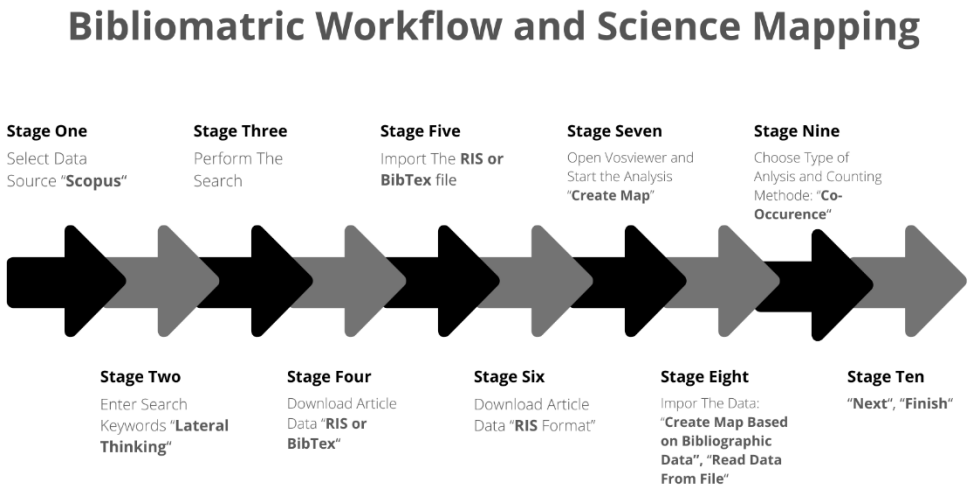

Figure 1. Bibliometric Workflow and Science Mapping (Aria & Cuccurullo, 2017; Tekdal, 2021; van Eck & Waltman, 2010b)

Data collection was conducted using the keywords "mathematics education," "global collaboration," and "research trends" to identify relevant articles. Selected articles had to meet inclusion criteria: a focus on mathematics education, publication within the 2014–2024 period, and inclusion of data on international collaboration and geographical distribution. The metadata of the selected publications were downloaded using VOSviewer and Excel software to facilitate further analysis (P. C. Crismono, 2024; Hashem E et al., 2023a; Jing et al., 2024).

The data analysis involved several stages. First, a bibliometric analysis was conducted to identify temporal trends in the number of publications per year, map the geographical distribution of country contributions using GIS software, and visualize collaboration networks among authors and institutions using VOSviewer and Excel. Second, thematic analysis was employed to identify dominant subtopics in the research, particularly the integration of mathematics education with STEM, technology, and contextual values. Additionally, research impact was evaluated using citation indices (such as the h-index and g-index) to assess the relevance of the works and to identify the most contributing authors or institutions (Jing et al., 2024; van Eck & Waltman, 2010a).

To ensure data validity, this study employed triangulation by integrating multiple data sources, manually validating collaboration networks, and verifying geographical distribution through digital mapping. The research also adheres to academic ethical principles by using only publicly available data and properly acknowledging all referenced sources. The findings will be presented in the form of publication trend graphs, geographical distribution maps, visualizations of international collaboration networks, and thematic analyses of dominant subtopics, providing a comprehensive overview of the global dynamics of mathematics education research over the past decade (P. C. Crismono, 2023; Hashem E et al., 2023b).

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RESULT

Research Trend Developments from 2014 to 2024

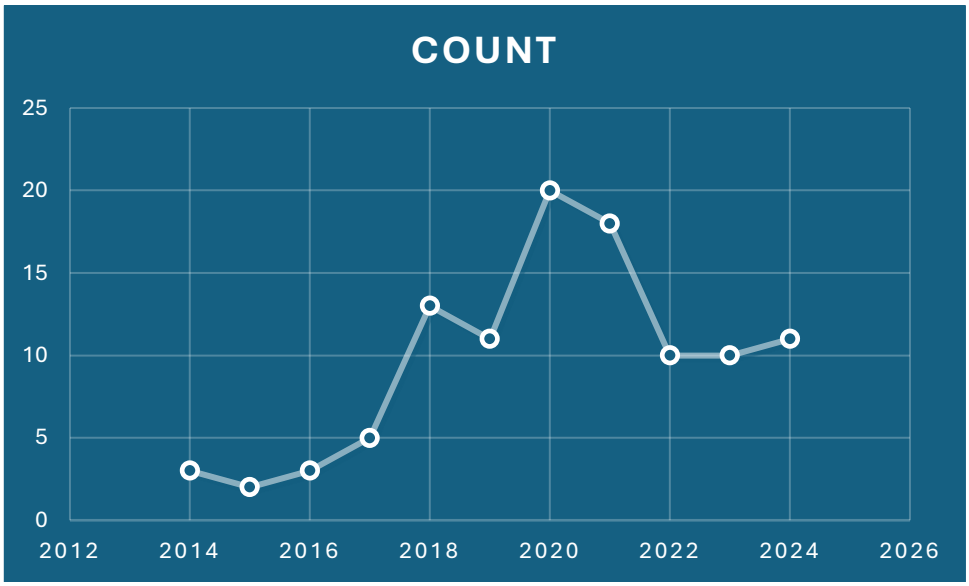

Figure 2. Annual Publication Trends in Mathematics Education Research (2014–2024)

The uploaded graph illustrates the trend in the number of research publications from 2012 to 2024. In the early period, from 2012 to 2016, the volume of research remained relatively low and stable, averaging only 2 to 4 publications per year. This phase reflects a period of slow research activity, possibly due to limited resources, low interest in specific topics, or other factors affecting research productivity. However, from 2017 to 2019, there was a significant increase in the number of studies. Research output grew steadily, from around 5 publications in 2017 to over 15 in 2019. This surge suggests rising interest in specific research areas or perhaps an increase in funding and academic collaboration during this period.

The peak of research activity occurred in 2020, with nearly 25 studies published. This year can be seen as a golden period for research in related fields, possibly driven by urgent needs or the relevance of certain topics, such as the COVID-19 pandemic, which spurred research in health, technology, and policy. However, following this peak, there was a sharp decline in 2021, with research output dropping significantly to around 10 publications. This decrease was likely caused by reduced urgency or the onset of resource constraints after the previous surge in activity. In the last three years (2022 to 2024), the trend shows a stabilization at approximately 10 publications per year. A slight increase in 2024 may indicate a recovery or renewed focus on previously overlooked topics. Overall, the graph reflects a cyclical pattern of research activity influenced by various factors, including academic interest, societal needs, and resource or funding limitations.

