

Evolving trends in mathematical proof research in Indonesian mathematics education: A systematic review from design to data analysis



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Abstract This study aims to analyze the research trends on mathematical proof in mathematics education journals in Indonesia by systematically reviewing articles indexed in the Sinta database from 2017 to 2024. Using a qualitative descriptive approach, the study selected 39 articles published in 16 accredited journals using the keyword "mathematical proof". The term "mathematical proof" refers to a logical argument that validates a mathematical statement, commonly investigated in the context of students' or preservice teachers' reasoning processes. The findings show a fluctuating but generally increasing trend in publications, with a peak in 2020 (14 articles) and a resurgence from 2022 to 2024, reflecting heightened academic interest in this field. Most studies employed qualitative methods (25 articles), while quantitative (10) and mixed methods (4) remained underutilized. Preservice teachers were the most frequently studied subjects, followed by high school and junior high school students. Algebra emerged as the dominant topic (36%), likely due to its foundational nature in mathematics. Test-based instruments, particularly in worksheet form, were the primary data collection tools, while percentage-based analysis was the most commonly used technique (18 articles). Despite the value of qualitative insights, the dominance of descriptive approaches and basic statistical analyses suggests a need for methodological diversification. This review highlights the underrepresentation of mixed-method studies and the limited exploration of geometric proof, pointing to gaps in the literature. Therefore, future research is encouraged to adopt mixed-method approaches and integrate scaffolding strategies to address students' difficulties in constructing proofs. These efforts are essential for improving instructional practices and enhancing the development of mathematical reasoning and proof skills in Indonesian mathematics education.

Keywords: proof, algebra, preservice, qualitative, assessment, geometry

1. Introduction

Proof is fundamental to mathematical thinking and deductive reasoning (Stylianides & Stylianides, 2008; Choe, 2024). Hernadi (2008) defines proof as a series of logical arguments that establish the truth of a statement. It plays a central role in mathematics education, serving as the core mechanism for developing a deep understanding of mathematical concepts (Knuth, 2022). In this context, proof is essential not only for verifying the truth of mathematical statements but also for fostering critical, logical, and analytical thinking skills that are crucial for mastering mathematics (Kurniawan & Hartono, 2020; Hanna et al., 2008; Morou & Kalospyros, 2011).

The role of proof in mathematics includes: (a) verifying the truth of statements, (b) explaining why statements are true, (c) communicating mathematical knowledge, (d) discovering or creating new concepts, and (e) systematizing knowledge into an axiomatic framework (De Villiers, 1990; Knuth, 2002). Despite its significance, research on the role of proof in mathematics education in Indonesia remains limited. Although proof is an important component of teaching, in-depth studies on how the proof process is taught, understood, and applied in classrooms are scarce. The importance of proof in developing critical and logical thinking, along with the role of teachers in facilitating this understanding, are often overlooked in the academic literature. Therefore, more research is needed to explore teaching strategies, challenges faced by both teachers and students, and their impact on mathematics learning. A more comprehensive study in this area could enrich the literature on mathematics education in Indonesia and help improve the quality of teaching and students' understanding of mathematics.

Mathematics education journals in Indonesia play a crucial role in identifying current trends (Irawan & Purwasih, 2024; Wardani et al., 2024), particularly in the teaching and research of mathematical proof. These journals serve as platforms for sharing various approaches to research design, teaching methods, and data analysis related to proofs. By examining these publications, we can better understand the evolution of proof research methodologies and how proof concepts are applied in Indonesian classrooms.



While global trends in mathematics education, especially regarding proof, provide valuable insights, it is essential to adapt these trends to the local context of Indonesia to ensure their relevance and effectiveness (Hidayat, & Chao, 2025; Samala et al, 2024). Educational approaches successful in other countries may not always align with the educational conditions, culture, and needs of Indonesian students (Pramana et al, 2021). Therefore, this study aims to explore how global trends can be tailored to fit the Indonesian educational landscape (Hafizah, 2023). By analyzing data from Indonesian mathematics education journals, this research aims to provide a deeper understanding of how proof is taught and learned in Indonesia, along with strategies to enhance proof skills in the curriculum.

