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Mapping Research on Mathematical Argument, Proof, and Reasoning in Indonesian Mathematics Education: A Bibliometric Study

Rindi Antika
Indonesia University of Education

Turmudi Turmudi
Indonesia University of Education

Rizky Rosjanuardi
Indonesia University of Education

Endang Cahya Mulyaning
Indonesia University of Education

Abstract: Mathematical argument, proof, and reasoning are central practices in mathematics education, yet research addressing these constructs has developed unevenly across educational contexts. This study aims to map research trends on mathematical argument, proof, and reasoning in Indonesian mathematics education using a bibliometric approach. Publications were retrieved from the Scopus database through a structured query focusing on journal articles written in English and published between 2010 and 2024 by authors affiliated with Indonesian institutions. A total of 48 articles were analyzed using Biblioshiny in R to examine publication trends, citation patterns, productive sources, authorship, keywords, and thematic structures. The results indicate a gradual increase in research output since the mid-2010s, with a publication peak around 2020, reflecting growing scholarly interest in mathematical argument in Indonesia. Keyword and thematic analyses reveal that research in this field is predominantly framed within pedagogical contexts, with realistic mathematics education and instructional design emerging as central themes. In contrast, studies focusing on formal proof and abstract algebra appear more specialized and less central. Overall, this study provides a structured overview of the development and conceptual orientation of mathematical argument research in Indonesian mathematics education and highlights directions for future research, particularly in strengthening theoretical integration and international collaboration.

Keywords: Mathematical argumentation, Proof and reasoning, Mathematics education, Bibliometric analysis,

Introduction

Mathematical argument, proof, and reasoning constitute central practices in mathematics and mathematics education. Through argumentation, learners construct, justify, and communicate mathematical ideas, while proof provides a means to establish the validity of mathematical statements within accepted deductive systems. Reasoning, in turn, underpins both informal and formal mathematical thinking, connecting intuitive understanding with rigorous justification (Hanna, 2000; Stylianides, 2007; Stylianides & Stylianides, 2009). Consequently, research on mathematical argument has become a crucial area within mathematics education, addressing how learners develop justificatory practices and how instruction can support this development (Balacheff, 2008; Miyakawa & Shinno, 2017).

Over the past decades, international research has increasingly examined mathematical argumentation from multiple perspectives, including cognitive, epistemological, and didactical viewpoints. Studies have explored students' difficulties in constructing proofs (Harel & Sowder, 1998; Stylianides & Stylianides, 2009), teachers' instructional practices in fostering reasoning (Hanna & Jahnke, 1996; Stylianides, 2007), and the role of representations, tasks, and classroom discourse in supporting argumentation (Balacheff, 2008; Miyakawa & Winsløw, 2009). These investigations highlight that argumentation is not merely a technical skill but a complex practice shaped by curricular traditions, pedagogical approaches, and cultural contexts (Hanna, 2000; Miyakawa & Shinno, 2017).

In the Indonesian context, mathematics education research has shown a growing interest in mathematical argument, proof, and reasoning. This interest is closely related to curricular reforms, the influence of international frameworks, and the adoption of instructional approaches such as Realistic Mathematics Education (RME), design research, and problem-based learning (Gravemeijer, 1994; Gravemeijer & Cobb, 2006). Indonesian researchers have examined argumentation across various mathematical domains, including geometry, fractions, and abstract algebra, as well as across different educational levels, particularly elementary and secondary education. Despite this growing body of work, a systematic overview of research trends, influential contributors, and thematic developments in this field remains limited.

Bibliometric analysis offers a powerful approach to mapping the intellectual structure and evolution of a research field. By quantitatively analyzing publication patterns, authorship, sources, keywords, and thematic networks, bibliometric methods enable researchers to identify dominant themes, emerging topics, and collaboration structures (Donthu et al., 2021). Such analyses have been widely applied in mathematics education research to investigate trends in areas such as computational thinking (Irawan & Herman, 2023; Tekdal, 2021), problem solving, and technology integration. However, to date, no comprehensive bibliometric study has specifically focused on mathematical argument, proof, and reasoning within Indonesian mathematics education.
To address this gap, the present study aims to analyze, visualize, and map research on mathematical argument, proof, and reasoning in Indonesian mathematics education using bibliometric methods. By examining publications indexed in international databases, this study seeks to provide an overview of publication trends over time, identify the most relevant sources, authors, and affiliations, and explore the conceptual structure of the field through keyword and thematic analyses. The findings are expected to contribute to a deeper understanding of how research on mathematical argument has developed in Indonesia and to highlight potential directions for future research.

