International Journal of Education, Vocational and Social Science
https://e-journal.citakonsulindo.or.id/index.php/IJEVSS
E-ISSN : 2963 4954
IJEVSS

Intuitionism in Mathematics Education: A Bibliometric Analysis of Major Trends and Future Directions Over the Past Decade

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Abstract

Mathematical intuition is widely acknowledged as a fundamental component of mathematical thinking, influencing conceptual understanding, reasoning, and learning processes. However, research on mathematical intuition in mathematics education has evolved across multiple disciplines and publication venues, resulting in a fragmented and heterogeneous body of literature. This study aims to systematically map research trends, thematic structures, and future research directions in the field through a bibliometric analysis of Scopus-indexed publications published between 2005 and 2025. Employing a descriptive-quantitative bibliometric approach, publication metadata were analyzed using the bibliometrics package in R and VOS-viewer, focusing on publication trends, document types, geographical distribution, international collaboration networks, keyword co-occurrence, and thematic evolution. The findings reveal a clear shift from early philosophical and epistemological inquiries, such as intuitionism, truth, and justification, toward more pedagogical, cognitive, and practice-oriented research themes, including mathematics education, diagrammatic reasoning, embodied cognition, and mathematical knowledge. Despite the global growth of publications, international research collaboration remains limited and unevenly distributed across regions. Thematic evolution analysis indicates that mathematical intuition consistently occupies a central position, functioning as a conceptual bridge between foundational philosophical perspectives and contemporary instructional concerns. Based on these findings, this study recommends several priority directions for future research, including research on visual, diagrammatic, and embodied approaches to fostering intuition.

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Keywords: Mathematical Intuition; Mathematics Education; Bibliometric Analysis; Intuitionism; Research Trends; Future Research Directions.

INTRODUCTION

Mathematics learning is essentially not limited to formal procedures, algorithms, and deductive proofs; rather, it is profoundly influenced by the role of intuition as a cognitive foundation for understanding, constructing, and exploring mathematical concepts. Mathematical intuition is viewed as an individual's ability to perceive patterns, estimate plausibility, and make rapid preliminary judgments prior to formal justification. In the history and philosophy of mathematics, intuition has even been regarded as an epistemological foundation that precedes symbolic formalization, as reflected in intuitionism, which places human mental constructions at mathematical meaning's center (Brouwer, 2000; Ernest, 1991).

In the context of mathematics education, intuition has long been recognized as a crucial component in the development of students' conceptual understanding and mathematical reasoning. (Fischbein, 1999) emphasized that intuition functions as a bridge between concrete experience and formal mathematical structures; therefore, it cannot be neglected in the learning process. In a similar vein, (Tall, 2013) conceptualized intuition as part of cognitive development that enables learners to progress from informal understanding toward more formal and abstract mathematical thinking. Accordingly, intuition should not be viewed as the opposite of logical reasoning, but rather as a complementary element that supports the formation of meaningful mathematical understanding.

Along with the growing emphasis on conceptual understanding, problem solving, and higher-order reasoning in contemporary mathematics education paradigms, research on intuition in mathematics learning has increased significantly over the past decade. Empirical studies have begun to associate intuition with various topics, including probabilistic intuition, geometric and visual intuition, intuition in mathematical proof, and the role of intuition in context-based learning and visual representations. Furthermore, advances in educational technology have stimulated research on how digital media, simulations, and interactive learning environments can facilitate the development of students' mathematical intuition (Gyöngyösi Wiersum, 2013).

Nevertheless, research developments on intuition in mathematics education tend to be scattered and fragmented. Publications on this topic appear across multiple disciplines, such as mathematics education, cognitive psychology, and the philosophy of mathematics, and are disseminated in diverse journals with varying foci and methodological approaches. This condition

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makes it difficult to obtain a comprehensive overview of research directions, dominant themes, influential authors and institutions, as well as patterns of scientific collaboration in the study of mathematical intuition. Consequently, researchers often encounter difficulties in positioning their studies, identifying significant research gaps, and formulating sustainable research agendas.

In this context, bibliometric analysis emerges as a relevant and strategic approach. Bibliometrics enables quantitative mapping of scientific production through the analysis of publication metadata, such as the number of articles, citation patterns, author collaboration networks, and the evolution of research keywords. According to Aria and Cuccurullo (2017), bibliometric analysis serves not only to measure scientific productivity but also to reveal the intellectual structure and developmental dynamics of a research field. In mathematics education, this approach has been effectively employed to map research trends in areas such as problem solving, mathematical literacy, and technology use; however, it has rarely been applied specifically to the study of mathematical intuition.