Adapting global trends to local contexts can significantly improve the quality of mathematics education in Indonesia (Eryani et al, 2024). Understanding the trends in mathematical proof reflected in Indonesian journals provides valuable insights for policymakers, educators, and researchers (Wijaya et al, 2024). For policymakers, this data can inform the development of more effective education policies integrating proof into the mathematics curriculum. Educators can use this information to refine their teaching methods to better meet students' needs, while researchers can leverage these findings to conduct further studies and address challenges faced in the classroom. Through collaboration among these groups, a deeper understanding of proof trends can improve the quality of mathematics teaching and strengthen students' abilities to think critically and logically.

This study, using content analysis of mathematics education journals published in Indonesia from 2017 to 2024, aims to gather insights into various studies on mathematical proof. Specifically, this research will address the following questions: (1) What trends can be observed in the number of studies on mathematical proof over the years? (2) What is the diversity of research designs used to investigate mathematical proof in Indonesia? (3) What are the most frequently researched topics related to mathematical proof? (4) What types of research are conducted to improve students' mathematical proof skills? (5) What instruments are used to assess students' mathematical proof abilities? (6) What data analysis techniques are employed by researchers? (7) What is the general description of the series of studies conducted by researchers in the field of students' mathematical proof?

2. Materials and Methods

This study employs a qualitative descriptive approach aimed at analyzing the trends in mathematical proofs within mathematics education journals in Indonesia. Data were gathered through content analysis of articles published in Indonesian mathematics education journals. All articles were sourced from journals registered in the Science and Technology Index (SINTA) as of August 2024. SINTA is a platform developed by the Indonesian Ministry of Research, Technology, and Higher Education to assess the development of science and technology. The SINTA database includes a total of 16 mathematics education journals. For this study, articles published between 2017 and 2024 were selected, with 38 articles specifically focusing on mathematical proofs being analyzed.

This section outlines the research design, subjects, and data analysis techniques used in the study. In order to ensure validity, the research utilized the same instrument as that of Susetyarini and Fauzi (2020), with several modifications made to suit the content analyzed in this study. The complete list of research instruments used is presented in Table 1.

Table 1 Aspects and categories used in research content analysis.

Aspect	Category
A. Types of research	A.1-R & D
	A.2-Mixed Method
	A.3- Qualitative Research
	A4- Quantitative Research
B. Research subject	B.1-Preservice teacher
	B.2- Senior High School
	C.3-Junior High School
C. Data collection instruments	D.1-questionnaire sheet
	D.2-observation sheet
	D.3-test sheet
	D.4-interview sheet
D. Data analysis methods	E.1-mean
	E.2-percentage
	E.3-t-test
	E.4-ANCOVA
	E.5- Chi-square
	E.6-Unidentified



Researchers categorize the articles found according to the aspects listed in the research instrument. The conclusions presented as findings are in the form of data reduction results from abstracts, methods, and discussions of the journals discussed. To make it easier for readers to analyze the information, the data found is presented in table form.

3. Results and Discussion

Based on data collecting technique, the findings of the research can be categorized according to the focus established at the beginning of the research, namely:

3.1. Number of publications

Some publication findings provide an overview of how many mathematical proof research publications have been conducted by researchers in a given decade. Based on the results of the analysis of 16 journals in the last 7 years, the data can be presented in Figure 1, as shown below.

