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Research Trends in Islamic-Based Mathematics Education: Global Studies and Academic Collaboration Networks

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ABSTRACT: This study analyzes global trends and collaboration in mathematics education research during the 2014–2024 period using a bibliometric approach. The findings indicate a significant increase in the number of publications, peaking in 2020 before stabilizing in recent years. Indonesia and Malaysia have been the primary contributors, with increasing involvement from other countries such as Turkey, Iran, and Saudi Arabia. International collaboration has expanded, marked by a growing academic network and contributions from major institutions such as Universitas Pendidikan Indonesia (UPI) and Universitas Syiah Kuala. The study also identifies a thematic shift from traditional pedagogical approaches toward integration with STEM, technology, and international assessments such as PISA and TIMSS. Furthermore, the collaborative network among researchers reveals that certain academics, such as S. Huda and M. Broer, have had a significant influence on the research community. These findings underscore the importance of cross-national and interdisciplinary collaboration in driving innovation and enhancing the effectiveness of mathematics education globally. Thus, this research provides valuable insights for academics, policymakers, and education practitioners in developing more inclusive and sustainable strategies for mathematics education research and teaching.

KEYWORDS: Bibliometrics, International Assessment, Islamic, Global Collaboration, Mathematics Education, Research Trends, STEM.

INTRODUCTION

Mathematics education plays a crucial role in supporting global development; however, research trends and dynamics in this field indicate significant challenges (P. Crismono, 2017; Ouvry & Furtado, 2019; Waite, 2020). Despite the increase in the number of publications and international collaborations between 2014 and 2024, the diversity of geographical and institutional contributions remains an issue. This raises questions about how temporal patterns in the number of studies and the geographical distribution of contributions reflect the evolving global needs for mathematics education. Additionally, while cross-national and institutional collaboration networks have expanded, their impact on the relevance and influence of research is not yet fully understood. This study also needs to explore to what extent the diversity of participating institutions affects the inclusivity of research networks and the innovations produced.

Furthermore, mathematics education is increasingly integrating interdisciplinary approaches such as STEM, technology, and contextual values such as religion and culture. However, the impact of this integration on curriculum innovation and learning strategies remains an open question (Ingram, 2024; Kurniawan, 2021; Li et al., 2021). At the same time, international assessments such as PISA and TIMSS serve as key tools for evaluating the quality of mathematics education globally, yet their relationship with research trends and author contributions has not been comprehensively mapped. Moreover, the relationship patterns among authors, which reflect thematic focuses and research subtopics, need 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; Dian, 2022; Kemendikbud, 2019; Mullis et al., 2019; OCDE, 2023).

This research aims to identify key patterns in global mathematics education research networks, evaluate their impact on educational innovation, and provide practical recommendations for strengthening cross-national and institutional collaboration. Thus, this study is not only relevant to mathematics education but also encompasses sociological dimensions, education management, and technological applications, making it significant for various related fields. In a global context facing challenges such as pandemics, technological innovation, and cross-cultural education needs, this research is a crucial step in bridging knowledge gaps regarding the sustainability and relevance of international collaboration in mathematics education.

Research Questions

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1. What are the trends in the number of studies conducted between 2014 and 2024?
2. How has the diversity of countries involved in research evolved over time?
3. What are the patterns of country contributions to research collaboration each year?
4. How is the geographical distribution of research contributions worldwide?
5. How does the diversity of participating institutions affect the inclusivity of research networks and their impact on research outcomes?
6. How do mathematics education research networks reflect interdisciplinary and methodological approaches, and how do these influence curriculum development and learning strategies?
7. How are citation distribution and author contributions structured within the research network?
8. How do author relationship patterns reflect specific thematic focuses or research subtopics?
9. How do temporal developments in mathematics education research from 2018 to 2023 reflect shifts in focus and trends in this field?

RESEARCH METHODOLOGY

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

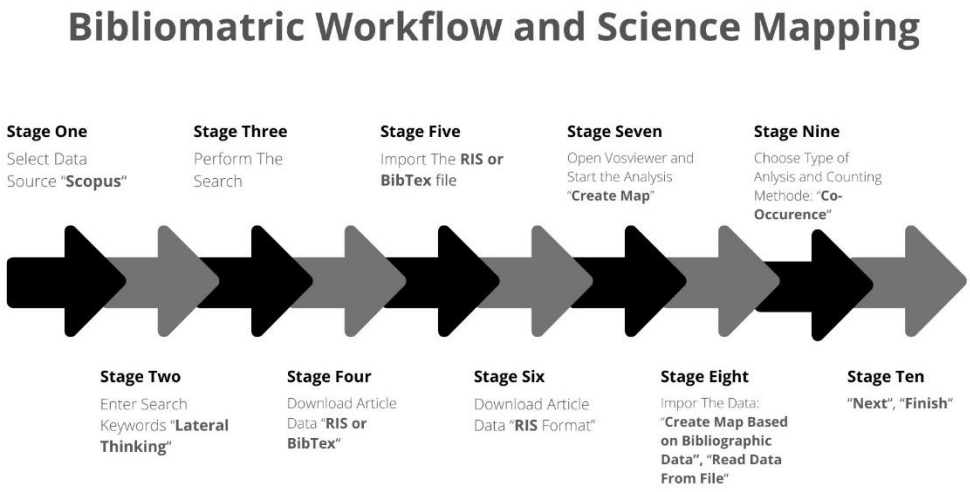

Figure 1. Bibliometric Workflow and Science Mapping
(Aria & Cuccurullo, 2017; Tekdal, 2021; van Eck & Waltman, 2010b)

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, namely a focus on mathematics education, publication within the 2014–2024 period, and coverage of international collaboration data and geographical distribution. The metadata of selected publications were downloaded using VOSviewer and Excel to facilitate further analysis (P. C. Crismono, 2024; Hashem E et al., 2023a; Jing et al., 2024).

Data analysis involved several stages. First, bibliometric analysis was performed 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 used to identify dominant research subtopics, including the integration of mathematics education with STEM, technology, and contextual values. Additionally,

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research impact was assessed using citation indexes (such as h-index and g-index) to measure the relevance of works and identify the most contributing authors or institutions (Jing et al., 2024; van Eck & Waltman, 2010a).

