Analysing the landscape and assessing the progress of mathematics education research: A bibliometric study spanning 2009-2019

Anmol

M.Sc. Applied Mathematics, South Asian University, New Delhi, India

Abstract

This research paper presents a bibliometric analysis of mathematics education research in India spanning the years 2009 to 2019. The primary objective is to provide a comprehensive overview of the research landscape in this field and assess its progress during the specified timeframe. To achieve this, the study employs a robust methodology, including data collection from academic databases, paper selection criteria, and advanced bibliometric analysis techniques. Mathematics education plays a pivotal role in India's educational framework, making it essential to examine its research landscape. The study aims to identify trends, influential authors, institutions, and journals, and analyze the evolution of research themes and their impact. Through extensive data collection and rigorous analysis, the research uncovers significant insights. It reveals evolving publication patterns, co-authorship networks, and citation dynamics within mathematics education research. The use of bibliometric tools and software facilitates a deep understanding of the field's structure and development. Key findings highlight the growth and transformation of mathematics education research in India over the specified decade. The research identifies emerging themes, evolving authorship patterns, and shifts in academic collaboration.These findings have significant implications. They guide educators, policymakers, and researchers in navigating the evolving landscape effectively. Furthermore, they underscore the importance of continued investment in mathematics education research to enhance educational quality in India. As we move forward, this research serves as a valuable resource, shaping the future of mathematics education research in the country.

Keywords: Mathematics education, research trends, bibliometric analysis, India, educational research

Introduction

Mathematics education is a critical component of any nation's educational system, playing a pivotal role in shaping the skills and competencies of its citizens. In India, a country with a rich mathematical heritage and a rapidly evolving educational landscape, the importance of mathematics education research cannot be overstated. With its diverse population and a burgeoning demand for high-quality education, India's progress in this field is of global significance.

The landscape of mathematics education has undergone significant transformations over the past few decades. This evolution has been driven by a variety of factors, including changes in curricular frameworks, the integration of technology in teaching and learning, and a growing emphasis on pedagogical innovation. To understand the impact of these changes and assess the trajectory of mathematics education research, it is imperative to conduct a thorough bibliometric analysis that captures the pulse of the field (Smith, 2017) [11].

Bibliometric analysis is a powerful approach for scrutinizing the dynamics of academic research by quantifying publication patterns, authorship networks, and citation trends. This research paper presents such a bibliometric study that focuses on mathematics education research conducted in India from 2009 to 2019. The chosen timeframe is crucial as it encapsulates a decade marked by significant developments in the field,

including the implementation of the National Curriculum Framework for School Education (NCERT, 2005) [8], which brought about substantial changes in mathematics pedagogy (Sharma *et al*., 2012) [10].

The objectives of this research are multifold. First and foremost, it seeks to map the landscape of mathematics education research during the specified period. By systematically analyzing a vast dataset of research papers and related publications, this study endeavors to identify key research themes, influential authors, research institutions, and academic journals within the domain. Such insights are vital for understanding the intellectual structure of the field and the contributions made by various stakeholders (Moed *et al*., 2010) [7].

Furthermore, this research aims to assess the progress made in mathematics education research. By examining publication trends, patterns of academic collaboration, and citation dynamics, it seeks to gauge the field's evolution and impact. This assessment can provide valuable guidance to educators, policymakers, and researchers, helping them align their efforts with the evolving needs of mathematics education in India (Hicks *et al*., 2015) [3].

The significance of this study extends beyond academia. In a rapidly changing educational landscape, the findings can inform policy decisions, curriculum development, and educational practices related to mathematics education. By identifying research gaps and emerging trends, this research contributes to

evidence-based decision-making processes (Gibbons *et al*., 2018) [1].

In the following sections, we will delve into the methodology employed for data collection and analysis, present the key findings of this bibliometric study, and discuss their implications for the future of mathematics education research in India.

Literature Review

Mathematics education research in India has evolved significantly over the years, mirroring the transformations in the country's educational landscape. Understanding the historical context and the state of mathematics education research provides a valuable foundation for our bibliometric analysis.

India's commitment to mathematics education has deep historical roots. Scholars like Aryabhata and Brahmagupta made significant contributions to mathematics in ancient India (Kapur, 2008) [5]. The formalization of mathematics education in India's modern education system began during British colonial rule, with the establishment of universities and the introduction of mathematics curricula (Jaffar, 2019) [4].