Accordingly, this study addresses the following research questions:

1. How has the scientific production on mathematical argument, proof, and reasoning in Indonesian mathematics education evolved over time?
2. Which journals, authors, and institutional affiliations are the most influential in this research area?
3. What are the most frequently used keywords and dominant research themes in the field?
4. How are research themes structured and interconnected based on keyword co-occurrence and thematic mapping?

Method

Research Design

This study employed a bibliometric research design to map the development, intellectual structure, and thematic orientations of research on mathematical argument, proof, and reasoning in Indonesian mathematics education. Bibliometric analysis was chosen because it enables a systematic and quantitative examination of publication patterns, influential contributors, and conceptual structures within a research field based on bibliographic metadata.

Data Source

The data were retrieved from the Scopus database, which was selected due to its comprehensive coverage of peer-reviewed international journals and its suitability for bibliometric studies. Scopus is widely used in mathematics education research to ensure data reliability and international visibility.

Search Strategy and Query String

The literature search was conducted using a structured query string designed to capture publications addressing mathematical argumentation, proof, and reasoning within the context of mathematics education, with authors affiliated with Indonesian institutions. The final query string used for data retrieval was:

```
(TITLE-ABS-KEY ("mathematical argument*"
OR "mathematical argumentation"
OR "proof"
OR "reasoning"
OR "mathematical justification"))
AND TITLE-ABS-KEY ("mathematics education")
AND AFFILCOUNTRY (indonesia)
AND PUBYEAR > 2009 AND PUBYEAR < 2025
AND (LIMIT-TO (SRCTYPE, "j"))
AND (LIMIT-TO (DOCTYPE, "ar"))
AND (LIMIT-TO (LANGUAGE, "english"))
```

This query ensured that:

1. The core constructs of argument, proof, and reasoning were explicitly mentioned in the title, abstract, or keywords.
2. The studies were situated within the domain of mathematics education.
3. At least one author was affiliated with an Indonesian institution, ensuring contextual relevance.
4. Only journal articles published in English between 2010 and 2024 were included.

Inclusion and Exclusion Criteria

The inclusion criteria were as follows:

- Journal articles indexed in Scopus;
- Publications written in English;
- Studies focusing on mathematics education;
- Articles addressing mathematical argument, proof, or reasoning;
- Publications with author affiliation in Indonesia.

The exclusion criteria included:

- Conference proceedings, book chapters, and review articles;
- Publications written in languages other than English;
- Studies not directly related to mathematics education;
- Articles focusing solely on pure mathematics without educational context.

After applying these criteria, a total of 48 articles were retained for analysis.

Data Analysis Procedure

The bibliographic data were exported from Scopus in BibTeX format and analyzed using the Bibliometrix package through its web-based interface Biblioshiny in R. The analysis comprised several stages:

1. Descriptive analysis, including annual scientific production and average citations per year;
2. Source and authorship analysis, identifying the most relevant journals, authors, and institutional affiliations;
3. Keyword analysis, including frequency analysis, word cloud visualization, and treemap representation;
4. Conceptual structure analysis, using keyword co-occurrence networks and thematic mapping to identify dominant, niche, and emerging research themes.

The thematic map was generated based on Callon's centrality and density measures, allowing research themes to be classified as motor themes, basic themes, niche themes, or emerging/declining themes.

Data Reliability

To ensure data reliability, the dataset was manually screened to remove duplicates and irrelevant records prior to analysis. All analyses were conducted using standardized bibliometric procedures, ensuring the reproducibility and transparency of the results.