To ensure data validity, this study conducted triangulation by combining multiple data sources, manually validating collaboration networks, and verifying geographical distribution through digital mapping. The study also adheres to academic ethical principles, utilizing only public data and properly acknowledging all referenced sources. The findings will be presented through publication trend graphs, geographical distribution maps, international collaboration network visualizations, and thematic analysis 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).

RESEARCH RESULTS

This study employed a qualitative approach using semi-structured interviews based on the Theory of Planned Behavior (TPB) framework to explore the influence of attitudes, subjective norms, and perceived behavioral control on students' cognitive flexibility in solving open-ended mathematical problems. Data were collected from three groups of students with varying levels of mathematical ability (high (A), medium (B), and low (C)) through interviews that examined their perspectives on open-ended problems, the social influence of peers and teachers, and their confidence in attempting alternative solutions. The analysis was conducted using thematic analysis, where students' responses were coded based on the main TPB components to evaluate the intensity and patterns of their attitudes. Data validation was ensured through triangulation involving interviews, observations, and documentation to guarantee the accuracy of the findings. The results revealed a strong relationship between positive attitudes, supportive social norms, and high perceived behavioral control with cognitive flexibility. The study also identified key challenges and strategies to enhance students' ability to explore solutions in mathematics learning.

1. Research Trend Developments from 2014 to 2024

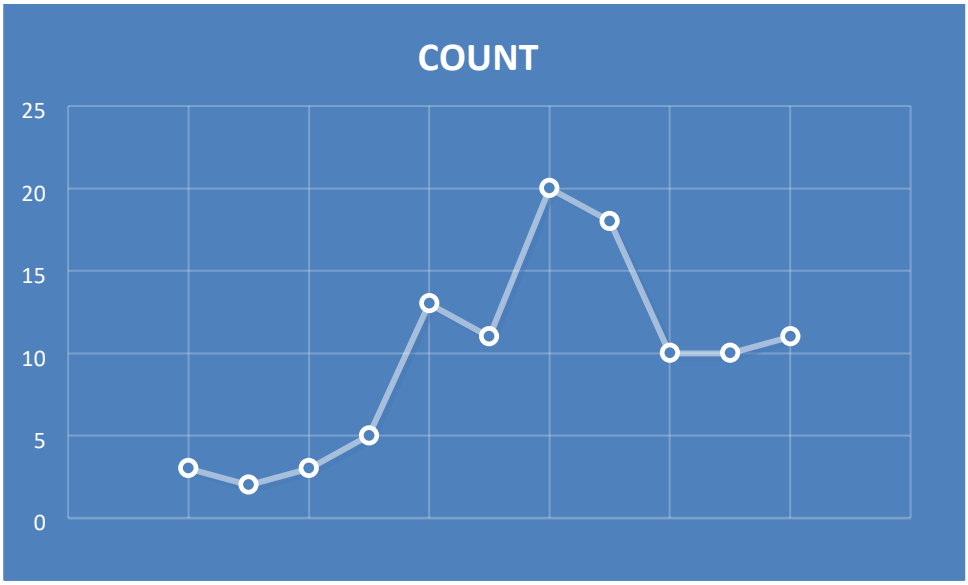

Figure 2. Trends in Mathematics Education Research Publications (2014–2024)

The uploaded graph illustrates the trend in the number of studies conducted from 2012 to 2024. During the initial period, from 2012 to 2016, the number of studies remained relatively low and stable, averaging only 2 to 4 studies 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, between 2017 and 2019, there was a significant increase in the number of studies. The number of publications grew consistently, from around 5 studies in 2017 to over 15 in 2019. This surge indicates a growing interest in the field, potentially driven by increased funding opportunities and stronger academic collaborations during this period.

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The peak of research activity was reached in 2020, with the number of studies nearing 25. This year can be considered a golden period for research in this field, possibly driven by urgent needs or the heightened relevance of certain topics, such as the COVID19 pandemic, which spurred research in health, technology, and policy. However, after reaching its peak, the trend saw a sharp decline in 2021, with the number of studies dropping dramatically to around 10. This decline may have resulted from the diminishing urgency of pandemic-related topics or resource constraints following the previous surge in research activity. In the last three years (2022 to 2024), the trend has shown stabilization, with the number of studies remaining at approximately 10 per year. There was a slight increase in 2024, which may indicate a recovery or renewed focus on previously overlooked topics. Overall, this trend reflects a cyclical pattern in research activity influenced by various factors, including academic interest, societal needs, and resource and funding constraints.

2. Research Country Trend Developments from 2014 to 2024

Table 1. Yearly Distribution of Research Publications and Contributing Countries (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 show an intriguing development in both the number of studies and the participation of various countries. In the early period (2014–2016), the number of studies was still very low, ranging between 2 to 3 studies per year. During this stage, countries such as Malaysia, Indonesia, and Tunisia were the primary contributors. This relatively limited activity suggests that the research focus and cross-country collaborations had not yet developed significantly.

From 2017 to 2019, the number of studies increased significantly. From only 5 studies in 2017, the number surged to 13 in 2018 and remained high at 11 studies in 2019. This increase can be seen as a result of growing international collaborations, with contributions from new countries such as Bosnia, Turkey, and Sudan, alongside the consistent leadership of Indonesia and Malaysia. The growing diversity of participating countries indicates an expansion of the global research network, making it more inclusive.

2020 marked the peak year in research activity, with 20 publications, reflecting an extraordinary level of research engagement. Contributions came from Saudi Arabia, Australia, and Kuwait, further enriching international collaboration. This surge was likely influenced by global conditions, particularly the COVID-19 pandemic, which drove increased research on topics related to health, technology, and policy. In 2021, although there was a slight decline, the research output remained high at 18 studies, supported by countries such as Canada, Iran, and Thailand.

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Between 2022 and 2024, research trends stabilized, with an average of 10 to 11 studies per year. Indonesia, Malaysia, and Turkey continued to be key players in this period, while India, Australia, New Zealand, and Yemen emerged as new contributors. The stability in research output suggests a more structured and sustainable international collaboration, although the intensity is not as high as the peak in 2020.