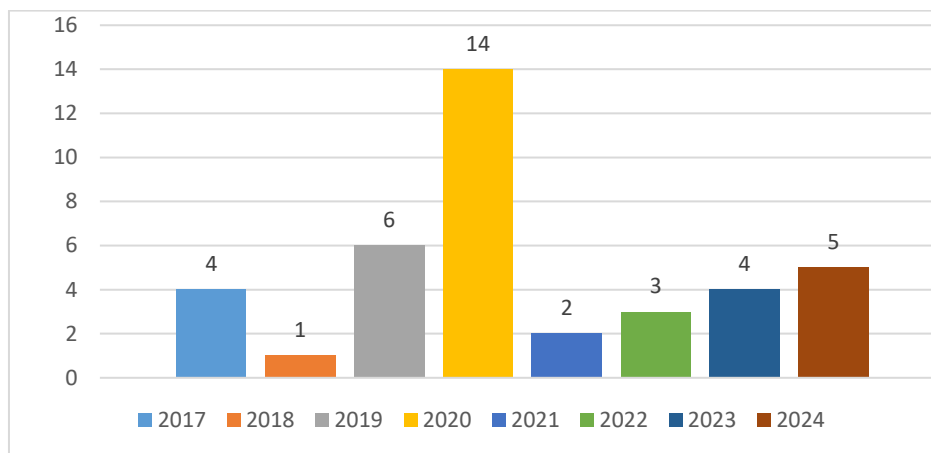


Figure 1 Distribution of number of research publications in the last 7 Years (2017-2024). *Source:* Sinta Database.

Based on the analysis of 16 journals from the past seven years (2017–2024), as shown in Figure 1, there has been notable fluctuation in the number of research publications in the field of mathematical proof. A significant peak occurred in 2020, with 14 articles published, marking it as the year with the highest research output. The years preceding and following 2020 exhibited more moderate fluctuations, with publication numbers generally remaining stable but varying over time. Specifically, in 2019, the number of publications reached seven, while 2018 saw the lowest output, with only one publication. After a decline in 2021, the trend rebounded from 2022 to 2024, with the number of publications rising from four to six articles. This fluctuation suggests that external factors, such as research policies, academic trends, or the practical needs of the mathematics community, may have influenced the volume of publications during certain periods.

In the past three years, several articles have highlighted prominent topics in the literature on mathematical proof, particularly issues related to proof ability (Harahap et al., 2024; Mirza et al., 2022; Aisyah et al., 2023), error analysis (Cipta et al., 2024; Hidayah et al., 2022; Mardiyah, 2024; Scristia et al., 2022), and learning strategies (Galili et al., 2023). These areas have become dominant in research, especially among prospective mathematics teachers. The focus of these studies underscores the importance of a deep understanding of the mathematical proof process and the need to develop effective methods for enhancing students' proof abilities. Additionally, error analysis plays a crucial role in identifying common weaknesses in proofs, while learning strategies are essential in helping students overcome challenges and improve their proficiency in proving mathematical statements.

3.2. Types of research

The type and design of research determine the focus of a study so that researchers need to explore it. From the results of the analysis in the journal above, the following was obtained. As shown in Figure 2, qualitative research is the most prevalent approach in studies on mathematical proof, with 25 articles employing this method.

Quantitative research follows as the second most common approach, while mixed methods and research and development (R&D) are represented in smaller numbers. The predominance of qualitative research indicates that researchers often favor descriptive and exploratory approaches when investigating mathematical proof abilities (Masfingatin et al., 2024; Arifin et al., 2024). Quantitative and mixed methods also contribute to mathematical proof research (Herutomo, 2019; Khusnah & Rosyidi, 2024; Perbowo & Pradipta, 2017), though their representation is more limited, particularly in addressing questions related to numerical data and statistical analysis.