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Development of Country Research Trends from 2014 to 2024

Table 1. Annual Country Participation in Mathematics Education Research (2014–2024)

Year	Count	Countries
2014	3	Japan, Malaysia, Tunisia
2015	2	Iran, USA
2016	3	Indonesia, Malaysia
2017	5	Bosnia, Indonesia, Malaysia, Turki, USA
2018	13	Canada, Indonesia, Malaysia, Sudan
2019	11	Indonesia, Turki, UAE, USA
2020	20	Saudi Arabia, Australia, Indonesia, Kuwait, Malaysia
2021	18	Canada, Indonesia, Iran, Qatar, Thailand
2022	10	India, Indonesia, Turki, Yaman
2023	10	Australia, Indonesia, Iran
2024	11	Indonesia, Malaysia, New Zealand, Turki

Based on the available data, research trends from 2014 to 2024 reveal a dynamic progression in both the volume of studies and the participation of contributing countries. In the early period (2014–2016), the number of publications remained very low, ranging from 2 to 3 per year. During this stage, countries such as Malaysia, Indonesia, and Tunisia were the primary contributors. This limited activity likely reflects the underdevelopment of cross-national research focus or collaboration at the time.

From 2017 to 2019, research output experienced a notable increase. Publications rose from just 5 in 2017 to 13 in 2018, maintaining a high level with 11 in 2019. This growth signals a rise in cross-border collaborations, with new contributions from countries like Bosnia, Turkey, and Sudan, in addition to the continued leadership of Indonesia and Malaysia. The increasing diversity of contributing countries highlights the expansion of a more inclusive global research network. The year 2020 marked the peak of research activity with 20 publications, signifying an exceptional surge. Countries such as Saudi Arabia, Australia, and Kuwait added to the international mix. This spike was likely driven by global events such as the COVID-19 pandemic, which accelerated research in areas like health, technology, and policy. In 2021, although there was a slight decline, output remained strong with 18 publications, supported by contributions from countries such as Canada, Iran, and Thailand. From 2022 to 2024, research trends stabilized with an average of 10 to 11 publications annually. Indonesia, Malaysia, and Turkey continued to play leading roles, while countries like India, Australia, New Zealand, and Yemen emerged as new contributors. This stability suggests a more organized and sustained pattern of international collaboration, though less intense than the 2020 peak.

Overall, this data reflects the evolution of international research, from limited collaboration to a broad and diverse global partnership. The prominent roles of Indonesia and Malaysia underscore the growing importance of the Asian region in global scholarship, while the emergence of new contributing countries signals a promising future for expanding global research networks.

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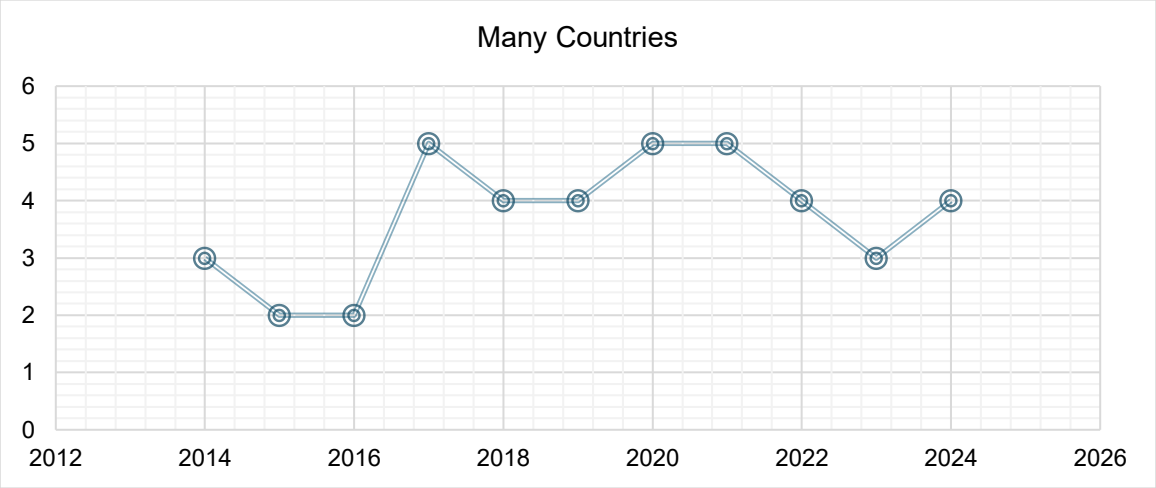

Figure 3. Annual Variation in the Number of Participating Countries in Mathematics Education Research (2014–2024)

In terms of the number of participating countries each year, the trend from 2014 to 2024 shows a significant rise in international collaboration during the middle of the period, followed by a stabilization in recent years. In the early phase (2014–2016), the number of countries involved was relatively small, ranging from 2 to 3 per year. This reflects the limited scale of cross-national collaboration at the time, with research likely focused on regional concerns or dominated by a few countries.

The year 2017 marked a turning point, with the number of collaborating countries increasing significantly to 5. This jump indicates the development of international research networks, likely driven by enhanced global connectivity and a growing need to address complex issues requiring cross-border perspectives. Although there was a slight dip in 2018 and 2019, with 4 countries participating annually, this level remained higher than in the earlier years, suggesting ongoing global engagement. The peak of international collaboration occurred in 2020 and 2021, with the highest number of participating countries 5 per year. This period coincided with a surge in research output, likely spurred by global challenges such as the COVID-19 pandemic. These circumstances prompted greater international mobilization to develop joint solutions through collaborative research. Cross-national cooperation during this time proved critical in combining resources, expertise, and technology from various regions. In the subsequent years (2022–2024), the number of participating countries slightly declined and stabilized at around 3 to 4 per year. This stability may reflect a realignment of research priorities in the post-pandemic era, where international collaborations became more selective or focused on specific topics. Although not as high as during the peak, international collaboration remained consistent, indicating that cross-border cooperation continues to be a vital component of the research ecosystem.