Results and Discussion

Annual Scientific Production

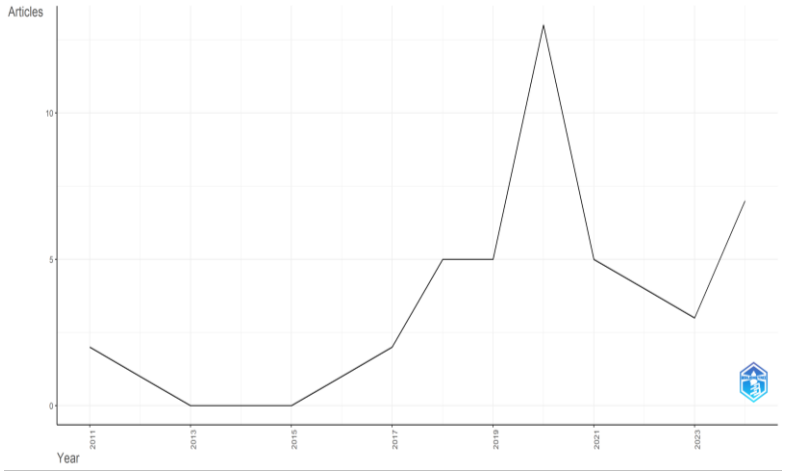

Figure 1. Annual scientific production

The analysis of annual scientific production reveals that research on mathematical argument, proof, and reasoning in Indonesian mathematics education has developed unevenly over time. In the early years of the observed period, publication output was relatively low, with only sporadic articles published. A noticeable increase in publication activity emerged after the mid-2010s, indicating growing scholarly interest in this research area. The production trend shows a peak around 2020, followed by a slight decline and subsequent recovery in recent years. This pattern suggests that research on mathematical argument in Indonesia has experienced phases of intensified attention, possibly influenced by curricular reforms, research funding cycles, and the adoption of innovative instructional approaches. Overall, the upward trend in later years indicates that this field continues to attract research interest.

Average Citations Per Year

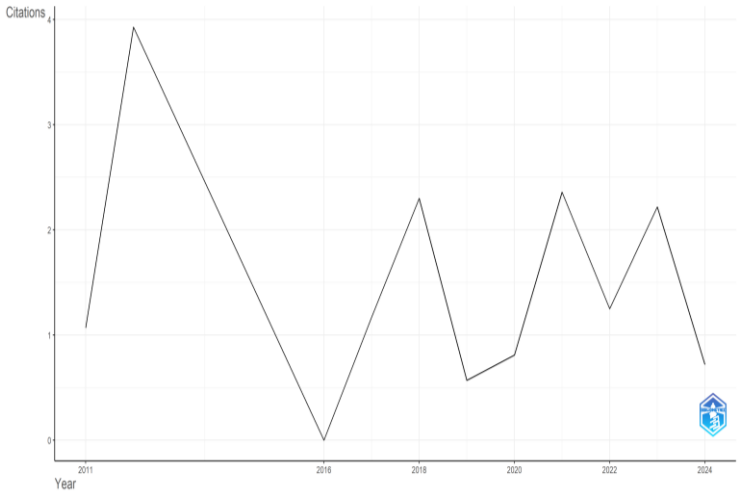

Figure 1. Average citations per year

The analysis of average citations per year demonstrates fluctuations across the study period. Some earlier publications received relatively higher average citations, reflecting their foundational role in shaping subsequent research. In contrast, more recent publications exhibit lower average citation counts, which is expected given

their shorter time since publication. Despite these variations, the citation pattern suggests that research on mathematical argument in Indonesian mathematics education has achieved a level of international visibility, with several studies contributing to ongoing scholarly discussions on proof and reasoning.