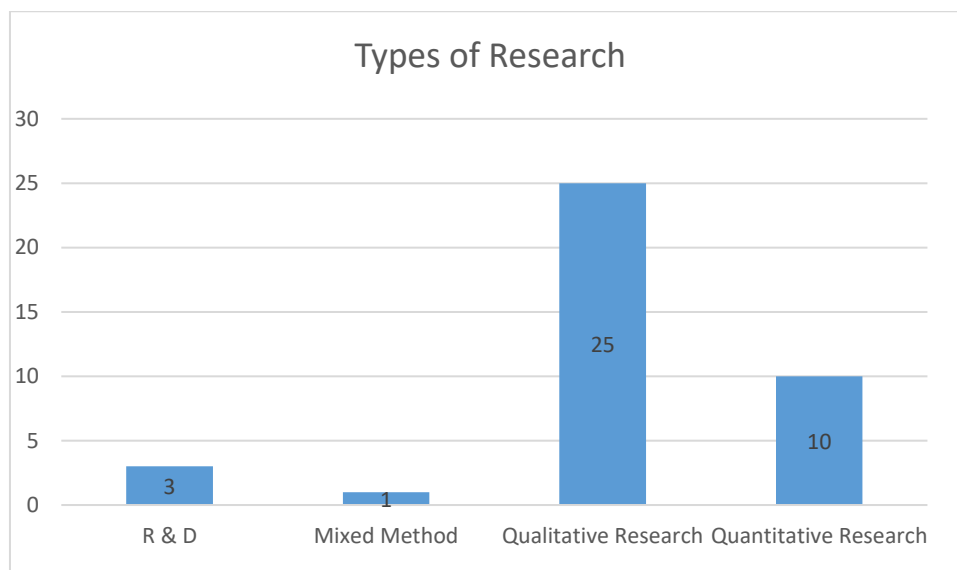


Figure 2 The distribution of researches with proof in mathematics as the main concern based on types of research. *Source:* Sinta Database.

Mixed methods, although relatively new in educational research, particularly in mathematics education, are gaining traction (Anil & Baldi, 2023; Fàbregues et al., 2023). This approach integrates both qualitative and quantitative components, allowing researchers to gain a more comprehensive understanding of the phenomenon being studied (Dehalwar & Sharma, 2024). In the context of mathematical proof ability, mixed methods can provide a deeper analysis by enabling researchers to measure quantitative aspects, such as students' performance on proof tests, while simultaneously exploring the thinking processes, strategies, and challenges faced by students during the proof process through qualitative methods.

Despite the emerging trend of using mixed methods, the number of studies employing this design remains relatively small compared to qualitative and quantitative research (Hartono et al., 2025), highlighting a significant opportunity for further exploration. The underrepresentation of mixed methods in the current literature presents a valuable opportunity for researchers to examine various aspects of mathematical proof that may not be fully captured by a single approach. For example, mixed methods could be used to identify common error patterns in mathematical proofs through quantitative analysis, followed by qualitative interviews to explore the underlying reasons behind these errors.

Moreover, mixed methods can enhance the quality of mathematical proof education by evaluating the effectiveness of different teaching strategies through quantitative data, while also revealing students' experiences and perceptions through qualitative data (Khalil et al., 2024). By offering a more balanced and nuanced perspective, mixed methods can uncover more effective solutions to improve students' proof abilities. Moving forward, an increase in research utilizing this design could make significant contributions to both mathematics education literature and teaching practices.

3.3. Research subjects

In conducting research, researchers need research subjects to test their hypotheses related to the research to be conducted. The following are the results of data analysis related to the research subject, namely. As shown in Figure 3, research on mathematical proof predominantly involves prospective teachers as the main subjects, followed by high school and junior high school students.

This trend indicates that current research is primarily focused on enhancing the abilities of prospective mathematics teachers, who are expected to master and effectively teach mathematical proof. Proof is a crucial aspect of mathematics education, requiring not only a deep understanding of foundational concepts but also strong logical and deductive reasoning skills. Therefore, improving the quality of education for prospective teachers is a priority, with the goal of ensuring that they can guide their students in understanding and applying the concept of mathematical proof.

The use of prospective teachers as research subjects also highlights the challenges faced by educators in ensuring that teachers possess adequate competence in mathematical proof. It is vital for prospective teachers to not only comprehend proofs themselves but also to communicate and teach these concepts in ways that are accessible to students at various educational levels. Research focused on prospective teachers plays a crucial role in preparing educators who are well-equipped to address the complexities of teaching proof in the classroom, whether at the high school or university level.