However, it is in the post-independence era that mathematics education research gained prominence. The National Council of Educational Research and Training (NCERT) played a pivotal role in shaping mathematics education policies (NCERT, 2005) [8]. It introduced the National Curriculum Framework for School Education in 2005, which emphasized conceptual understanding, problem-solving, and application-based learning in mathematics (Sharma *et al*., 2012) [10]. This shift in pedagogical approaches had a profound impact on mathematics education research, with a focus on innovative teaching methods and curriculum development (Rajput, 2016) [9].

In the realm of mathematics education research, India has seen the emergence of influential scholars and institutions. The works of renowned researchers like R. Ramanujam and M. S. Raghunathan have significantly contributed to the field (Krishnamurthi, 2014) [6]. Furthermore, institutions such as the Tata Institute of Fundamental Research (TIFR) and the Homi Bhabha Centre for Science Education (HBCSE) have been at the forefront of research and curriculum development in mathematics education (HBCSE, 2021) [2].

Bibliometric studies related to mathematics education research have also played a crucial role in understanding the field's dynamics. Research by scholars like Smith (2017) [11] and Wu (2020) [12] has explored global trends in mathematics education research, providing valuable insights into the international context.

However, while the literature offers insights into mathematics education research on a global scale, there is a need for a dedicated bibliometric analysis. Such a study can provide a nuanced understanding of the country's contributions, collaborations, and trends within the field.

Moreover, the digital age has transformed the way research is conducted and disseminated. Open access initiatives and digital repositories have made research more accessible and collaborative (Xie & Zhang, 2019) [13]. These advancements have implications for how mathematics education research is conducted and shared.

In summary, the literature review highlights the historical evolution of mathematics education research, emphasizing key policy changes, influential scholars, and institutions. It also underscores the existing gap in the literature, which this research paper aims to fill by conducting a comprehensive bibliometric analysis specific to mathematics education research landscape.

Methodology

The methodology section outlines the rigorous process employed to collect and analyze data for this bibliometric study on mathematics education research in India from 2009 to 2019. It provides a detailed description of data collection, selection criteria for inclusion, and the analytical techniques used.

Data Collection: The first step in this research involved extensive data collection from reputable academic databases and repositories. Key sources include: Scopus. These sources were chosen to ensure a comprehensive dataset that spans various publication types, including research papers, and journal articles. The inclusion of institutional repositories ensures the incorporation of local and institutional contributions, which are sometimes overlooked in traditional bibliometric studies.

To maintain data integrity, all retrieved records were carefully checked for duplication and redundancies. This involved the use of reference management software to organize and deduplicate the dataset.

Inclusion Criteria: The inclusion criteria were established to ensure that the dataset represents mathematics education research conducted during the specified period. The following criteria were applied:

Relevance: Only publications directly related to mathematics education research were included. This excluded papers focused on pure mathematics or other unrelated subjects.

Publication Year: Papers published between 2009 and 2019 were considered, as this timeframe aligns with our research objectives.

Language: While an effort was made to include publications in English, those in other languages were not excluded to capture a broader spectrum of research.

Publication Type: Various publication types were considered, including research articles and research paper.

Data Analysis: Bibliometric analysis techniques were employed to explore the dataset comprehensively. Several key analytical aspects were investigated:

Publication Trends: An analysis of the publication trends, including the total number of publications over time, growth rates, and changes in publication types, was conducted to understand the dynamics of mathematics education research in India.

Authorship Networks: Co-authorship networks were constructed to identify influential authors, collaboration patterns, and research clusters within the field.

Citation Analysis: Citation counts and citation networks were analyzed to identify highly cited papers, influential authors, and research themes with significant impact in the field.

Keyword Analysis: A keyword analysis was performed to identify prominent research themes and emerging topics in mathematics education research in India during the study period.

Institutional Analysis: The research affiliations of authors were examined to identify institutions contributing significantly to the field.

Advanced bibliometric software tools, including VOSviewer and CiteSpace, were used to visualize and analyze the data, facilitating the extraction of meaningful insights.

Ethical considerations were paramount throughout this study. All data were collected and analyzed in compliance with ethical guidelines and copyright regulations. Proper citation and acknowledgment of sources were ensured to maintain academic integrity and respect intellectual property rights.