Overall, these findings reflect the evolution of international research, transitioning from limited collaborations to a broader cross-country cooperation network. The dominant role of countries like Indonesia and Malaysia highlights the significance of the Asian region in global research, while the emergence of new contributing countries signals great potential for further expansion of the global research network in the future.

3. Annual Research Country Trend Developments from 2014 to 2024

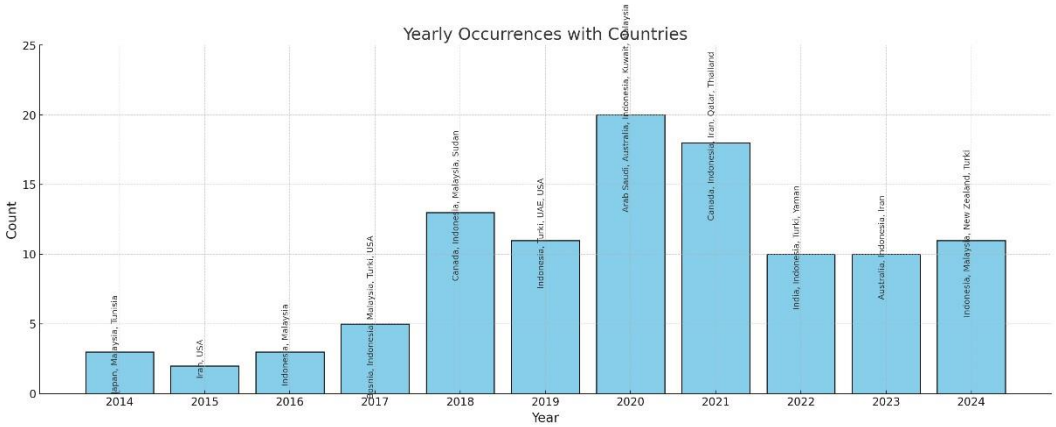

Figure 3. Yearly Distribution of Research Publications and Contributing Countries (2014–2024)

The trend in the number of studies per year and the countries involved from 2014 to 2024 demonstrates significant shifts in research volume and international participation. Over this period, research collaboration evolved from a limited initial phase to a peak period, followed by stabilization in recent years. This pattern reflects how global and regional needs have influenced the intensity and scale of international research cooperation.

During the initial phase (2014–2016), research activity remained relatively low, with only 2 to 3 studies published per year. International collaboration was also minimal, with Malaysia, Indonesia, and Tunisia being the primary contributors. Research during this time was largely regional in scope, indicating that cross-border cooperation had not yet developed extensively.

The growth phase (2017–2019) marked a turning point, with a notable increase in research output. The number of studies rose significantly, exceeding 10 publications per year in 2018 and 2019. This period also saw an expansion in the number of participating countries, with Turkey and Sudan joining as key contributors alongside Indonesia and Malaysia. The rise in international collaboration during this time was likely driven by greater global connectivity and the increasing need for cross-national research to address complex educational and technological challenges.

In the peak phase (2020–2021), the number of studies reached its highest level, with 18 to 20 publications per year. This surge in research was accompanied by a wider international participation, including contributions from Saudi Arabia, Australia, Kuwait, and Qatar. The peak in research activity was likely influenced by the global urgency caused by the COVID-19 pandemic, which spurred intensive cross-border collaboration in fields such as education, technology, and policy. This period highlighted how global crises can act as catalysts for strengthening international research networks.

The stabilization phase (2022–2024) saw a more consistent research output, with 10 to 11 studies published per year. Although the intensity of research decreased slightly compared to the peak period, new contributors such as India, Yemen, and New Zealand emerged, signifying a broader and more diverse international collaboration network. Meanwhile, Indonesia and Malaysia remained key players, ensuring continuity in global research efforts.

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Overall, this trend illustrates the evolution of research collaboration, transitioning from a limited early stage to an era of peak global cooperation, followed by a more structured and sustainable stabilization. The data underscores how both global challenges and regional priorities shape the landscape of international research collaboration, influencing academic partnerships and research output over time.

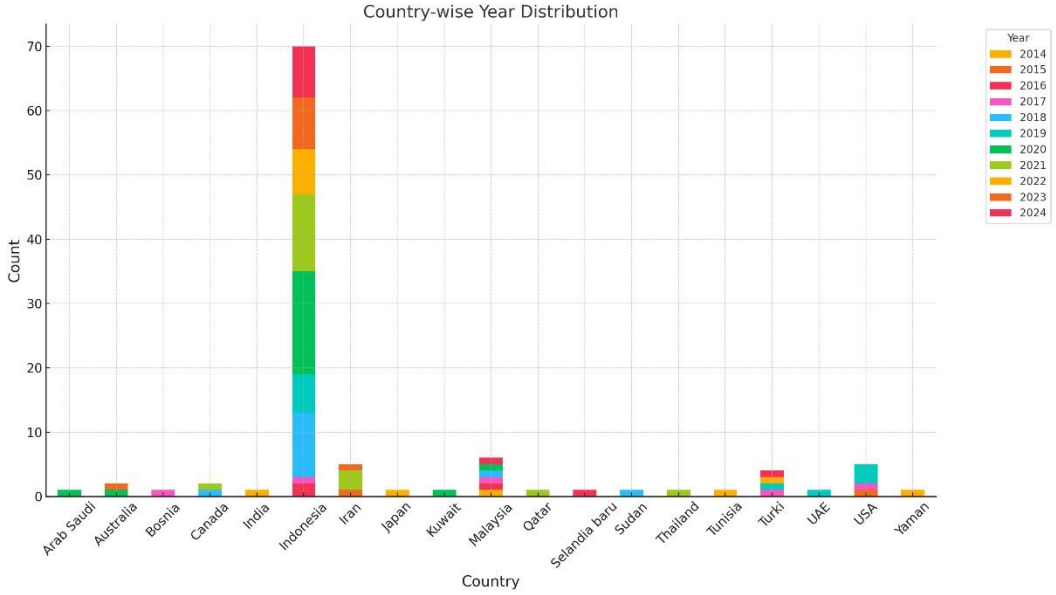

Figure 4. Country-wise Distribution of Research Publications by Year (2014–2024)

This data illustrates how different countries have contributed to research activity over the 2014–2024 period. The distribution not only highlights the dominance of certain key countries but also reveals how international research collaboration networks have evolved over time. The graph clearly shows that Indonesia has the highest number of contributions compared to other countries. Indonesia's involvement is evident almost every year, reflecting its role as a consistent and active research hub. This significant contribution indicates that Indonesia serves as a key center for international collaboration, linking multiple countries through research that is relevant both regionally and globally. Indonesia's dominant position also suggests its strong capacity to lead research initiatives across a wide range of topics and issues.