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Annual Trends in Country-Level Research Participation from 2014 to 2024

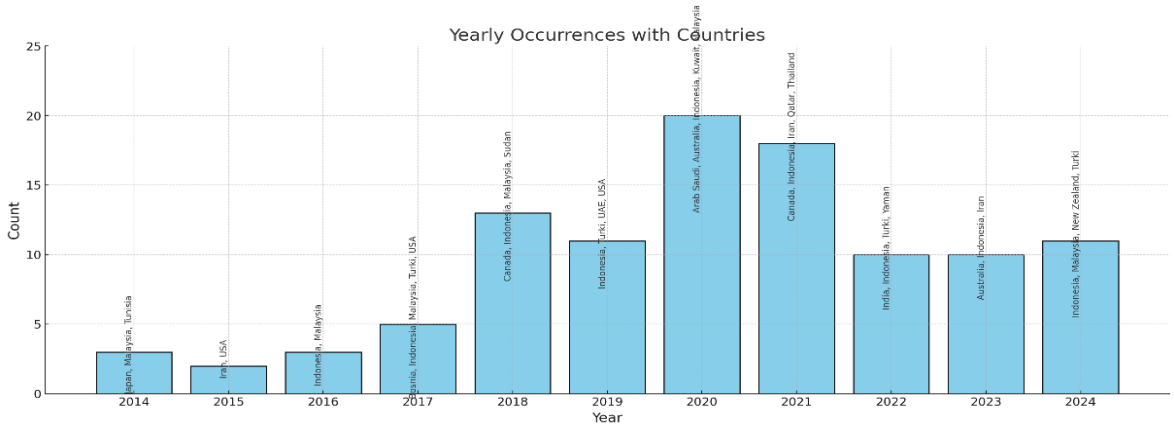

Figure 4. Annual Country Contributions to Mathematics Education Research (2014–2024)

The trend in the number of research publications per year and the contribution of participating countries from 2014 to 2024 reveals a significant shift in both research output and international engagement, transitioning from a limited initial phase to a peak period and subsequent stabilization. The analysis is structured according to the following periods:

2014–2016 (Initial Period):

During this phase, the number of research publications remained relatively low, averaging between 2 and 3 studies per year. International collaboration was also limited, with main contributors including Malaysia, Indonesia, and Tunisia. Research activities at this stage were largely localized or regional in scope, indicating that cross-border collaboration had not yet widely developed.

2017–2019 (Growth Phase):

This period saw a substantial increase in research output, with more than 10 studies published in both 2018 and 2019. Countries such as Indonesia, Malaysia, Turkey, and Sudan became more prominent contributors, marking a phase in which international collaboration networks began to expand significantly. This rise was likely driven by the growing need to address global issues that require cross-national cooperation.

2020–2021 (Peak Research Activity):

Research output peaked during these years, reaching 18 to 20 publications annually. This increase coincided with broader participation from countries such as Saudi Arabia, Australia, Kuwait, and Qatar. The surge in research activity was likely influenced by global urgencies such as the COVID-19 pandemic, which prompted intensified international collaboration to address health, social, and technological challenges. This period highlights how global needs can serve as a catalyst for strengthening research cooperation.

2022–2024 (Stabilization Phase):

The final phase reflects a more stable pattern, with annual research output ranging from 10 to 11 studies. Although the intensity of research slightly declined compared to the peak period, new contributors such as India, Yemen, and New Zealand emerged, indicating a diversification of international collaboration. At the same time, major players like Indonesia and Malaysia remained consistently active, demonstrating continuity and a sustained focus on priority issues.

Overall, the trend illustrates the evolution of research collaboration—from a limited early stage to a period of global expansion, followed by more focused stabilization. This pattern underscores

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how global and regional needs can shape the intensity and scale of cross-border research cooperation.

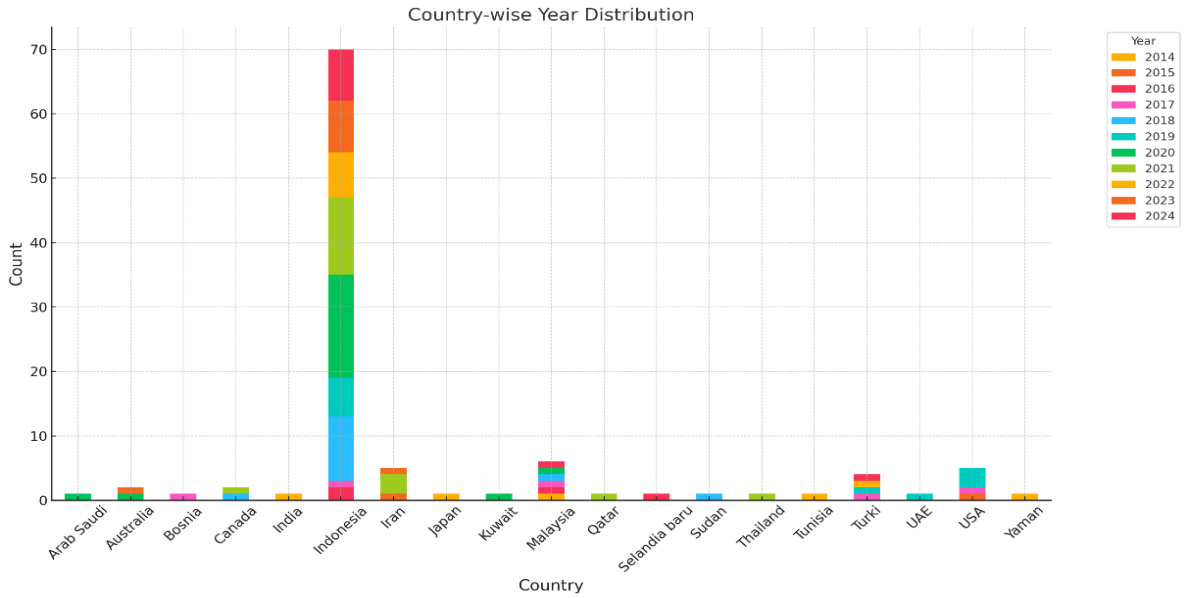

Figure 5. Annual Distribution of Country Contributions in Mathematics Education Research (2014–2024)

The distribution of country contributions to research from 2014 to 2024 illustrates how each nation participated in academic activity over the decade. This distribution not only highlights the dominance of certain countries but also reflects the evolving nature of international collaboration networks over time.

The graph clearly shows that Indonesia has the highest number of contributions compared to other countries. Indonesia's involvement is evident in nearly every year, underscoring its role as a consistently active and central hub of research. This significant contribution suggests that Indonesia has become a focal point for international collaboration, playing a key role in connecting various countries through research that is both globally and regionally relevant. Indonesia's dominance also reflects its substantial capacity to lead research across diverse topics and issues. In addition to Indonesia, Malaysia and Turkey have emerged as major contributors, particularly during the growth phase from 2017 to 2024. Malaysia, which has maintained steady involvement, often acts as a primary partner in collaborations with Indonesia. This points to a strong bilateral research relationship that supports cross-border academic efforts. Turkey, meanwhile, has shown a notable rise in contributions, especially after 2017, enriching the collaborative network with new perspectives in international research.