Therefore, to date, no comprehensive scientific mapping of research on intuitionism or intuition in mathematics learning is available, particularly one that reflects developments and shifts in research focus over the past decade. Such mapping is essential for identifying well-established topics, emerging themes, and research areas that remain open for further exploration. Moreover, bibliometric analysis can reveal the geographical distribution of research and potential disparities in contributions across regions, which is particularly relevant in the context of the globalization of educational research.

Based on this background, the present study aims to conduct a bibliometric analysis of scientific publications addressing intuition in mathematics learning over the last ten years. Specifically, this study seeks to identify major research trends, key actors, and the evolution of thematic foci, while also proposing future research directions grounded in empirical evidence derived from a global literature map. Accordingly, the findings are expected to contribute theoretically by enriching the understanding of the role of intuition in mathematics education, and practically by serving as a reference for researchers, educators, and curriculum developers in designing mathematics instruction that is more meaningful and oriented toward the development of students' intuitive reasoning.

HIGHER EDUCATION SHIFT

Several research organizations, like the Pew Research Center, were taken aback by the change of institutions of higher education from principal suppliers of prestigious conventional

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learning to organizers of unstructured and online learning settings (Goldie, 2016). Students in higher education are happy with their online lessons, viewing distance learning as comparable to traditional learning (Allen et al., 2011). Higher education is a lively, complicated structure contained in a flexible, complicated super system - modern civilization. New technologies have fundamentally altered this super system in six major ways (see Table 1) that higher education must identify and comprehend (Buckingham et al., 2012; Wiley & Hilton, 2009).

This study employs a bibliometric approach with a descriptive–quantitative design to map and analyze the focus and research trends related to mathematical intuition in mathematics education. This approach was selected because it enables a systematic mapping of the development of scholarly literature through the analysis of publication metadata, including titles, abstracts, keywords, year of publication, and citation data.

Data Sources

The data for this study were obtained from the Scopus database, which was selected due to its broad coverage of international journals and the high quality of its metadata, making it well suited for bibliometric analysis. Scopus also provides subject-area filtering features that allow searches to be focused specifically on the context of mathematics education and mathematics learning.

Literature Search Strategy

Data collection was conducted by retrieving publications that contained the term mathematical intuition in the title, abstract, or keywords. The search was limited to publications released within the period 2005–2025, representing developments in research over the past two decades and encompassing a time frame that is relevant to the objectives of the study.

To ensure contextual relevance, publications from non-educational and non-mathematics learning fields, such as computer science, engineering, biochemistry, neuroscience, chemistry, physics, medicine, economics, business, agriculture, and earth sciences, were excluded. This subject-area filtering was intended to focus the search results on studies of mathematical intuition related to educational, instructional, and conceptual aspects of mathematics.

Through this search strategy, the analyzed publications are expected to accurately represent the research landscape of mathematical intuition in mathematics education, while minimizing the inclusion of articles that address intuition in purely scientific or applied contexts that are not aligned with the aims of the study.

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Inclusion and Exclusion Criteria

The inclusion criteria for this study comprised scholarly publications that address mathematical intuition and were published between 2005 and 2026, including peer-reviewed journal articles and conference proceedings indexed in Scopus. The exclusion criteria included publications unrelated to mathematics education or mathematics learning, non-article documents such as editorials and book reviews, and duplicate records.

Data Analysis Procedure

Publication metadata that met the selection criteria were exported from Scopus and analyzed using the bibliometrics package in R and VOS-viewer. The analysis focused on mapping publication trends, identifying research foci through keyword analysis, and tracing the evolution of research themes over time.

Research Validity

The validity of the research findings was ensured through clear documentation of the search strategy and literature selection criteria, thereby making the analytical process transparent and replicable. In addition, the interpretation of bibliometric results was strengthened by a narrative review of key publications that represent major foci and trends in research on mathematical intuition.

RESULTS

Publication Characteristics and Document Types

Figure 1 illustrates the distribution of research publications on mathematical intuition in mathematics education according to document type. The analysis shows that journal articles constitute the most dominant form of publication, accounting for 55.7% of the total documents. This is followed by book chapters, which contribute 24.1%, and books, which account for 11.4%. Meanwhile, review articles represent only 6.3% of the publications, and conference proceedings papers comprise the smallest proportion, at 2.5%.

The dominance of journal articles indicates that research on mathematical intuition has developed into a relatively well-established field and is predominantly disseminated through publications that demand strong methodological rigor and substantial theoretical contributions. The notable presence of books and book chapters suggests that mathematical intuition is frequently discussed within comprehensive conceptual and philosophical frameworks, which is

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consistent with the epistemological roots of intuition in mathematics education. The low proportion of conference proceedings implies that this topic is less often positioned as an exploratory or preliminary issue and is more commonly examined in depth through long-term and substantive scholarly publications.