Beyond Indonesia, Malaysia and Turkey have also been major contributors, particularly during the growth phase (2017–2024). Malaysia, which has consistently participated in research, often serves as a primary partner in collaborations with Indonesia. This indicates a close research relationship between the two countries, reinforcing their commitment to cross-border academic cooperation. Meanwhile, Turkey has shown significant contributions, especially after 2017, enriching global research networks by introducing new perspectives and collaborations.

Other countries, such as Iran, the USA, and Saudi Arabia, were actively involved in specific years, particularly during the research peak in 2020–2021. Their participation likely reflects a global response to urgent needs, such as the COVID-19 pandemic, which increased international research efforts on health, technology, and education. Additionally, new contributors like India, Yemen, and New Zealand began participating during the stabilization phase (2022–2024). Their presence indicates that research collaboration continues to expand, not only maintaining long-standing partnerships but also attracting new countries into the global research network.

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4. Geographical Distribution of Research Based on Researchers' Countries

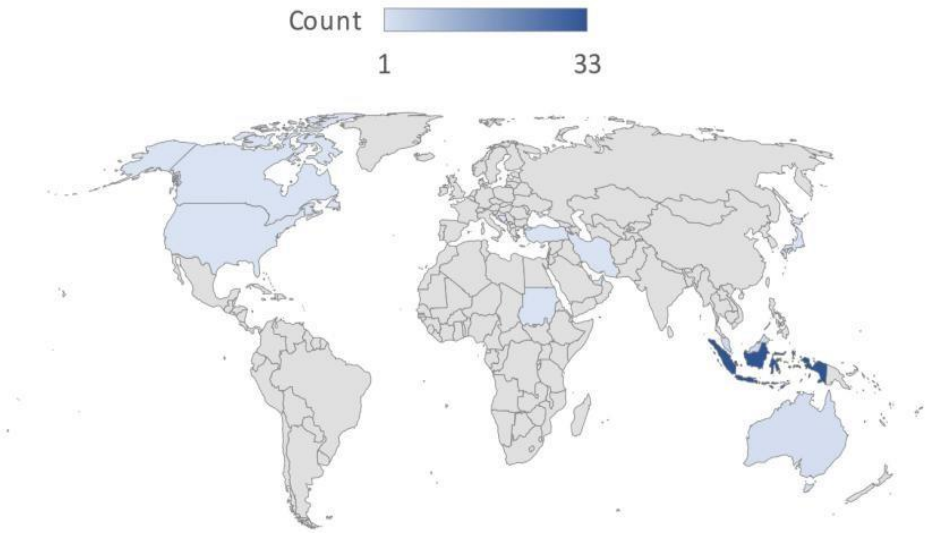

Figure 5. Global Distribution of Research Publications in Mathematics Education (2014–2024)

When analyzing the global distribution of research contributions, this world map visualization highlights how different countries have participated in research activity based on color intensity. The darker blue shades represent a higher number of contributions, while lighter blue shades indicate a lower contribution level. This visualization provides valuable insights into the geographical spread of research involvement and how international collaboration has evolved over time.

Among all contributing countries, Indonesia stands out as the most active participant, with dark blue shading representing the highest number of contributions (33). This dominance indicates that Indonesia plays a central role in global research collaboration, particularly in mathematics education and related fields. The country's high contribution suggests that Indonesian researchers and institutions have established strong academic networks, making Indonesia a key hub for research development in the region. This also implies that much of the analyzed research is strongly tied to local or regional themes relevant to Indonesia.

Beyond Indonesia, several Southeast Asian, North American, and European nations also exhibit notable engagement, albeit with lower intensity. The lighter blue shading in these regions reflects moderate but still meaningful contributions. For example, Malaysia consistently appears as a research collaborator, often partnering with Indonesia in cross-border academic projects. European countries and North America, despite being involved in international research networks, show less dominance in this particular dataset compared to Indonesia. However, their contributions remain relevant in shaping global research trends.

A large portion of the world, including Africa, South Asia, and South America, is represented in gray, indicating little to no contributions in this dataset. This may be due to limited access to research funding, infrastructure constraints, or different research priorities in these regions. For example, the absence of substantial contributions from Africa and South Asia may be influenced by factors such as resource limitations, a lower focus on this specific field of study, or variations in national research agendas.

Overall, the distribution of research contributions is highly concentrated, with Indonesia as the dominant player, followed by select Southeast Asian, European, and North American countries. This pattern suggests that research collaborations and activities are often linked to regional academic hubs and specific institutional networks. The findings provide valuable insights into the global landscape of research involvement, illustrating how certain countries lead research efforts while others remain underrepresented. As international collaboration continues to grow, future studies may seek to bridge research gaps in underrepresented regions, fostering a more inclusive and diverse global research ecosystem.