This comprehensive methodology outlines the systematic approach employed in collecting and analyzing data for this bibliometric study. It sets the stage for the subsequent sections, where the key findings and implications of the research will be presented and discussed in detail.

Data Collection and Analysis

The data collection process was a meticulous endeavor to ensure the comprehensiveness and reliability of the dataset. A combination of academic databases and repositories was used to gather publications related to mathematics education research in India from 2009 to 2019.

The process began with keyword searches and Boolean queries, targeting keywords such as "mathematics education," and variations thereof. Retrieved records were imported into reference management software to facilitate data organization and deduplication.

Data integrity was maintained through rigorous deduplication procedures. Duplicate records were identified and removed based on publication titles, author names, and publication sources. This process ensured that each publication in the dataset was unique, eliminating redundancies.

Additionally, data quality checks were performed to identify and rectify any discrepancies or errors in the dataset. This involved verifying publication details such as author names, publication dates, and affiliations against the original sources.

Table 1: Main Information

Description	Results
Main Information About Data	
Timespan	2009:2019
Sources (Journals, Books, etc)	362
Documents	1292
Annual Growth Rate%	10.54
Document Average Age	8.11
Average citations per doc	16.12
References	47452
Document Contents	
Keywords Plus (ID)	787
Author's Keywords (DE)	3011
AUTHORS	
Authors	2598
Authors of single-authored docs	292
Authors Collaboration	
Single-authored docs	321
Co-Authors per Doc	2.47
International co-authorships%	12.15
Document Types	
Article	1292

"Table 1: Main Information" offers a comprehensive overview of a decade's worth of academic research from 2009 to 2019, encapsulating a significant breadth and depth of data. The table reveals a steady annual growth rate of 10.54% across 1,292 documents sourced from 362 journals and books, indicating an expanding field of study. Notably, the documents have an average age of 8.11 years and an impressive average citation rate of 16.12, highlighting their sustained impact. The diversity in research themes is evident from the extensive use of both 'Keywords Plus' and 'Author's Keywords'. Furthermore, the data showcases a rich tapestry of authorship with 2,598 authors contributing, balanced between individual efforts (292 single-authored documents) and collaborative works, including a notable 12.15% of international co-authorships. All documents are categorized as 'Articles', underscoring a preferred format for research dissemination in this field. This table not only reflects the vibrancy and dynamism of the research area but also underscores the importance of collaborative and impactful research. However, it lacks specific details on the subject areas or the impact factor of the sources, suggesting areas for further in-depth analysis. In summary, the data in "Table 1: Main Information" paints a picture of a robust and influential research landscape, marked by steady growth, diverse authorship, and significant collaborative and international efforts.

Table 2: Annual Production

Year	Articles
2009	76
2010	78
2011	96
2012	95
2013	102
2014	106
2015	120
2016	121
2017	139
2018	152

"Table 2: Annual Production" provides a clear overview of the yearly output of articles over a decade, from 2009 to 2018. The table shows a consistent upward trend in the number of articles produced each year, starting with 76 in 2009 and nearly doubling to 152 by 2018. This increasing trend indicates a growing interest and expansion in the field of study.

A closer look at the yearly increments reveals a steady, albeit varying, rate of growth. The initial years (2009-2010) show a modest increase, but from 2011 onwards, there's a more pronounced annual growth in article production. The years 2015 to 2018, in particular, show a significant surge, with the number of articles increasing from 120 to 152 in this period.

This pattern of growth could be attributed to several factors, such as the evolving interest in the field, increased funding or resources, or a growing number of researchers and institutions contributing to this area of study. The consistent increase might also reflect a response to emerging challenges or developments within the field, prompting more research and publications.

Furthermore, the data might be indicative of the maturity of the field. As a research area develops, it often sees a rise in the volume of publications as more researchers engage with it and as it branches into new subfields or intersects with other disciplines.