Although studies involving high school and junior high school students are less prevalent than those focusing on pre-service teachers, their inclusion as research subjects remains significant. This suggests a growing interest in understanding how secondary-level students learn and engage with proof concepts. Research at this level is essential for identifying the challenges students face when learning proof, allowing for the development of more effective teaching strategies to help them overcome

these difficulties. Since proof is a fundamental skill in secondary mathematics education, gaining insights into the challenges students face at this stage will contribute significantly to improving teaching and learning practices at both the primary and secondary levels.

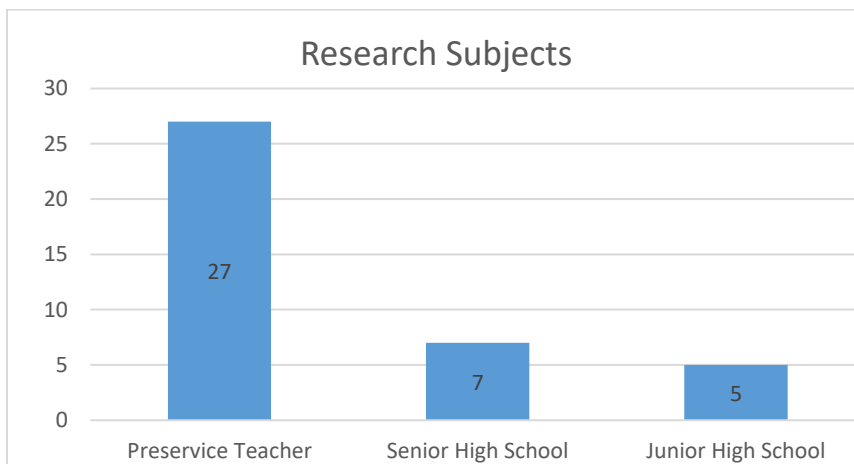


Figure 3 The distribution of research subjects in some educational researches with proof in mathematics as the main concern in Indonesia. *Source:* Sinta Database.

3.4. Mathematics topics selected

Based on the data shown in Figure 4, the research topics related to mathematical proofs mostly focus on algebra at 36%. This shows that algebra is the main area that is often used as the object of research in mathematical proofs, possibly because of its complexity and leaving it as an important foundation in various other branches of mathematics. Proofs in algebra require a deep understanding of the structure and logic that can be applied to many contexts, including number theory and abstract algebra, which are often used in advanced education and research.

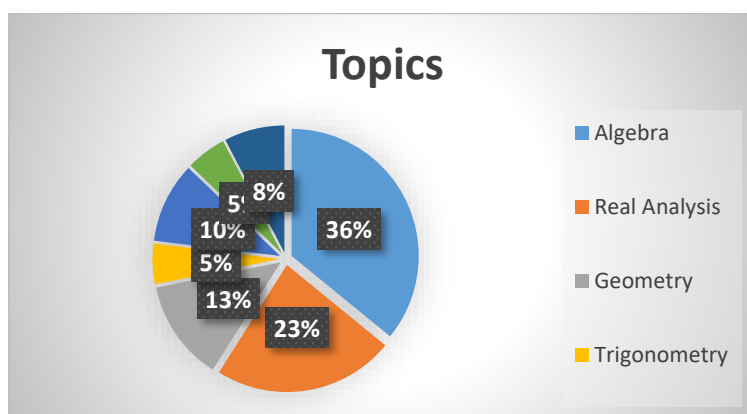


Figure 4 Seven mathematics topics mostly selected in mathematics educational researches with proof in mathematics as the main concern in Indonesia. *Source:* Sinta Database.

In addition to algebra, other topics such as real analysis, geometry, trigonometry, mathematical induction, and the Pythagorean theorem also appear, although with lower frequency. This shows that research related to proofs is not limited to just one branch of mathematics, but tends to prefer topics that are more fundamental and have many applications. For example, proofs in real analysis may be more complex and oriented towards advanced theory, while proofs of the Pythagorean theorem and mathematical induction tend to focus on elementary and secondary education.