Other countries such as Iran, the USA, and Saudi Arabia were active in specific years, particularly during the peak research period of 2020–2021. Their participation likely reflects a global response to pressing needs, such as those posed by the COVID-19 pandemic. Furthermore, new contributors like India, Yemen, and New Zealand began participating during the stabilization phase (2022–2024). Their emergence demonstrates that the collaborative network continues to grow not only maintaining existing partnerships but also attracting new countries into the fold. Overall, this data highlights both the dynamic nature of international research collaboration and the increasingly diverse participation across countries, driven by shared academic interests and global challenges.

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Geographical Distribution of Research Based on Researchers' Countries

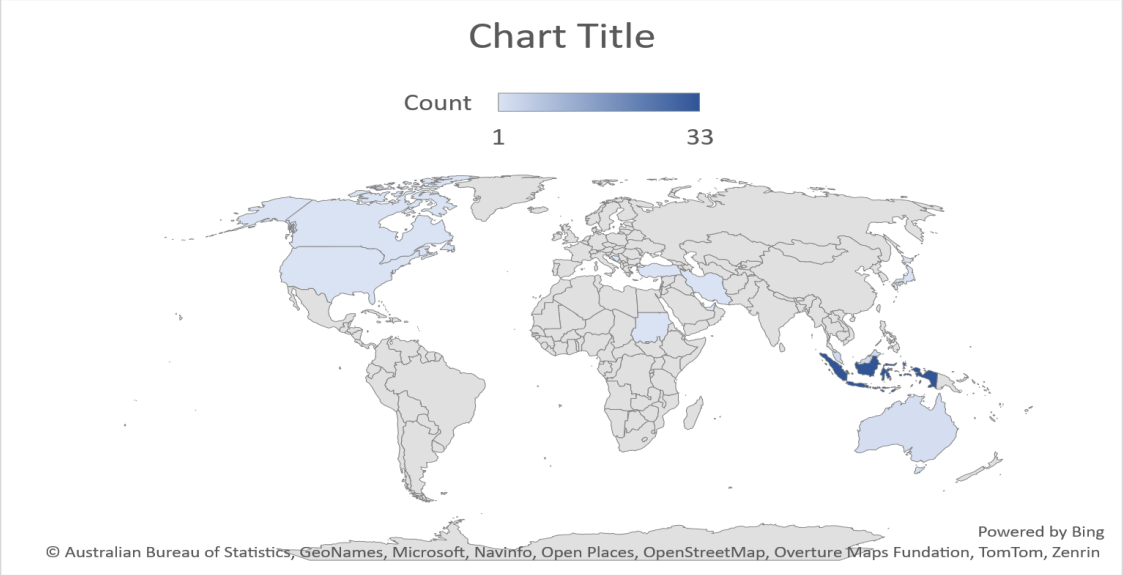

Figure 6. Geographical Distribution of Country Contributions in Mathematics Education Research (2014–2024)

When analyzing its global spread, this world map illustrates the distribution of research contributions or data based on color intensity, which indicates the number of contributions (Count). Darker blue shades represent higher levels of contribution, while lighter shades indicate lower contributions. The map offers insight into the geographical distribution of research activity or country involvement within the context of the analysis presented.

Indonesia emerges as the primary contributor, marked by a deep blue color that reflects the highest number of contributions (33). This indicates that Indonesia is a central hub of research activity or collaboration, whether in terms of the number of publications, participation, or other forms of contribution. This dominance suggests that the research or data represented in this map is strongly focused on Indonesia, possibly in connection with locally or regionally relevant themes. Other countries in Southeast Asia, North America, and Europe show notable involvement, although at lower intensities compared to Indonesia. The lighter blue shades in these regions reflect smaller yet still meaningful contributions. For instance, European countries may be engaged in international collaborations, but their level of activity is not as prominent as Indonesia's. North America also displays a moderate level of contribution, underscoring its role in the global research network. Large portions of the world such as Africa, South Asia, and South America appear in gray, indicating little to no contribution in this analysis. This may reflect limited access or relevance of the research topic in these regions. For example, the lack of data from Africa and South Asia could be due to resource constraints, limited research infrastructure, or differing research priorities.

Overall, the map illustrates a research contribution distribution heavily centered on Indonesia, with additional engagement from several countries in Southeast Asia, Europe, and North America. This distribution suggests a pattern of collaboration or research activity potentially tied to specific regional themes or driven by major institutions in the involved areas. The pattern offers valuable insight into the geographic dynamics of the research or data under analysis.

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Global Institutional Involvement in Research

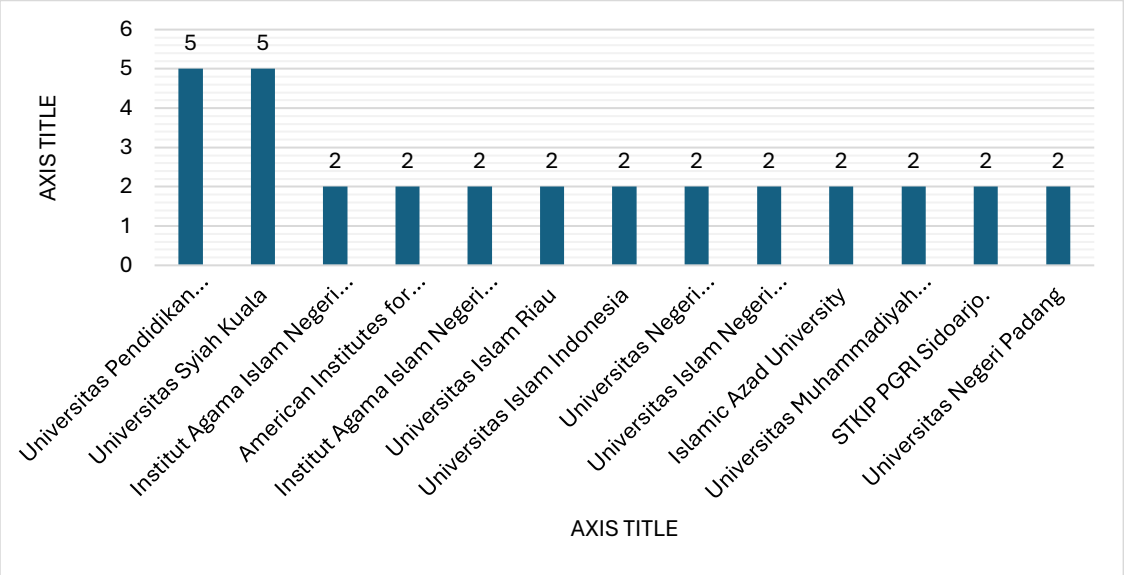

Figure 7. Institutional Contributions to Mathematics Education Research (2014–2024)

When examining the distribution of contributions based on institutional affiliations within the context of this specific research, the data reveals the level of involvement among various educational and research institutions in producing scholarly output. Universitas Pendidikan Indonesia (UPI) and Universitas Syiah Kuala emerge as the most active institutions, each contributing five publications. This places them at the top of the list, reflecting their capacity and commitment to supporting and leading research activities. Their pivotal roles within the research network indicate that these institutions possess sufficient resources and a strong reputation in the relevant academic field.