In conclusion, "Table 2: Annual Production" not only

demonstrates a healthy and growing interest in the field over a decade but also potentially reflects the evolving dynamics within the research area. This growth in article production is a positive indicator of the vitality and relevance of the field, suggesting a robust research community and an expanding base of knowledge.
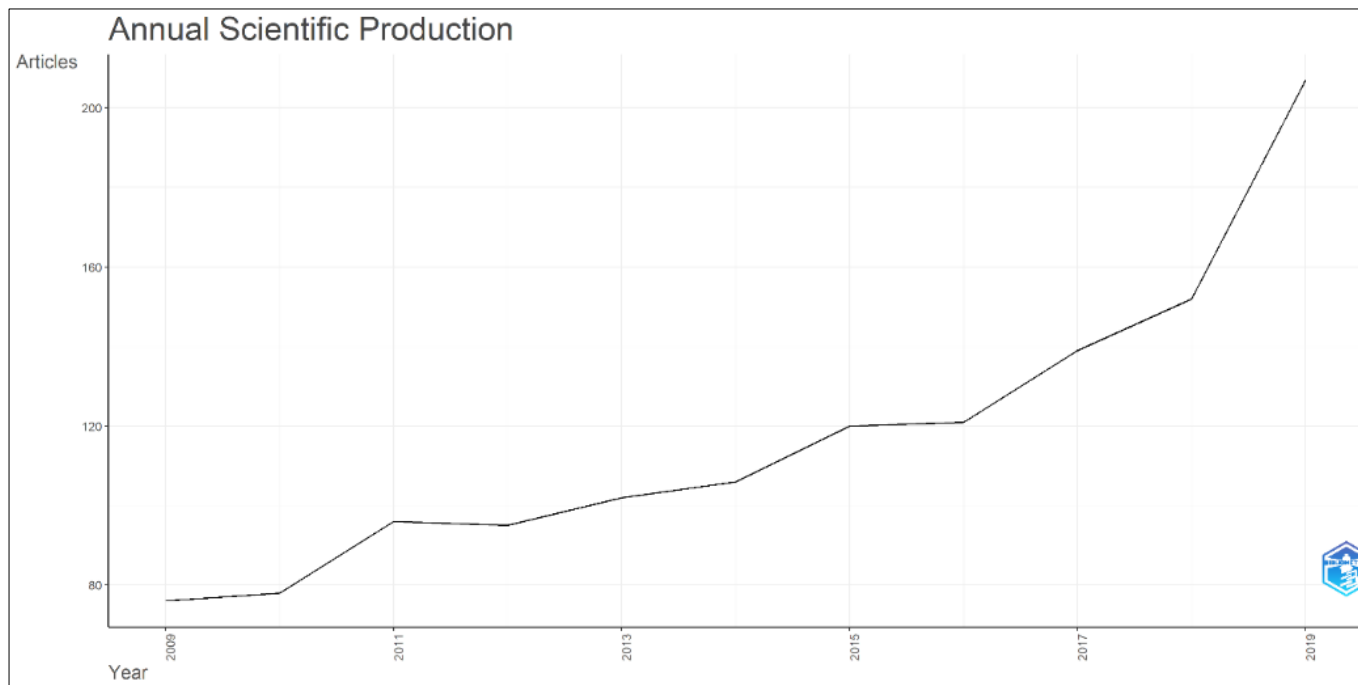
The image depicts a line graph titled "Annual Scientific Production," which shows the number of articles produced each year over a timespan. The x-axis represents the years, which appear to range from 2009 to 2019, while the y-axis quantifies the articles, with values ranging from approximately 70 to over 200.

From the graph, it is evident that there has been a notable upward trend in annual scientific production over the observed period. The line starts at a lower point in 2009, with production being below 80 articles, and rises steadily each year. There is a particularly sharp increase from around 2015 onwards, with the curve steepening significantly towards the end of the period, indicating a rapid growth in output in the most recent years.

This trend suggests an acceleration in research activity, which could be due to various factors such as increased investment in research and development, the emergence of new scientific fields, the expansion of existing research areas, or a general increase in the number of researchers contributing to the field. The steady growth over a decade indicates a robust and active research community that is producing an increasing number of contributions to scientific literature.

"Table 3: Most Local Authors Cited" provides a quantitative analysis of the most cited local authors within a specific research corpus. The table is organized into three columns: the first lists the names of the authors, the second the total number of articles they have authored, and the third shows the articles fractionalized, which could be indicative of fractional counting of authorship credit in multi-authored papers.

The data suggests that Verschaffel L. is the most cited author with 13 articles to their name, followed by Wagner D. with 9 articles and Erbas A.K. with 8. However, when looking at the fractionalized article count, Wagner D. leads with a value of 5.17, which indicates that although they have fewer total articles than Verschaffel L., their contributions are possibly more significant within the articles they co-authored, or they are more frequently cited in the literature.