Interestingly, the topic of geometry seems to have received little attention, despite the unique challenges of visual and logistic proofs, which often require a different approach than algebra or analysis. The lack of research in this area could be an opportunity for the future, where more research on geometric proofs could be conducted. Further research could explore different proof methods in geometry, both synthetic and analytic, and explore how geometry learning can be linked to the development of students' mathematical proof abilities.

3.5. Data collection techniques or instruments

Research instruments serve to collect data needed in a study. With the instruments developed by researchers, it is expected to measure students' mathematical proof abilities. Here are some instruments used in research related to



mathematical proof, including. Based on the data shown in Figure 5, the most widely used instruments in mathematical proof research are test sheets.

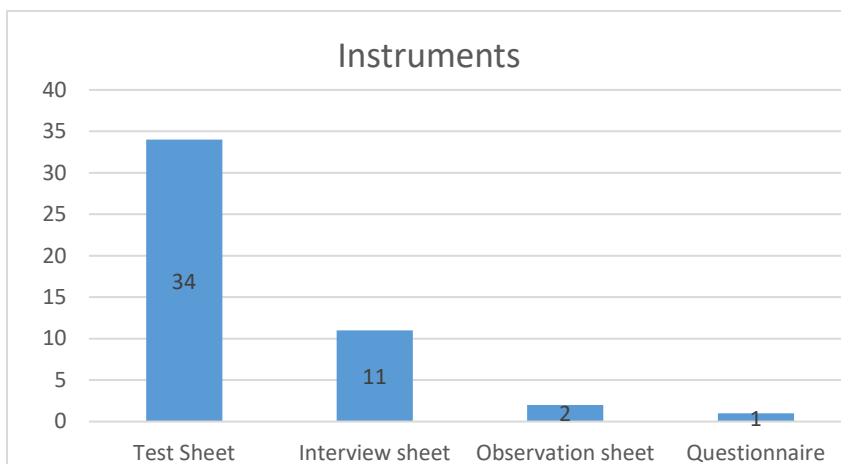


Figure 5 The distribution of data collection techniques or instruments used in proof in mathematics. *Source:* Sinta Database.

This shows that data collection through tests is considered more objective than questionnaires and observations. There are several tests that can be given to measure students' mathematical proof abilities. The most commonly found in Indonesian publications to determine the validity of the instrument in proof in mathematics is the Item-level content validity index (ICVI), along with the assessment of mathematical proof ability in the form of an essay developed by Ariawan et al. (2024). It is important that the validity and reliability of the instrument must be tested before it is used to collect any data (Bajpai & Bajpai, 2014). In other words, information about validity and reliability is considered important to convince researchers. Based on the data above, for further research, this test sheet can be used if researching related to mathematical proof.

3.6. Data analysis techniques

The selection of the right data analysis technique is very important, because it will affect the level of accuracy and reliability of the research results. Techniques that are appropriate to the type of data and research objectives can produce more valid and in-depth findings, so that the conclusions drawn are more reliable. The following are the results of the selection of data analysis methods in several studies of mathematics education related to mathematical proof, namely. Based on Figure 6, it is evident that percentage analysis (18 articles) is the most commonly used data analysis method among researchers.