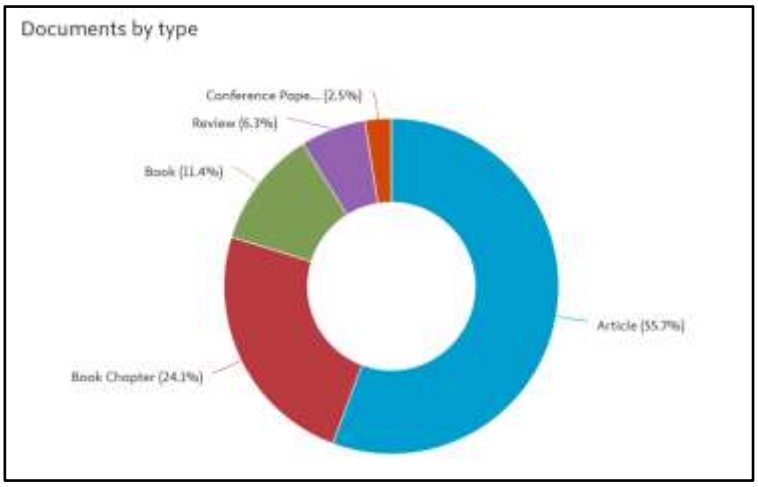


Figure 1. Distribution of Publications by Document Type

Fields of Study in the Publications

Figure 2 presents the keyword co-occurrence network that represents the conceptual structure and fields of study in research on mathematical intuition. It is evident that mathematical intuition occupies a central position and functions as a connecting node among various key concepts across multiple disciplines. Strong associations with terms such as intuition, intuitionism, phenomenology, and truth indicate the dominance of philosophical and epistemological perspectives in studies of mathematical intuition. Furthermore, the appearance of influential thinkers such as Gödel and Benacerraf highlights that discussions of mathematical intuition are deeply rooted in classical debates concerning the nature of mathematical truth and knowledge.

At the same time, the network also reveals connections between mathematical intuition and pedagogical as well as mathematical concepts, including mathematics education, diagrammatic reasoning, Euclidean geometry, and category theory. This finding suggests that mathematical intuition is not examined solely as an abstract construct within the philosophy of mathematics, but also as a relevant construct in learning processes and the development of mathematical reasoning. Accordingly, the visualization underscores the multidisciplinary nature

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of research on mathematical intuition, characterized by a strong intersection among the humanities, mathematics, and mathematics education. This observation further reinforces the quantitative findings indicating the dominance of publications in the fields of Arts and Humanities, Mathematics, and Social Sciences.

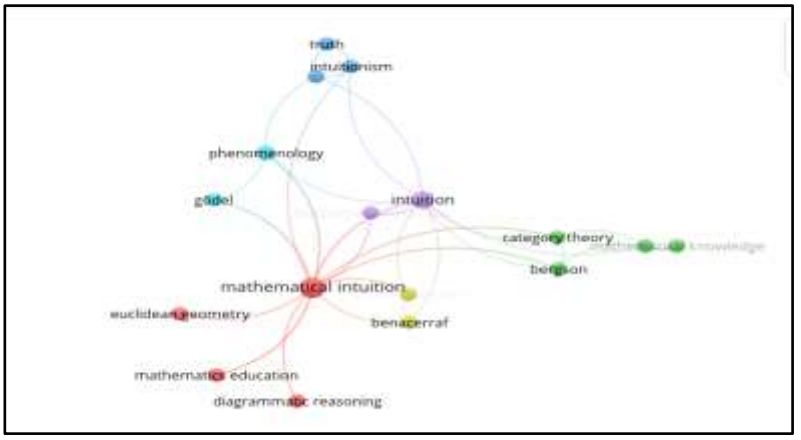


Figure 2. Distribution of Publications by Field of Study

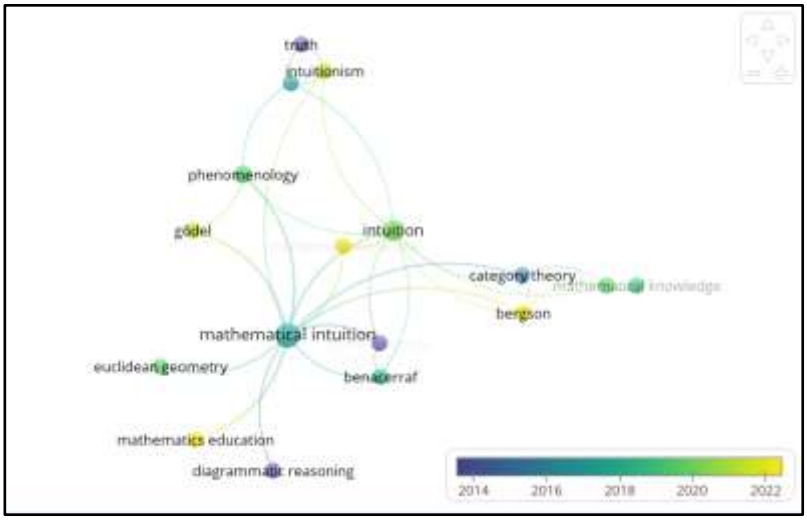


Figure 3. Overlay Visualization of the Development of Research Themes in Mathematical Intuition