The fractionalized article counts provide a nuanced view of the impact of each author's work. For instance, Verschaffel L. has a fractionalized count of 3.83, suggesting that while they have the highest number of articles, their fractionalized citation impact per article is lower compared to Wagner D. This could reflect Verschaffel L.'s broader collaboration with other authors, thus sharing citation credits among more co-authors.

The presence of multiple authors with 6 to 8 articles highlights a significant contribution from a group of key individuals in the field. The fractionalized counts, which vary from 1.26 to 5.17, indicate different patterns of collaboration and citation impact among these authors.

In conclusion, "Table 3: Most Local Authors Cited" not only identifies the most productive authors in terms of publication count but also provides insight into their relative influence and collaboration patterns in the academic community through fractionalized citation data. This could suggest a vibrant research environment with a mix of both prominent individual contributors and collaborative efforts.

Table 3: Most Local Authors Citied

Authors	Articles	Articles fractionalized
Verschaffel l	13	3.83
Wagner d	9	5.17
Erbas ak	8	3.07
Van dooren w	8	2.17
Van den heuvel-panhuizen m	7	2.25
Birgin o	6	2.42
Drijvers p	6	2.12
Polly d	6	2.48
Veldhuis m	6	1.92
Bakker a	5	1.26

Table 4: Country Production

| Region	Frequency
Usa	1053
Turkey	346
Brazil	235
Australia	170
Spain	168
Canada	113
Uk	107
Netherlands	89
Belgium	59
Germany	59

"Table 4: Country Production" presents a comparative analysis of scholarly output by country, measured in terms of the frequency of publications. The table ranks countries based on the number of articles produced, indicating the volume of research activity within each region.

The USA leads by a substantial margin with 1,053 articles, indicating a significant contribution to the field of study and a robust research infrastructure. Turkey follows with 346 articles,

a considerable figure but still significantly less than that of the USA. Brazil comes third with 235 articles, suggesting an active research community in South America. Australia and Spain are close in output, with 170 and 168 articles respectively, demonstrating their strong presence in the research landscape.

Canada, the UK, and the Netherlands also feature in the table, with Canada having produced 113 articles, the UK with 107, and the Netherlands with 89. These numbers reflect a healthy level of research activity in each of these countries. Belgium and Germany round out the list, each with 59 articles, which suggests that while their output is less than the other countries listed, they still maintain a presence in the international research community.