Most other institutions, such as Institut Agama Islam Negeri (IAIN) Kediri, American Institutes for Research, and Universitas Islam Riau, each contributed two publications. While their level of activity is lower than the leading institutions, they still play an important role in supporting the research network. Institutions like Universitas Negeri Semarang (UNNES) and Universitas Islam Negeri Sunan Ampel also made notable contributions, indicating active involvement in the research collaboration, though their participation may be more focused or specialized. What stands out in the data is the involvement of international institutions, such as the American Institutes for Research and Islamic Azad University, each with two contributions. This highlights the global dimension of the research, where cross-country collaboration plays a vital role. The presence of these international institutions demonstrates that the research under analysis extends beyond local or national relevance and involves academic actors from various regions worldwide. The diversity of participating institutions from major universities like UPI and Universitas Syiah Kuala to smaller colleges such as STKIP PGRI Sidoarjo reflects the inclusiveness of this research network. The fact that smaller-scale institutions are also able to contribute underlines the importance of cross-institutional collaboration, where different types of institutions bring varied perspectives and expertise to the table.

Overall, this table provides a clear picture of institutional contribution dynamics within the research network. UPI and Universitas Syiah Kuala clearly lead the field, while other institutions continue to play vital roles in expanding the reach and impact of the research. The presence of

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international institutions and the diversity in institutional scale illustrate that this research has broad coverage and the potential for significant local and global impact.

Mathematics Education Research Network

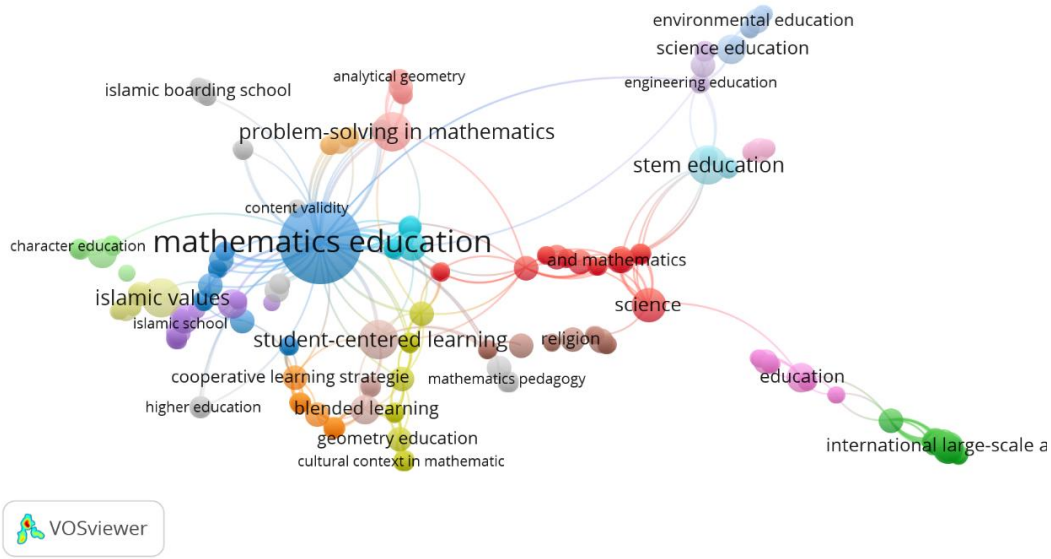

Figure 8. Co-Occurrence Map of Research Themes in Mathematics Education (2014–2024)

The topic map visualization of "mathematics education," generated using VOSviewer, illustrates how this field is interconnected with various subtopics and research approaches. The central topic, "mathematics education," appears as the largest node at the core of the map, reflecting its role as the primary focus of scholarly work in the domain. The relationships depicted in this map reveal interdisciplinary, methodological, and contextually integrated approaches within mathematics education.

At the center of the topic map, "mathematics education" serves as the core node connecting to a wide range of subtopics. Research in this area frequently encompasses broad approaches, from instructional strategies to multidisciplinary applications. Its link with subtopics like "problem-solving in mathematics" emphasizes the importance of problem-based learning as a key pedagogical focus for developing students' critical thinking skills. This demonstrates that mathematics education prioritizes not only theoretical understanding but also practical competencies. A strong association with "STEM education" highlights the role of mathematics as a foundational element in interdisciplinary teaching, especially in preparing students for the challenges of the modern world. Related nodes such as "science education" and "environmental education" further illustrate how mathematics supports broader educational objectives, such as understanding environmental issues or conducting scientific experiments.

Significant nodes such as "student-centered learning," "blended learning," and "cooperative learning strategies" emphasize the adoption of innovative teaching methods in mathematics education. These approaches aim to maximize student engagement, utilize modern technologies, and encourage collaborative learning to enhance comprehension. The prominence of these strategies signals a shift in mathematics education toward more interactive and personalized learning experiences. Additionally, nodes like "Islamic values," "character education," and "Islamic boarding school" reflect the integration of religious and moral values into mathematics education,

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particularly in regions with substantial Muslim populations. This suggests a culturally responsive approach that enriches mathematical learning with socially relevant ethical and spiritual dimensions.

The inclusion of subtopics like "international large-scale assessments" underscores the significance of global evaluations such as PISA and TIMSS in measuring the effectiveness of mathematics education across different countries. This indicates a broader objective to improve the quality of mathematics education worldwide by comparing varied instructional methods and their impact on student outcomes. In summary, the topic map reveals a rich, multidimensional landscape of mathematics education research, highlighting its interdisciplinary connections, pedagogical innovations, and cultural adaptations.