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5. Global Institutional Involvement in Research

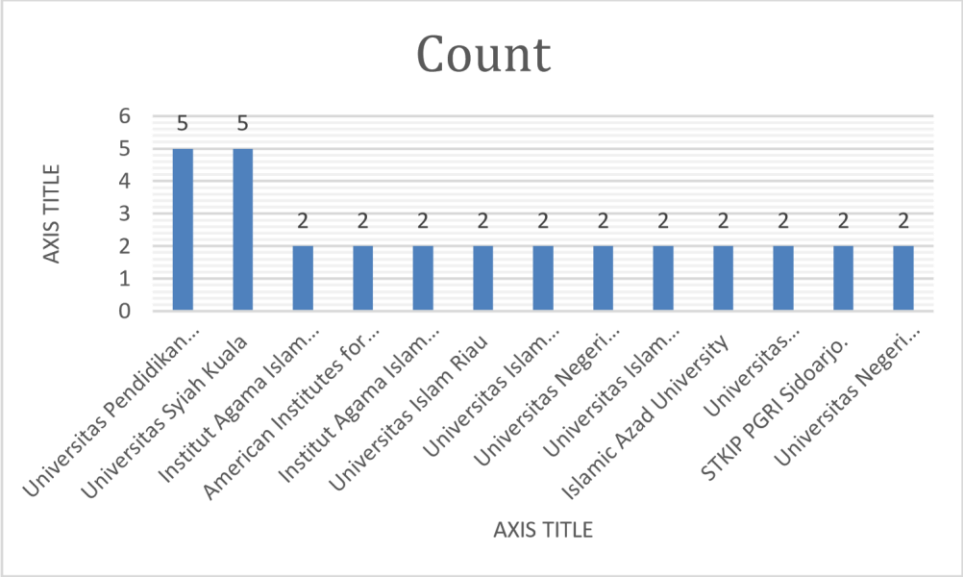

Figure 6. Institution-wise Publication Count in Mathematics Education

The distribution of research contributions based on institutional affiliations provides valuable insights into the level of involvement of various educational and research institutions in producing scientific work. This data highlights leading institutions, their roles in research collaboration, and the global dimension of academic networks. Among all institutions, Universitas Pendidikan Indonesia (UPI) and Universitas Syiah Kuala stand out as the most active contributors, each with five research contributions. Their position at the top of the list reflects their strong commitment and capacity to support and lead research activities. Their consistent involvement suggests that these institutions possess significant research resources and a strong reputation, allowing them to play a central role in academic collaboration.

Several other institutions, such as Institut Agama Islam Negeri (IAIN) Kediri, American Institutes for Research, and Universitas Islam Riau, have contributed two publications each. While their contributions are smaller in scale, they still play a critical role in expanding the research network. Similarly, Universitas Negeri Semarang (UNNES) and Universitas Islam Negeri Sunan Ampel have made notable contributions, demonstrating active participation in research, although their involvement may be more specialized or focused on particular themes. One notable aspect of this data is the presence of international institutions, such as American Institutes for Research and Islamic Azad University, both contributing two publications. Their involvement highlights the global reach of this research, where cross-country collaboration plays an essential role. The participation of international institutions suggests that this research extends beyond local and national contexts, gaining global relevance and attracting engagement from diverse academic environments.

The presence of both regional and global institutions underscores the importance of collaborative knowledge exchange in advancing research. It also reflects the increasing trend of cross-border partnerships aimed at addressing shared academic and societal challenges. The diversity of participating institutions, ranging from large universities such as UPI and Universitas Syiah Kuala to smaller institutions like STKIP PGRI Sidoarjo, demonstrates the inclusive nature of this research network. The active involvement of smaller institutions suggests that collaborative research is not limited to major academic hubs—instead, a broad range of institutions can contribute unique perspectives and expertise, enriching the overall research landscape. This institutional diversity is essential for ensuring a wide representation of ideas and methodologies, promoting interdisciplinary collaboration, and enhancing the impact of research on both local and global scales.

Overall, the data provides a comprehensive picture of the institutional contributions to research collaboration. UPI and Universitas Syiah Kuala emerge as dominant players, actively shaping research efforts, while other institutions contribute to strengthening and diversifying the academic network. The presence of international institutions and the variety of contributors

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indicate that this research has a broad scope and significant potential to make an impact both locally and globally. As collaborative research efforts continue to grow, fostering stronger institutional partnerships, increasing funding opportunities, and promoting interdisciplinary collaboration will be crucial in ensuring the sustainability and expansion of global research networks.

6. Mathematics Education Research Network

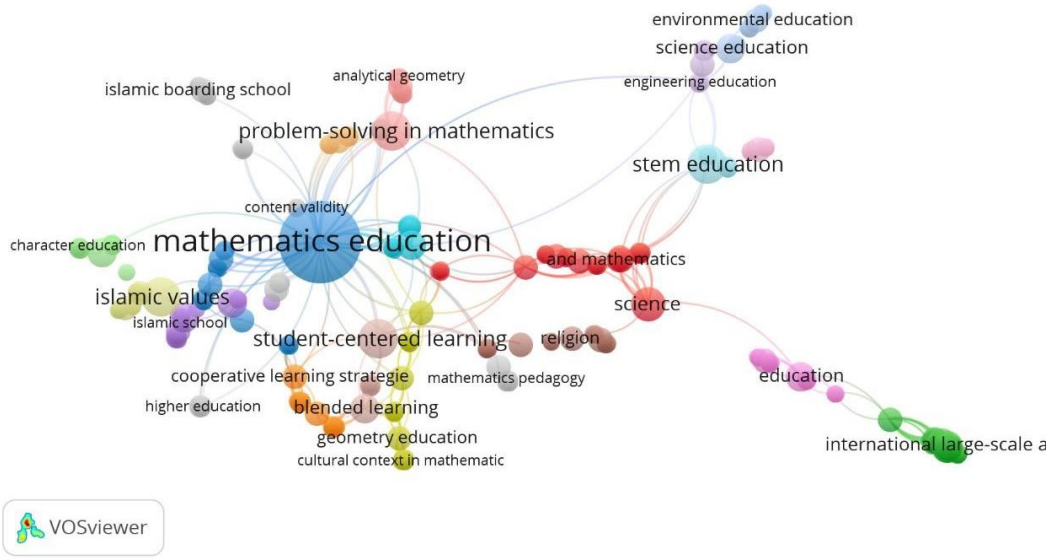

Figure 7. Keyword Co-occurrence Network in Mathematics Education Research

The topic map visualization of "mathematics education" generated using VOSviewer illustrates how this field is connected to various subtopics and research approaches. The main topic, "mathematics education," is positioned at the center of the map with the largest node, reflecting its primary focus within the field of mathematics education research. The relationships depicted in this visualization reveal interdisciplinary approaches, methodological connections, and the integration of contextual values in mathematics education. At the core of the topic map, "mathematics education" serves as the foundation for numerous subtopics and research connections. Studies in mathematics education often encompass a broad spectrum of approaches, ranging from teaching strategies to multidisciplinary applications. The connection to subtopics such as "problem-solving in mathematics" indicates that problem-based learning is a key focus for enhancing students' critical thinking skills. This suggests that mathematics education is not only concerned with theoretical knowledge but also with practical skill development.