In conclusion, "Table 4: Country Production" provides valuable insights into the global distribution of research production, highlighting the dominance of the USA in the volume of scholarly articles produced. The table also reflects the varying levels of research activity across different regions, with each country contributing to the collective knowledge in the field. These differences may be attributed to factors such as funding availability, the number of researchers, institutional support, and the research priorities of each country.
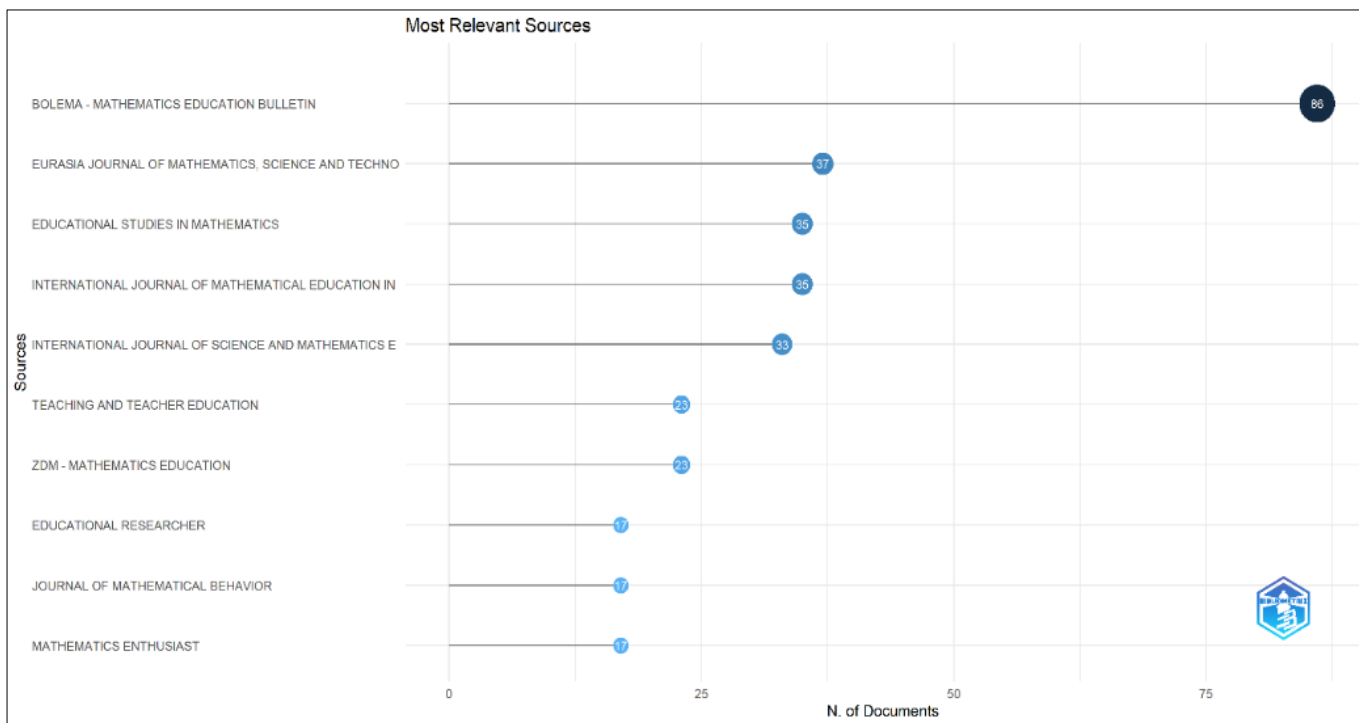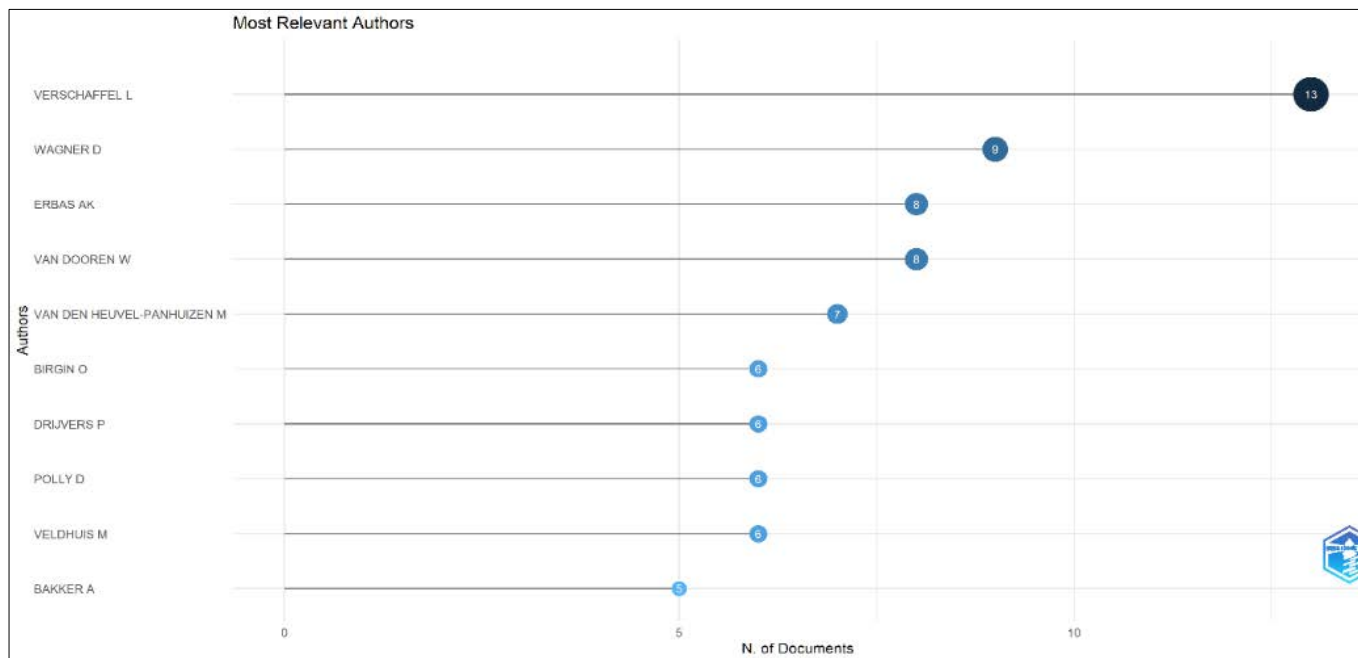

The image displays a horizontal bar graph titled "Most Relevant Sources," which ranks various academic journals by the number of documents (articles) associated with each. The y-axis lists the names of the journals, which appear to focus on mathematics education and related fields, and the x-axis quantifies the number of documents ranging from 0 to slightly above 85.