Authors' Contribution to Research Trends

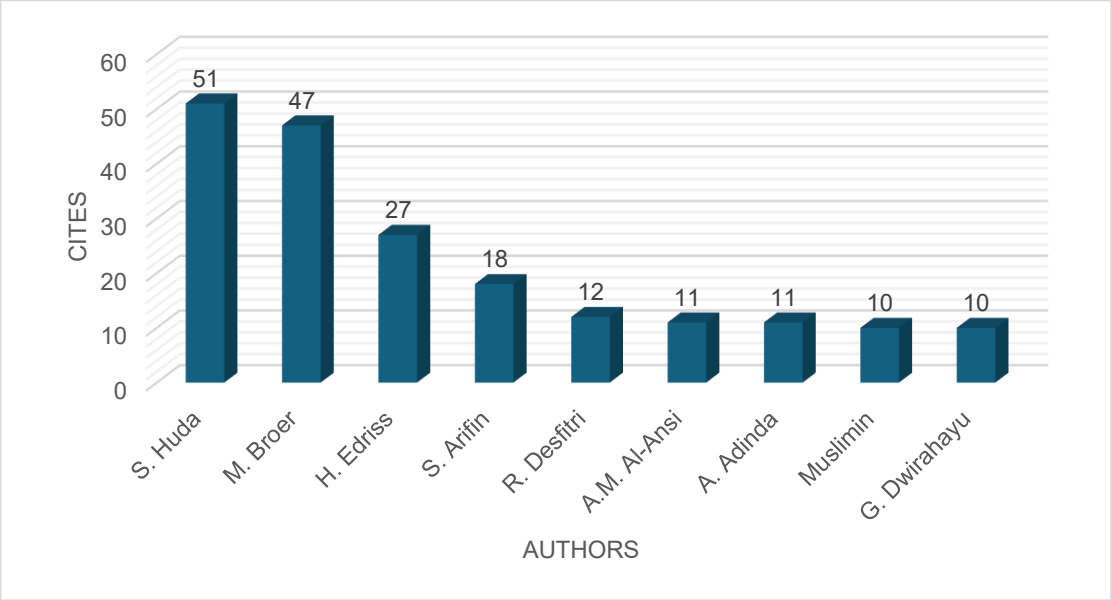

Figure 9. Author Citation Rankings in Mathematics Education Publications (2014–2024)

The table provided presents the number of citations received by a selection of authors, offering insight into their influence and contribution within the research community or a specific academic field. Citations are a key indicator of scholarly impact, reflecting the extent to which a researcher's work is recognized, referenced, and utilized by peers. Below is a detailed analysis based on the data:

The most cited author is S. Huda, with a total of 51 citations. This figure suggests that Huda's work is highly relevant and influential, likely addressing innovative topics or offering critical insights that serve as foundational references for many researchers. His leadership in scholarly output underscores a prominent role within the academic community. In second place, M. Broer has accumulated 47 citations. Although slightly fewer than Huda, this count still signifies a substantial academic impact. The minimal difference between their citation counts indicates that both authors wield nearly equal influence within the same research ecosystem, possibly contributing to complementary areas or collaborative themes.

H. Edriss, in third place with 27 citations, also demonstrates a meaningful contribution to the field. While his citation count is lower than that of the top two, it still reflects the importance of his work, likely focused on a specialized but significant area of research. Authors S. Arifin and R. Desfitri,

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with 18 and 12 citations, respectively, have also made notable contributions. Although their citation counts are not as high, they indicate a respectable level of recognition, potentially within more narrowly defined subfields or niche topics. Further down the list, authors such as A.M. Al-Ansi and A. Adinda, each with 11 citations, along with Muslimin and G. Dwirahayu, each with 10 citations, show that their research has begun to gain traction. These authors may be at earlier stages in their academic careers or contributing to more specialized research domains.

Overall, this citation data provides a snapshot of the hierarchy of influence among authors in the given research landscape. S. Huda and M. Broer stand out as key figures, reflecting the strong impact of their scholarly contributions. Meanwhile, the other authors, though cited less frequently, continue to play important roles in advancing relevant and meaningful research. The distribution of citations also highlights how an author's influence may vary depending on the relevance and scope of their work within the broader scientific community.

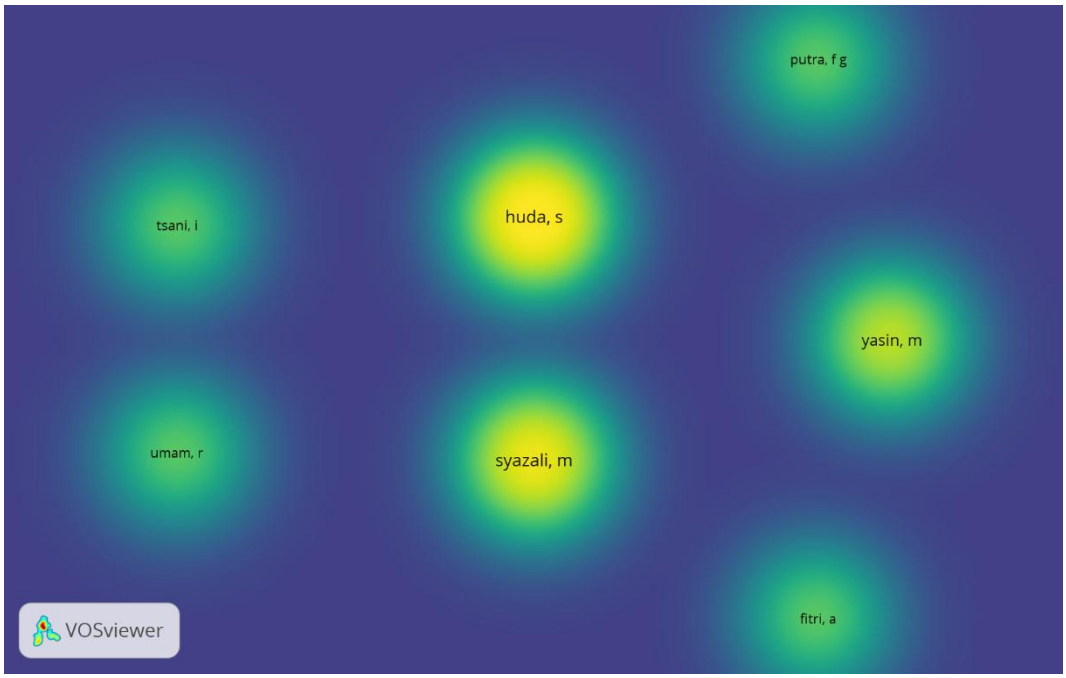

Figure 10. Visualization of Author Impact Based on Citation and Collaboration Intensity (2014–2024)

A similar insight is revealed through the visual density map generated in VOSviewer, which illustrates the distribution of author contributions within the research network. This visualization reflects each author's influence based on citation count, collaborative activity, or their overall contribution to the field. Brighter areas indicate higher concentrations of influence, while darker regions signify lower impact or more limited involvement.