A strong link with "STEM education" demonstrates that mathematics education is frequently associated with science, technology, and engineering. This reflects the fundamental role of mathematics in interdisciplinary learning, particularly in preparing students for modern challenges. Other subtopics, such as "science education" and "environmental education," highlight how mathematics is used to support broader learning contexts, such as understanding environmental concepts 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 suggest a growing focus on maximizing student engagement through modern technology and collaborative learning environments. The prominence of these strategies indicates a shift in mathematics education towards more interactive and personalized learning experiences.

Nodes such as "Islamic values," "character education," and "Islamic boarding school" highlight the integration of religious and moral values in mathematics education, particularly in regions with significant Muslim populations. This reflects how mathematics education can be adapted to cultural and religious contexts, enriching learning with socially relevant values.

Subtopics such as "international large-scale assessments" underscore the importance of global evaluations, such as PISA and TIMSS, in assessing the success of mathematics education across different countries. This focus on international assessments reflects a

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commitment to improving the quality of mathematics education globally, by comparing different educational approaches and their impact on student learning outcomes.

7. Authors' Contributions to Research Trends

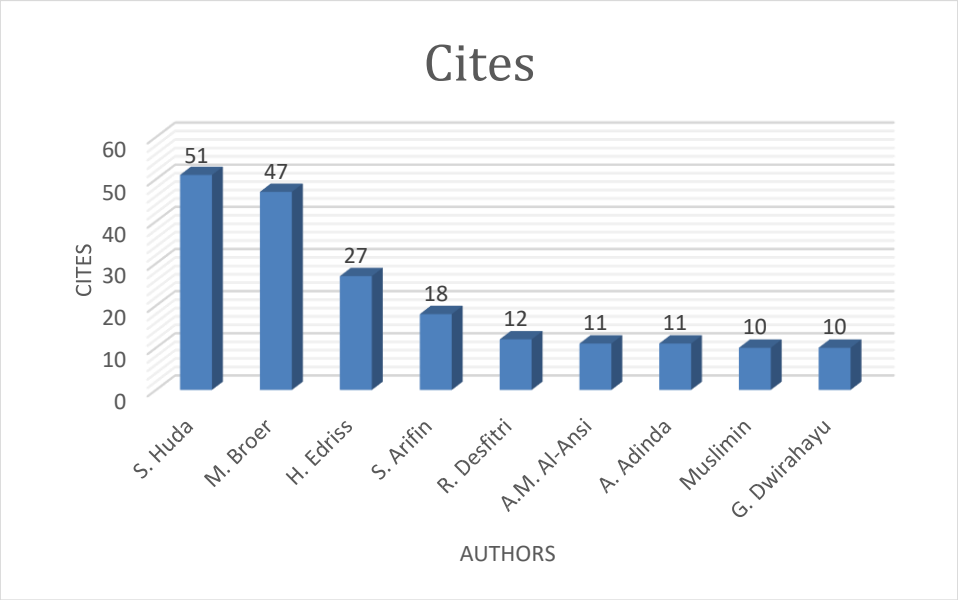

Figure 8. Citation Distribution by Author

The citation data provided highlights the influence and contributions of various researchers within their respective fields. Citations serve as a key metric in assessing the impact of academic work, indicating how widely referenced an author's research is by other scholars. The number of citations reflects the relevance, quality, and influence of a researcher's work in shaping discussions within the academic community. Among all the authors, S. Huda ranks highest with 51 citations, making them the most influential contributor in this dataset. This high citation count suggests that S. Huda's research is widely recognized and serves as a primary reference in the field. It is likely that their work covers innovative or highly relevant topics, making a substantial impact on ongoing research.

M. Broer follows closely in second place with 47 citations, demonstrating an almost equal level of influence. The small difference between S. Huda and M. Broer's citations suggests that both authors play a critical role in advancing research and are highly regarded within their academic community. Their work has likely been referenced across multiple studies, contributing to broader academic discussions. In third place, H. Edriss has received 27 citations, which, while lower than the top two, still indicates a significant contribution to the field. The difference in citation numbers suggests that H. Edriss's research may focus on a more specialized topic, yet it remains impactful within its niche.

Authors such as S. Arifin (18 citations) and R. Desfitri (12 citations) also show notable contributions, though on a more focused scale. These researchers may have specialized areas of expertise that attract attention from a specific subset of scholars rather than the broader academic community. Their research is still valuable, contributing essential insights to their respective fields. Similarly, A.M. Al-Ansi (11 citations) and A. Adinda (11 citations), along with Muslimin (10 citations) and G. Dwirahayu (10 citations), have established their presence within the research landscape. While their citation counts are lower, this could be due to several factors, such as being early-career researchers, working in highly specialized areas, or having recently published studies that have yet to accumulate widespread citations.

Overall, the citation data illustrates a clear hierarchy of influence within the research community. S. Huda and M. Broer emerge as the most impactful authors, shaping key discussions and serving as primary references in their field.

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Other authors, despite having fewer citations, still contribute significantly by advancing specific research areas and providing valuable insights within specialized topics. The differences in citation counts also highlight how author influence varies depending on the relevance, scope, and accessibility of their research. As research continues to evolve, citation trends may shift, allowing emerging scholars to gain greater recognition and impact over time.