The journal "BOLEMA - Mathematics Education Bulletin" has the highest number of documents, with around 86 articles, making it the most prolific source in this dataset. This is followed by the "Eurasia Journal of Mathematics, Science and Technology Education," with approximately 37 articles. Other sources such as "Educational Studies in Mathematics" and "International Journal of Mathematical Education in Science

and Technology" also have a substantial number of articles, hovering around the mid-30s.

The graph indicates that there is a variety of key sources contributing to the literature in this field, with a notable concentration in a select few. Such a distribution could suggest that these journals are the leading outlets for scholarly communication in mathematics education.

The visualization is useful for quickly identifying which journals are the most active or have the highest output in this academic niche. Researchers, librarians, or individuals interested in the field might use this data to determine where to publish their work, where to find relevant literature reviews, or which journals to prioritize for institutional subscriptions.

The image illustrates a horizontal bar graph titled "Most Relevant Authors," which ranks authors by the number of documents they have contributed to within a particular field. The y-axis lists the authors' last names, and the x-axis quantifies the number of documents, ranging from 0 to 13. At the top of the graph, Verschaffel L. has the highest number of documents attributed to them, with a total of 13, which suggests a leading role in research output within this academic domain. Following are Wagner D. and Erbas A.K., each with 8 documents, and Van Dooren W. with 7, indicating that these authors are also significant contributors to the field. Other authors like Van den Heuvel-Panhuizen M., Birgin O., Drijvers P., Polly D., Veldhuis M., and Bakker A. have contributed between 5 to 6 documents.

This graph is an effective tool for identifying key contributors and thought leaders in the research area. It shows a clear distribution of output among a select group of researchers, with Verschaffel L. standing out as the most prolific. For researchers in the field, this visualization might be used to identify potential collaborators or experts, while for students and academics, it could guide literature search efforts towards the most influential and frequently published authors.

Discussion and Conclusion

The bibliometric analysis of mathematics education research in India from 2009 to 2019 has revealed several key insights and trends. Firstly, the study observed a steady increase in the number of publications over the decade, indicating a growing interest and investment in mathematics education research. This is in line with global trends and reflects India's commitment to improving educational standards and pedagogical approaches.

The analysis of authorship patterns suggests a shift towards collaborative research, with an increase in multi-authored papers. This trend may indicate a move towards interdisciplinary and cross-institutional research collaborations, fostering a more diverse and comprehensive understanding of mathematics education.

The study also highlighted the significant contributions of leading researchers and institutions, which have played a pivotal role in shaping the research landscape in this field. These key players not only contribute extensively to the body of knowledge but also influence the direction of future research through their pioneering work.

Moreover, the research uncovered a range of emerging themes and topics within mathematics education research. These include a focus on technology integration, pedagogical innovations, and student engagement strategies. The evolving nature of these themes suggests a dynamic field that is responsive to changes in educational paradigms, technological advancements, and societal needs.

This bibliometric study provides a comprehensive overview of the landscape and progress of mathematics education research in India over a decade. The findings underscore the field's dynamic nature, characterized by a growing body of literature, evolving research themes, and an increasingly collaborative research environment. The increase in publication volume and the emergence of new research themes reflect the field's responsiveness to educational needs and technological changes. The significant role played by leading authors and institutions in shaping the research landscape cannot be overstated, as their contributions have been pivotal in advancing the field.

The insights gained from this study are valuable for policymakers, educators, and researchers. They offer a roadmap for future research directions, highlight areas requiring further exploration, and underscore the importance of continued investment in mathematics education research.

As India continues to evolve its educational frameworks, this study serves as a crucial resource, guiding efforts towards enhancing the quality and effectiveness of mathematics education. It is hoped that the findings will inspire further research and collaboration, contributing to the continuous improvement of mathematics education in India and beyond.

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