In this visualization, S. Huda stands out as the most prominent author, represented by the largest and brightest node at the center of the map. The bright yellow glow surrounding his node signifies substantial contributions to the research network, whether through highly cited publications or extensive collaborations with other scholars. His influence is unmistakably central, positioning him as a key figure in the relevant field of study. Authors such as M. Syazali, M. Yasin, and F.G. Putra also have relatively large and bright nodes, though not as intense as that of S. Huda. The bright green shades around their nodes indicate that their contributions remain important, likely involving notable collaborations or influential publications, but their impact is somewhat more limited in scale

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or scope within the network. On the other hand, authors like I. Tsani, R. Umam, and A. Fitri are represented by smaller nodes in darker green to blue hues. This suggests a more modest contribution to the research network, possibly due to involvement in narrower or emerging research topics, fewer citations, or less extensive collaborative activity. Nevertheless, their presence is still meaningful, adding diversity and depth to the overall structure of the research community.

Overall, the visual density map reveals a clear hierarchy of influence within the research network. Leading authors like S. Huda dominate with considerable impact, while others contribute more selectively or within specific domains. This visualization provides valuable insight into how individual authors support the sustainability and development of research within the scholarly community.

Research Author Collaboration Network

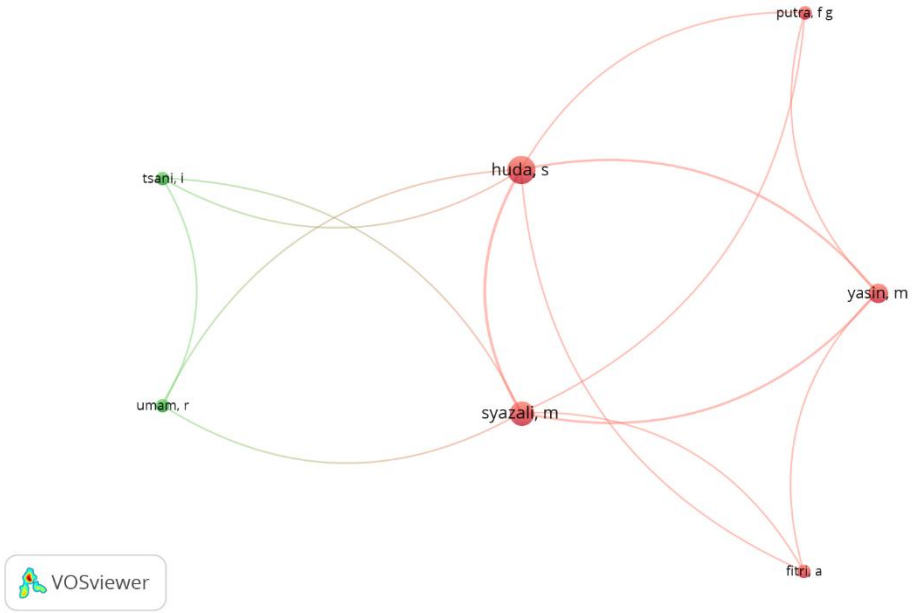

Figure 11. Author Collaboration Network in Mathematics Education Research (2014–2024)

Analyzing the collaboration network visualization, the map offers a clear depiction of the relationships between authors based on co-authored research. Larger, darker-colored nodes represent authors with greater influence or contributions within the research network. The connecting lines (edges) between nodes reflect collaborative ties, with thicker lines indicating more frequent or intense collaboration.

S. Huda stands out as the central figure in the network, represented by the largest and darkest red node. This positioning indicates that Huda is the most influential author, with extensive connections to numerous other researchers, including M. Syazali, M. Yasin, and F.G. Putra. The high number of direct links to S. Huda underscores his critical role as a hub of collaboration, suggesting that projects involving him often serve as a foundation for further research partnerships. M. Syazali and M. Yasin also feature relatively large nodes, signifying their importance as key collaborators. Their strong links with S. Huda reflect a close working relationship across multiple research projects. These connections form the core structure of the collaboration network, where their joint efforts amplify the collective influence of the group. In contrast, I. Tsani and R. Umam form

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a smaller sub-cluster that is indirectly linked to S. Huda through M. Syazali. The green color of their nodes indicates more specialized contributions, likely tied to narrower research themes. Their thinner connecting lines suggest a lower frequency of collaboration compared to the central cluster. Authors like F.G. Putra and A. Fitri have direct ties to both S. Huda and M. Yasin, but their influence appears more limited in the overall network. This likely reflects involvement in specific projects without broader integration into the full scope of the network's collaborative dynamics.

Overall, the visualization reveals a well-organized structure of research collaboration, with S. Huda at its core. The strong ties between Huda, Syazali, and Yasin form a stable nucleus, while smaller subgroups like those of Tsani and Umam highlight more focused research interactions. This network structure provides valuable insight into how individual contributions shape broader patterns of academic collaboration and knowledge production.

Temporal Developments in Mathematics Education Research

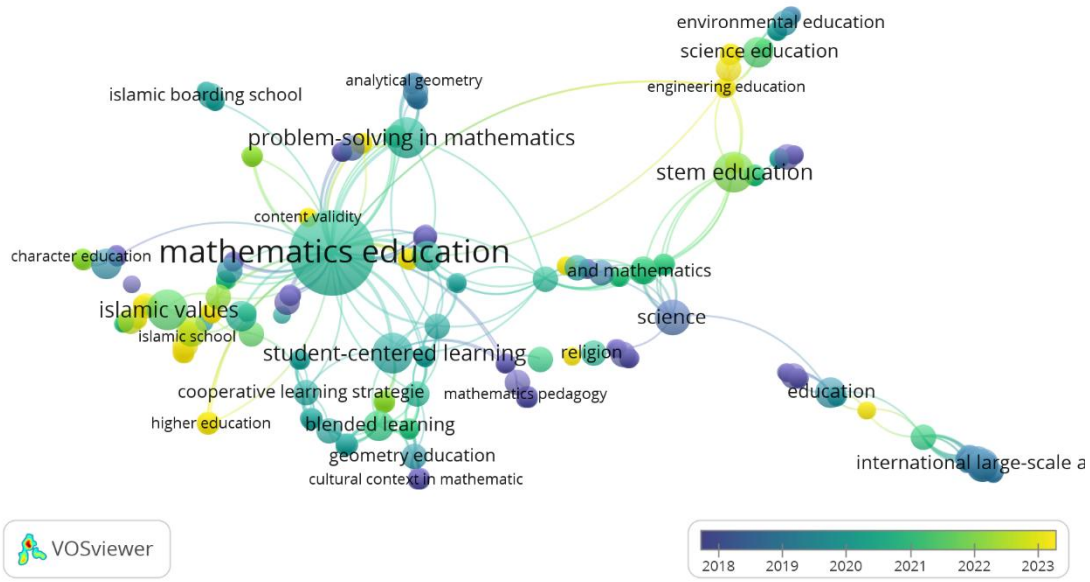

Figure 12. Temporal Evolution of Research Themes in Mathematics Education (2018–2023)

The visual overlay from VOSviewer offers a clear depiction of the temporal development in mathematics education research, based on data from 2018 to 2023. The color gradient, ranging from blue (2018) to yellow (2023), illustrates the timeline during which specific topics gained prominence. This temporal mapping provides valuable insight into how research priorities have shifted and evolved over time.