8. Research Authors' Collaboration Network

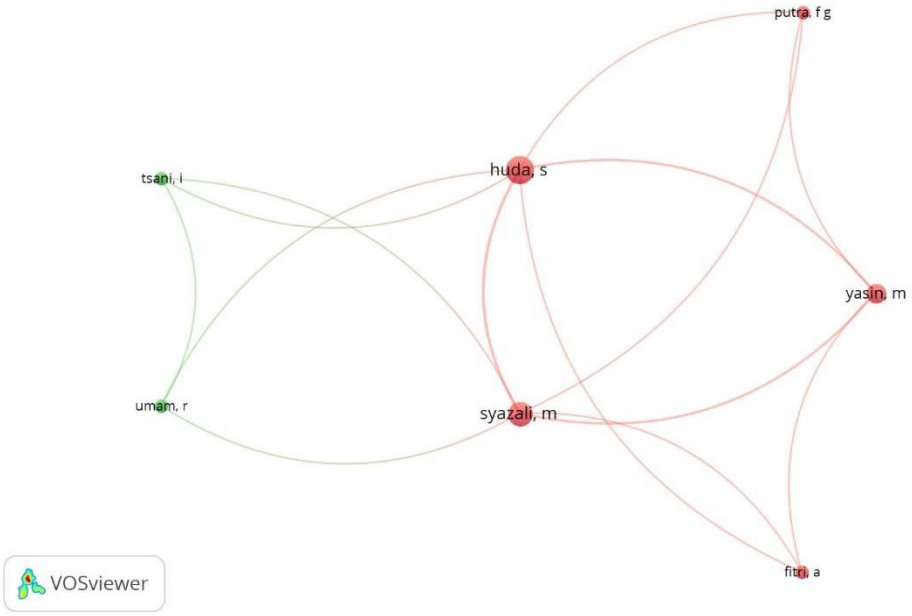

Figure 9. Co-Authorship Network Visualization

The visualization of the research network provides a clear representation of collaborative relationships among authors based on their published studies. Larger and darker-colored nodes indicate authors with greater influence or more significant contributions within the research network. The connecting lines between nodes represent collaborations or co-authorship links, with thicker lines signifying stronger or more frequent collaborations. In this network, S. Huda stands out as the most central and influential author, represented by the largest and darkest red node. This position reflects S. Huda's extensive connections with multiple researchers, including M. Syazali, M. Yasin, and F.G. Putra. The numerous direct connections originating from S. Huda's node indicate a key role in fostering collaborations and leading research initiatives. The strong links within this network also suggest that studies involving S. Huda serve as foundational references for further research collaborations.

Authors M. Syazali and M. Yasin also have relatively large nodes, indicating their roles as primary collaborators within the network. Their strong direct connections with S. Huda suggest a close research partnership, particularly in joint projects and coauthored publications. This interconnected structure highlights the core of the research collaboration network, where their collective contributions enhance the overall influence of the group. In contrast, I. Tsani and R. Umam form a smaller subgroup, which is indirectly connected to S. Huda through M. Syazali. Their green-colored nodes indicate that their contributions are more specialized and likely focused on niche research topics. The thinner connecting lines between these authors suggest that their collaborations occur less frequently compared to the core members of the network.

Similarly, F.G. Putra and A. Fitri maintain direct links to both S. Huda and M. Yasin, but their overall influence appears more limited. This suggests that while they are involved in research collaborations, their contributions are more specific to certain projects rather than having a broader impact across the entire network.

Overall, this visualization of research collaborations reveals a well-organized network, with S. Huda at its core, maintaining strong connections with the majority of other authors. The close partnerships between S. Huda, M. Syazali, and M. Yasin indicate a solid research foundation, while smaller subgroups like I. Tsani and R. Umam highlight the existence of specialized research clusters.

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This structure provides valuable insights into how individual contributions shape the dynamics of a larger research collaboration. It also underscores the importance of core research leaders, who serve as hubs of innovation and academic exchange, ensuring that collaborative research efforts continue to evolve and expand.

9. Temporal Developments in Mathematics Education Research

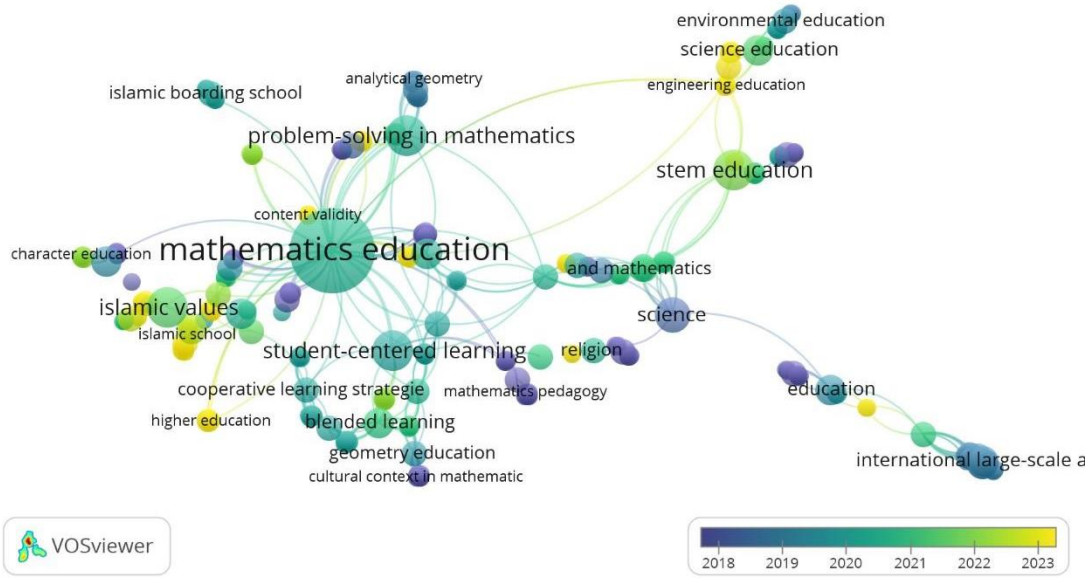

Figure 10. Research Trend Temporal Visualization in Mathematics Education

The overlay visualization from VOSviewer provides a detailed view of the temporal evolution of mathematics education research from 2018 to 2023. The colors in the visualization represent the time frame when specific topics were dominant, ranging from blue (2018) to yellow (2023). This temporal mapping allows researchers to track changes in research focus, identify emerging trends, and understand how different topics have gained relevance over time.

At the center of the visualization, "mathematics education" stands out as the main research focus, represented by the largest node in cyan-green shades. This indicates that between 2019 and 2021, mathematics education remained the primary theme in academic research, with various subtopics branching out from it. The cyan-green color suggests that research in this field continued to expand and diversify, with different subtopics gaining prominence at different points in time.