Most Relevant Sources

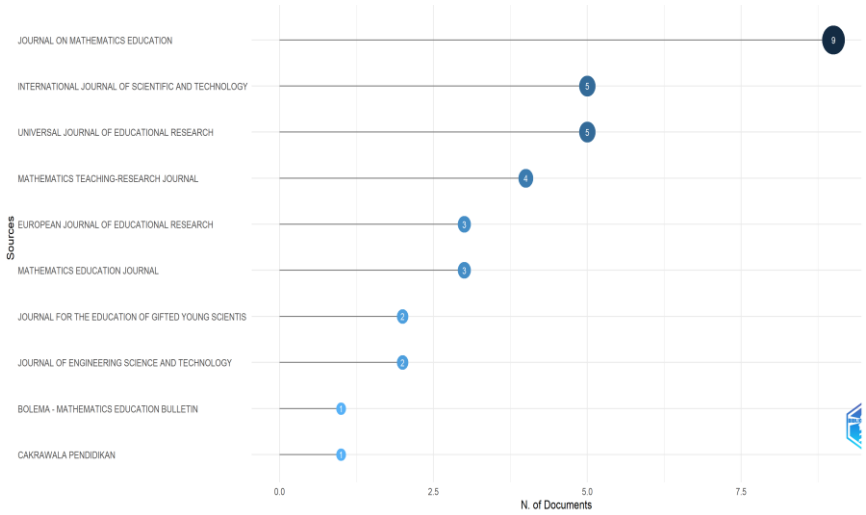

Figure 1. The most relevant sources

The analysis of the most relevant sources indicates that research on mathematical argument in Indonesia is published across a range of international and regional journals. The *Journal on Mathematics Education* emerges as the most relevant source in terms of the number of published articles, followed by journals focusing on educational research and science and technology education. This distribution highlights that research on mathematical argument is primarily situated within mathematics education journals, while also intersecting with broader educational research outlets.

Most Relevant Authors and Authors' Production Over Time

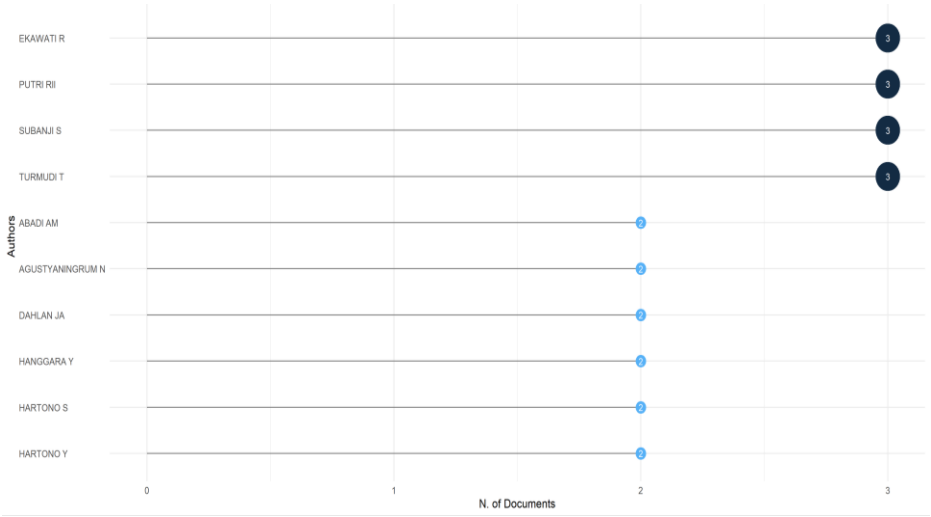

Figure 1. The most relevant authors

The analysis identifies a group of authors who have contributed multiple publications to the field. These authors demonstrate varying patterns of productivity over time, ranging from sustained engagement across several years to concentrated publication activity within specific periods. The authors' production over time reveals that most contributors exhibit intermittent publication patterns rather than continuous long-term productivity. This finding suggests that research on mathematical argument in Indonesia is often conducted within specific projects or research initiatives rather than as part of long-term, continuous research programs by individual authors.