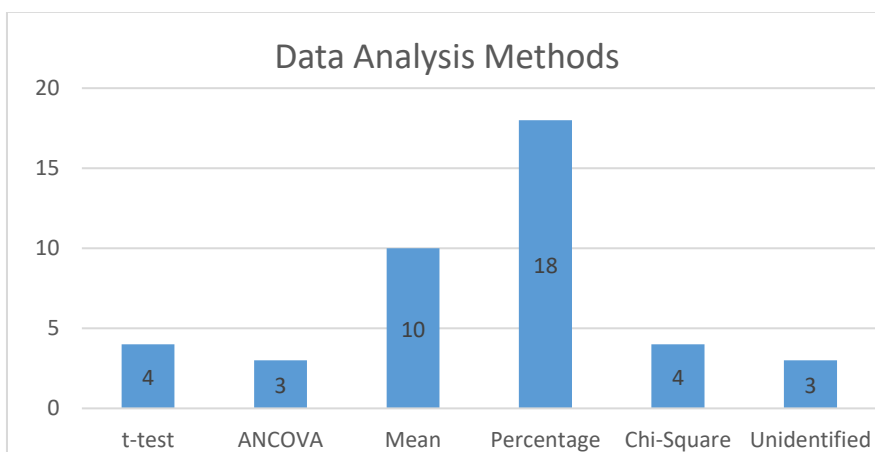


Figure 6 The distribution of data analysis methods used in proof in mathematics. *Source:* Sinta Database.

This finding highlights the frequent use of percentages to compare the achievements of two groups or classes. Percentage analysis is effective for measuring the success level of mathematical proofs or experiments. Moreover, in mathematical proofs involving large datasets or experiments, using percentages can help identify specific patterns or trends, allowing researchers to draw clearer conclusions regarding the behavior of the data or the mathematical solutions being tested.

The analysis of tests used to assess mathematical proof abilities (Figure 5) reveals a variety of analysis techniques. The most frequently used method for test instruments is the mean, which appears in ten articles. Other techniques include t-tests (four articles), chi-square tests (four articles), ANCOVA (three articles), and unspecified methods (three articles). This diversity suggests that researchers employ various statistical tools based on the research questions and data types involved. However,



the predominance of mean analysis points to a potential preference for basic descriptive statistics in mathematical proof studies, which may limit the depth of inferences about underlying patterns in student performance.

For interview instruments, triangulation data analysis is the primary method used in two articles, while Usher (2009) qualitative analysis—comprising data reduction, data display, and conclusions—dominates with seven articles. The reliance on qualitative methods aligns with the exploratory nature of mathematical proof research, where in-depth analysis of students' cognitive processes and error patterns is often critical for understanding the complexities of proof comprehension (Zeynivandnezhad et al, 2024). This preference for qualitative analysis likely reflects the nuanced nature of mathematical reasoning, which is often best captured through non-numerical methods that explore individual understanding and thought processes (Thomas, 2003).

The analysis of publication trends reveals a fluctuating pattern in studies focusing on mathematical proof. The peak in 2020, with 14 articles, marks a period of heightened interest or external motivation for research. This surge could be attributed to the increased academic focus on mathematical competencies and educational challenges during the COVID-19 pandemic (Bielaczyc & Collins, 2020). Changes in research priorities, government funding, and the evolving nature of education during global crises likely influenced this surge. Conversely, the dip in 2018, followed by moderate fluctuations, suggests that broader educational policies and shifts in research priorities may have impacted the consistency of mathematical proof publications (Korshunova et al, 2024). The gradual increase from 2022 to 2024 further suggests a renewed interest in this field, possibly driven by a growing emphasis on developing proof skills in mathematics curricula (Hiele, 1986).

The prevalence of qualitative research methods in mathematical proof studies aligns with the need to explore the complex cognitive and pedagogical processes involved in learning proofs. Qualitative research is essential for understanding students' thought processes, error patterns, and conceptual understanding of proof concepts, which are often difficult to quantify (Murtonen, 2015). However, the relatively limited use of quantitative and mixed-method approaches indicates a potential gap in the literature. Quantitative methods could provide robust, statistically significant findings that complement qualitative insights, offering a more comprehensive understanding of the challenges related to mathematical proof. Additionally, mixed-method research, which integrates both quantitative and qualitative approaches, could offer a richer, more holistic perspective by combining numerical data with in-depth observational insights (Zeynivandnezhad et al, 2024). The emerging, though still limited, use of mixed methods presents an opportunity for future studies to adopt this approach, addressing both the "what" and "why" of students' difficulties in proving mathematical statements.