At the center of the map, "mathematics education" appears as the largest node, colored bluish green, indicating its status as the core focus of research from around 2019 to 2021. From this central node, multiple subtopics branch out, reflecting broad connections to various dimensions of education. The bluish-green hue suggests that the field has experienced steady development, with associated subtopics dominating during specific timeframes. In the early years (2018–2020), the focus was on topics such as "Islamic values," "student-centered learning," and "problem-solving in mathematics", represented in blue to light green. This indicates that research during this period was oriented toward value-based and innovative pedagogical approaches, particularly integrating

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religious, moral, and student-centered frameworks into mathematics education. These themes laid the foundation for broader exploration in the years that followed.

Between 2020 and 2022, research attention expanded to more interdisciplinary and global themes, such as "STEM education," "science education," and "environmental education." These nodes appear in bright green, signaling their dominance during this period. This trend likely reflects an increased effort to connect mathematics education with science, technology, and environmental issues. Simultaneously, "blended learning" gained prominence, mirroring the shift toward tech-enhanced instruction accelerated by the COVID-19 pandemic. In the most recent period (2022–2023), the focus shifted toward more specialized topics, including "international large-scale assessments" and "engineering education," which appear in yellow. This color signifies their recent emergence and growing importance. The prominence of international assessments such as PISA and TIMSS illustrates a global emphasis on evaluating mathematics education quality. Likewise, the rise of engineering education highlights the practical application of mathematics in technical and professional fields, marking a new research direction.

Overall, this visual overlay demonstrates the dynamic evolution of mathematics education research, transitioning from value-based and pedagogical approaches to cross-disciplinary collaboration and global evaluation metrics. The changing colors in the visualization clearly reflect how interconnected research topics have grown and adapted to meet evolving academic, social, and global challenges.

DISCUSSION

Research on global trends and collaboration in mathematics education during the 2014–2024 period reveals a significant increase in publication volume and the involvement of various countries. In the early years, the number of studies was limited, but a marked rise began in 2017, peaking in 2020. This surge was likely driven by growing interest in STEM-based education and international assessments such as PISA and TIMSS. However, following this peak, the number of publications declined and stabilized, possibly due to reduced research urgency after the pandemic and challenges in academic funding. These findings align with previous studies (Ouvry & Furtado, 2019; Waite et al., 2020), which suggest that the dynamics of mathematics education research are often influenced by external factors such as global education policy and social change.

In addition to publication trends, this study also highlights the diversity of countries involved in mathematics education research. Indonesia and Malaysia emerged as the most dominant contributors over the past decade, followed by Turkey and several countries in the Middle East and North America. The growing involvement of these countries reflects the strengthening of international academic collaboration networks, as noted by Crismono (2017) and Baiduri et al. (2020). However, a disparity remains in the geographical distribution of research, with minimal contributions from countries in Africa and South Asia. These findings suggest that access to research resources and national educational priorities continue to be key determinants of global participation in mathematics education.

In terms of academic collaboration, this study found that Universitas Pendidikan Indonesia (UPI) and Universitas Syiah Kuala are the most active institutions in publishing mathematics education research. This highlights the significant role of higher education institutions in Indonesia in building broader and more sustainable research networks. Previous studies by Donthu et al. (2021) and Gao et al. (2022) also emphasize the importance of academic collaboration as a key factor in enhancing the quality and impact of global research. Moreover, the involvement of

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institutions from the United States and Iran in these collaborative networks indicates the participation of scholars from diverse backgrounds in advancing mathematics education on a global scale.

In addition to institutional involvement, the analysis of author networks reveals that several scholars hold significant influence in mathematics education research. Authors such as S. Huda and M. Broer have the highest citation counts, indicating that their work serves as a key reference in the field. The presence of strong collaborative networks among authors from various countries reflects a growing awareness of the importance of academic cooperation in producing more comprehensive and relevant research. This finding aligns with studies by Crismono (2023) and Hashem et al. (2023a), which concluded that cross-institutional and international collaboration can enhance research impact and accelerate innovation in mathematics education.

Thematically, this study identifies several key subtopics within mathematics education, including problem-based learning, integration with STEM, and contextual approaches that incorporate religious and cultural values. These shifting trends reflect a movement away from traditional pedagogical methods toward technology-based education and large-scale evaluation frameworks. These findings are consistent with studies by Ingram (2024) and Li et al. (2021), which demonstrate that mathematics education is increasingly evolving into an interdisciplinary field, combining various methods and approaches to enhance learning effectiveness.

Overall, this study provides valuable insights into the dynamics of mathematics education research over the past decade. The rise in academic collaboration, thematic shifts, and the influence of global factors on publication trends indicate that the field is undergoing significant evolution. Looking ahead, mathematics education research must continue to promote more inclusive international collaboration, develop technology-driven approaches, and leverage international assessments to enhance learning effectiveness. In doing so, mathematics education can not only contribute to improving the global quality of education but also serve as a more effective tool in preparing future generations to navigate an increasingly complex world.

CONCLUSION

This study reveals the development of trends and collaboration in global mathematics education research over the period 2014–2024, highlighting a significant rise in publication output that peaked in 2020, followed by a period of stabilization in recent years. Indonesia and Malaysia emerged as leading contributors, while international collaboration expanded steadily, indicating that mathematics education research is becoming increasingly global and interdisciplinary. Institutions such as Universitas Pendidikan Indonesia (UPI) and Universitas Syiah Kuala played key roles within this research network, with influential scholars like S. Huda and M. Broer making substantial contributions to the academic literature. Thematic focus has also shifted, moving away from traditional pedagogical approaches toward the integration of STEM, technology, and international assessments such as PISA and TIMSS. These findings suggest that mathematics education is evolving not only in terms of geographic reach but also in approach and methodology, becoming increasingly modernized. This affirms the importance of global collaboration in driving innovation and improving learning effectiveness within the field.

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