Most Relevant Affiliations

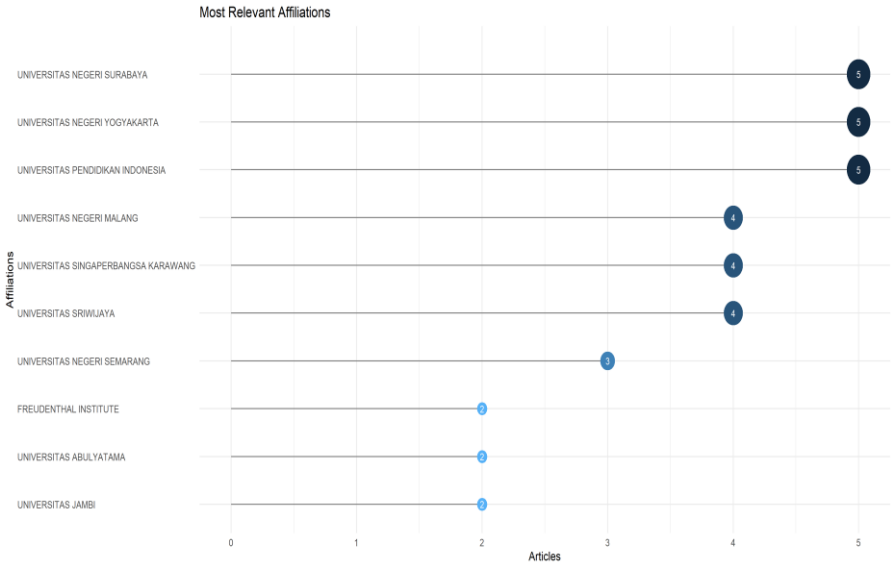

Figure 1. Institutional contributions

In terms of institutional contributions, several Indonesian universities stand out as the most relevant affiliations. Universities such as Universitas Negeri Surabaya, Universitas Negeri Yogyakarta, and Universitas Pendidikan Indonesia contribute the highest number of publications. These institutions are well-known centers for mathematics education research in Indonesia, indicating their central role in advancing studies on mathematical argument, proof, and reasoning. The presence of multiple contributing institutions also suggests a relatively distributed research landscape, with scholarly activity spread across various regions.

Most Relevant Words and Conceptual Structure

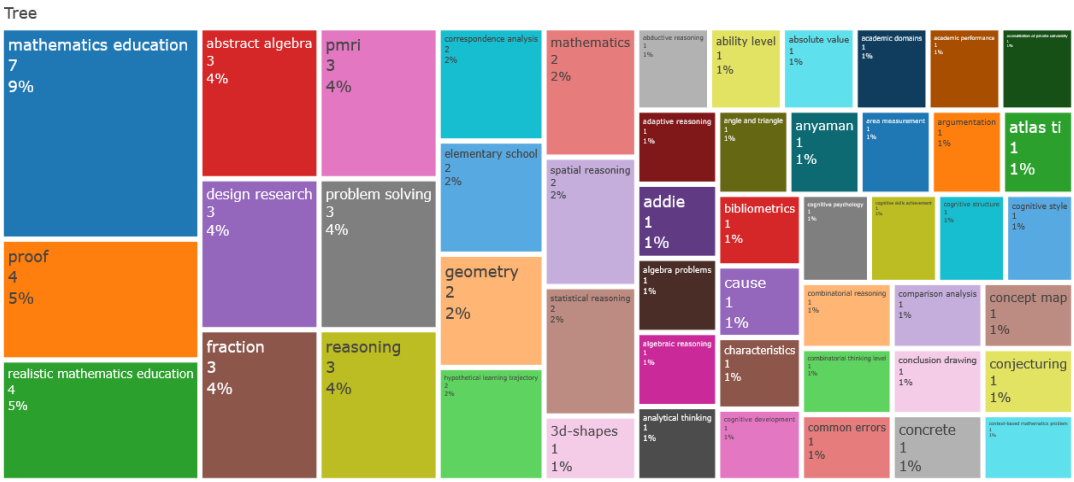

Figure 1. Treemap

Keyword analysis shows that the most frequently occurring terms include *mathematics education*, *proof*, *realistic mathematics education*, *reasoning*, *problem solving*, and *abstract algebra*. The prominence of *mathematics education* reflects the educational orientation of the research, while the frequent occurrence of *proof* and *reasoning* confirms the central focus of the field. The word cloud and treemap visualizations further illustrate the dominance of these keywords, alongside domain-specific terms such as *fraction*, *geometry*, and *elementary school*. This indicates that research on mathematical argument in Indonesia spans multiple mathematical topics and educational levels.