During the early years (2018–2020), research predominantly focused on topics such as "Islamic values," "student-centered learning," and "problem-solving in mathematics," which appear in blue to light green shades. These topics indicate an early emphasis on pedagogical innovation and values-based education, particularly in:

- The integration of moral and religious perspectives in mathematics education.
- Student-centered learning methodologies aimed at enhancing engagement and improving problem-solving skills.
- Innovative teaching strategies, such as inquiry-based and collaborative learning approaches.

These foundational research trends set the stage for subsequent interdisciplinary developments, broadening the scope of mathematics education beyond traditional classroom instruction.

From 2020 to 2022, the research focus began shifting towards broader, interdisciplinary themes, including "STEM education," "science education," and "environmental education," represented in bright green shades. This shift suggests an increasing emphasis on:

- Mathematics as a foundational component of STEM disciplines, reinforcing its role in interdisciplinary education.
- Mathematics applications in environmental and sustainability education, aligning with the global focus on climate change and ecological awareness.

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- The rise of blended learning and digital education models, which became increasingly relevant during the COVID-19 pandemic, prompting research on technology integration in mathematics teaching.

This period marked a significant transition in research direction, as scholars explored how mathematics education intersects with other disciplines and adapts to technological advancements.

In the most recent phase (2022–2023), research has become more specialized, with increased attention to topics such as "international large-scale assessments" and "engineering education," which appear in yellow shades. These emerging research themes highlight:

- A growing focus on global education assessment frameworks, such as PISA and TIMSS, which measure the effectiveness of mathematics education worldwide.
- The integration of mathematics into engineering education, emphasizing its practical applications in technical and professional fields.

These trends reflect a shift towards evaluating the global impact of mathematics education and ensuring that it aligns with industry needs and international educational standards.

The VOSviewer overlay visualization effectively illustrates the progressive evolution of mathematics education research. Initially, studies focused on pedagogical innovation and values-based education before transitioning into STEM integration, interdisciplinary learning, and digital education strategies. In recent years, research has further evolved to focus on global assessment frameworks and the practical applications of mathematics in engineering and other technical fields. The color transitions in the visualization depict these shifts clearly, demonstrating how mathematics education research has continuously adapted to academic, societal, and technological developments. This visualization provides a valuable roadmap for future research, offering insights into how different topics are interconnected and how they have shaped the field over time.

DISCUSSION

Research on global trends and collaboration in mathematics education from 2014 to 2024 reveals significant growth in publication volume and international involvement. In the early years, research output was relatively limited but began to increase in 2017, reaching its peak in 2020. This surge was likely driven by growing attention to STEM-based education and international assessments such as PISA and TIMSS. However, after peaking, publication numbers declined and stabilized, possibly due to reduced urgency in pandemic-related research and challenges in academic funding. These findings align with previous studies by Waite et al. (2020) and Ouvry & Furtado (2019), which suggest that mathematics education research trends are often influenced by external factors such as global education policies and social changes.

Beyond publication trends, this study highlights the diversity of countries contributing to mathematics education research. Indonesia and Malaysia have emerged as the leading contributors over the past decade, followed by Turkey and several countries from the Middle East and North America. The increasing involvement of these nations reflects a strengthening global academic collaboration network, as noted by Crismono (2017) and Baiduri et al. (2020). However, geographical imbalances remain, with limited contributions from African and South Asian countries. This indicates that access to research resources and national education priorities continue to shape global participation in mathematics education research. Regarding academic collaboration, this study identifies Universitas Pendidikan Indonesia (UPI) and Universitas Syiah Kuala as the most active institutions in mathematics education publications. This underscores the critical role of Indonesian higher education institutions in expanding and sustaining global research networks. Previous studies by Donthu et al. (2021) and Gao et al. (2022) also emphasize that academic collaboration is a key factor in enhancing research quality and impact. Additionally, the presence of institutions from the United States and Iran within the collaboration network demonstrates the involvement of scholars from diverse backgrounds in advancing global mathematics education research.

Beyond institutions, an analysis of author networks reveals that certain scholars hold significant influence in mathematics education research. Authors like S. Huda and M. Broer have the highest citation counts, indicating that their works serve as primary references in the field. The strong collaboration network among authors from different countries reflects a growing awareness of the importance of academic partnerships in producing comprehensive and relevant research. These findings align with studies by Crismono (2023) and Hashem E et al. (2023), which suggest that cross-institutional and international collaborations enhance research impact and accelerate innovation in mathematics education. In terms of research themes, this study identifies several

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dominant subtopics, including problem-based learning, STEM integration, and contextual approaches incorporating religious and cultural values. These evolving trends reflect a shift from traditional pedagogy toward technology-driven education and large-scale evaluations. This transformation aligns with findings from Ingram (2024) and Li et al. (2021), which indicate that mathematics education has become an increasingly interdisciplinary field, incorporating diverse methods and approaches to improve learning outcomes.

Overall, this study provides valuable insights into the evolving landscape 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 this field continues to undergo significant transformations. Looking ahead, mathematics education research should focus on promoting more inclusive international collaboration, developing technology-enhanced learning strategies, and leveraging global assessments to improve educational effectiveness. By doing so, mathematics education can not only contribute to the overall improvement of global education quality but also serve as a powerful tool in preparing future generations to face increasingly complex global challenges.

CONCLUSION

This study reveals the evolution of trends and collaboration in global mathematics education research over the 2014–2024 period, highlighting a significant increase in publications that peaked in 2020 before stabilizing in recent years. The findings indicate that Indonesia and Malaysia have emerged as the leading contributors, while international collaborations have expanded, demonstrating that mathematics education research is becoming increasingly global and interdisciplinary. Institutions such as Universitas Pendidikan Indonesia (UPI) and Universitas Syiah Kuala play a key role in the research network, with prominent authors like S. Huda and M. Broer exerting significant influence in academic literature. Additionally, the thematic focus of research has shifted from traditional pedagogical approaches to STEM integration, technological advancements, and international assessments such as PISA and TIMSS. These findings suggest that mathematics education is evolving not only in geographical scope but also in methodologies and approaches, emphasizing the importance of global collaboration in driving innovation and improving learning effectiveness in the field.

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