Algebra's prominence as the most frequently researched topic in mathematical proof studies underscores its foundational significance in mathematics education (Hartono et al, 2024). Algebraic proofs are central to mathematical reasoning and have broad applicability across various mathematical domains. This focus reflects the complexity of algebraic proofs and their integration into other areas of mathematics. Although less frequently explored, topics such as real analysis, geometry, trigonometry, and mathematical induction still receive attention, highlighting a wider interest in mathematical proofs. However, the relatively lower emphasis on geometry suggests an underexplored opportunity for future research. Geometric proofs, which involve unique challenges and require spatial reasoning, warrant further investigation (Hohol & Miłkowski i, 2019). Comparing different instructional methods for teaching geometric proofs could provide valuable insights into enhancing students' understanding of spatial reasoning and logic in a proof-based context.

The widespread use of test sheets as data collection instruments indicates a preference for objective measures of proof ability. These instruments provide clear, quantifiable evidence of students' skills, making them valuable for evaluating instructional outcomes. Test-based methods, by offering standardized measures, allow for efficient comparisons across groups and can offer insights into the effectiveness of various teaching approaches (Hattie, 2009). However, this reliance on tests may overlook the nuances of students' thought processes, strategies, and underlying reasoning that contribute to their ability to construct proofs. As noted by Ericsson et al. (1993) that understanding expertise in cognitive domains like mathematics requires more than just performance outcomes; it involves insight into the cognitive strategies and mental models that underlie student learning. Therefore, integrating tests with qualitative instruments, such as interviews or think-aloud protocols, could yield richer data and provide a more holistic understanding of students' proof-related difficulties (Tharp & Gallimore, 1988). This mixed-methods approach would allow researchers to capture not only the outcomes of student performance but also the cognitive processes involved in proof construction, thereby enhancing the educational value of the research.

The emphasis on instrument validity and reliability underscores a commitment to methodological rigor. Ensuring that instruments are both valid (i.e., measuring what they are intended to measure) and reliable (i.e., producing consistent results across different contexts and times) is essential for producing credible and applicable research findings (Gonçalves et al, 2025). In mathematics education, where precision in assessing cognitive and pedagogical outcomes is crucial, the robust validation of instruments is critical. The application of established frameworks, such as Cronbach's alpha for reliability or content validity measures, is important to ensure that research outcomes reflect real-world educational settings.

The prevalence of percentage analysis indicates a focus on summarizing and comparing group performance or success rates in mathematical proof tasks. This method is especially effective for identifying general trends and assessing the impact of instructional interventions (Abdullah et al, 2024). For example, percentage analysis can help researchers track improvements in students' ability to provide valid mathematical proofs after specific teaching methods are applied, offering valuable insights

into the effectiveness of various instructional strategies. However, relying solely on percentages may limit the depth of analysis, as it does not account for the complexity of cognitive processes or the qualitative aspects of learning (MacIntyre, 2017). A more nuanced understanding of student performance could be achieved by complementing percentage analysis with other techniques, such as statistical hypothesis testing, qualitative coding, or thematic analysis (Usher, 2009). By combining multiple data analysis methods, researchers can better capture the multifaceted nature of students' challenges and successes with mathematical proof tasks, thus informing the development of more targeted educational strategies.

5. Final Considerations

This study reviewed articles published in mathematics education journals across Indonesia from 2017 to 2024, focusing on students' mathematical proof skills. The analysis revealed an increasing trend in publications that prioritize students' mathematical proof abilities, particularly in the last three years. Out of the 39 articles examined, qualitative research was the most prevalent, while mixed-method research was the least common. Furthermore, preservice teachers were most frequently chosen as research subjects, and algebra was the most commonly addressed topic. For data collection and analysis, worksheet tests, using percentages, were the most widely used instrument. Based on these findings, several recommendations for future research are proposed, including the need for more mixed-method studies, as this approach is still relatively rare in the field. Additionally, scaffolding strategies should be explored to help address students' challenges in the mathematical proof process.

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Ethical Considerations

Not applicable

Conflict of Interest

The author declares no conflicts of interest.

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