Thematic Mapping

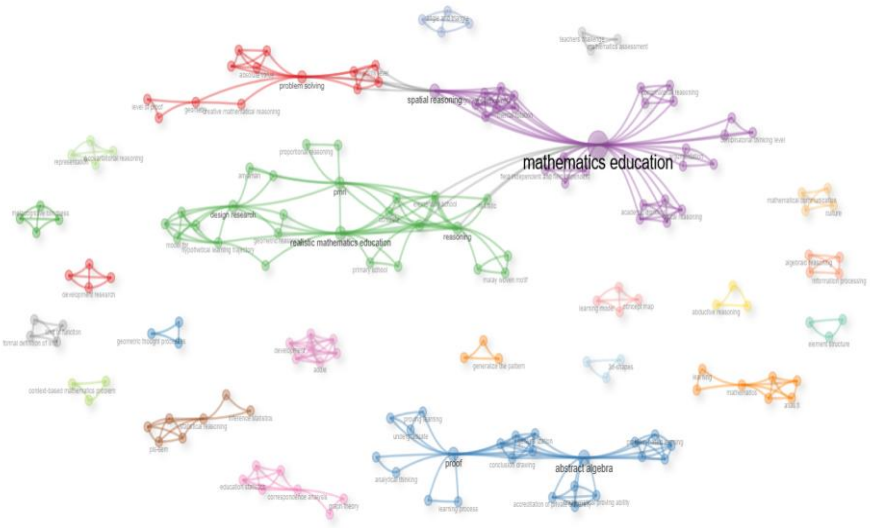

Figure 1. The thematic map

The thematic map reveals several distinct clusters. Themes related to *realistic mathematics education* and *reasoning* appear as highly developed and central, indicating their role as motor themes in the field. Themes associated with *proof* and *abstract algebra* show strong internal development but lower centrality, suggesting their classification as niche themes. Other themes, such as *correspondence analysis* and *statistical reasoning*, appear as emerging or less developed themes, indicating potential directions for future research. Overall, the thematic structure reflects a field that is conceptually diverse, with strong pedagogical orientations and opportunities for further theoretical consolidation.

Conclusion

This study provides a bibliometric overview of research on mathematical argument, proof, and reasoning in Indonesian mathematics education. The findings show a growing research interest since the mid-2010s, with strong emphasis on pedagogical approaches such as realistic mathematics education. While research on formal proof and abstract algebra exists, it remains relatively specialized and less integrated with broader instructional discussions. The results highlight opportunities for future research to strengthen theoretical coherence, expand longitudinal investigations, and enhance collaboration among researchers and institutions. Despite its limitations, this study offers a structured mapping of research trends that can inform future studies on mathematical argument in Indonesia.

Recommendations

Future research is recommended to (1) integrate pedagogical studies with established theories of mathematical argumentation and proof, (2) expand research contexts to include longitudinal and cross-level studies, and (3) foster sustained national and international collaboration to enhance research impact.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article belongs entirely to the authors.

Conflict of Interest

* The authors declare no conflict of interest.

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Author(s) Information

Rindi Antika
Indonesia University of Education (Universitas Pendidikan Indonesia), Bandung, West Java, Indonesia
ORCID ID: https://orcid.org/0000-0003-1128-4806
Contact e-mail: *rindiantika89@upi.edu*

Turmudi Turmudi
Indonesia University of Education (Universitas Pendidikan Indonesia), Bandung, West Java, Indonesia
ORCID ID: https://orcid.org/0000-0001-7976-211X

Rizky Rosjanuardi
Indonesia University of Education (Universitas Pendidikan Indonesia), Bandung, West Java, Indonesia
ORCID ID: https://orcid.org/0000-0001-5280-6901

Endang Cahya Mulyaning
Indonesia University of Education (Universitas Pendidikan Indonesia), Bandung, West Java, Indonesia
ORCID ID: https://orcid.org/0009-0009-8495-7873

*Corresponding author(s) contact email

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