Figure 3 presents a keyword co-occurrence network using a temporal overlay approach, illustrating the dynamic evolution of research foci in mathematical intuition over time. The colour gradient of each node represents the average year of keyword occurrence, where darker colours indicate earlier appearances and lighter colours denote more recent topics. The visualization

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shows that concepts such as intuitionism, truth, phenomenology, as well as the figure of Gödel, tend to appear in earlier periods, indicating that early research on mathematical intuition was largely rooted in philosophical and epistemological discourses concerning the nature of truth and the construction of mathematical knowledge.

In contrast, keywords displayed in lighter colours, such as mathematics education, diagrammatic reasoning, category theory, and mathematical knowledge, tend to emerge in more recent periods. This pattern suggests a shift in research focus from conceptual–philosophical inquiries toward more applied and pedagogical approaches, particularly within the context of mathematics learning and mathematical reasoning. The continued central position of mathematical intuition, which remains connected across different periods, highlights its role as a core concept that bridges earlier theoretical traditions and emerging research directions. Accordingly, this visualization confirms that research on mathematical intuition has undergone a dynamic thematic evolution, progressing from philosophical foundations toward stronger integration within mathematics education and contemporary cognitive studies.

Publication Trends in Research on Mathematical Intuition by Year

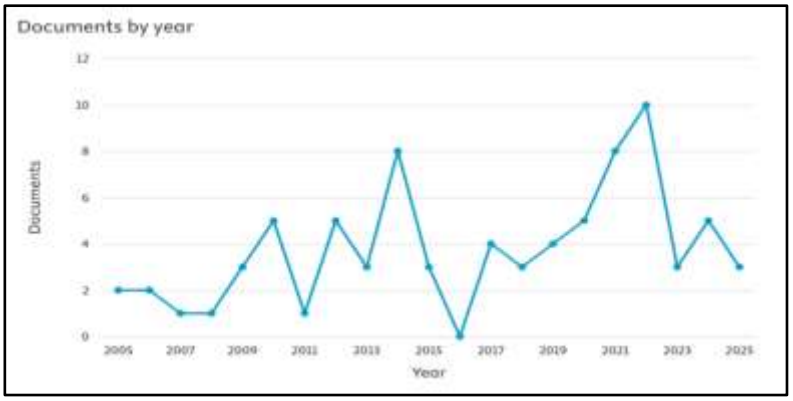


Figure 4. Annual Number of Documents

Figure 4 illustrates the development of the number of research publications on mathematical intuition by year of publication over the period under review. Overall, the publication trend exhibits a fluctuating pattern, particularly during the early phase, characterized by a relatively low and unstable number of documents. During this period, research on mathematical intuition was still limited in scope and had not yet become a major focus within mathematics education. Beginning in the middle of the review period, the number of publications

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shows a more consistent increase, with several notable peaks, especially around 2014 and again during the period 2020–2022. The peak in publications around 2022 indicates a growing level of academic attention to mathematical intuition as an important aspect of mathematics learning. The decline in publication counts in the most recent years is likely attributable to limitations in the completeness of indexed publication data and therefore does not necessarily reflect a decrease in research interest.

To complement these quantitative findings, Figure 3 presents an overlay visualization of the development of research themes in mathematical intuition based on year of publication, as indicated by colour gradients. Darker colours represent themes that emerged in the early stages of research, while progressively lighter colours indicate themes that have developed more recently. The visualization shows that early research on mathematical intuition was predominantly characterized by philosophical and epistemological inquiries, such as intuitionism, truth, and phenomenology. As the volume of publications has increased over the past decade, research themes have shifted toward more pedagogical and applied orientations, marked by the emergence of keywords such as mathematics education, diagrammatic reasoning, and mathematical knowledge. Thus, Figure 3 reinforces the findings in Figure 4 by demonstrating that the growth in publication volume is not merely quantitative but is also accompanied by an evolution in research focus from conceptual studies toward more contextualized and learning-oriented mathematics education research.

Geographical Distribution of Publications on Mathematical Intuition

This section presents the geographical distribution of research publications on mathematical intuition based on the country or region of the authors' affiliations. The analysis indicates that research contributions remain concentrated in a limited number of countries. The United States occupies the leading position as the country with the highest number of publications, followed by several European countries, including Austria, France, Germany, and the United Kingdom. In addition, contributions are observed from other countries such as Brazil, Colombia, and the Russian Federation, although with relatively smaller numbers of publications.

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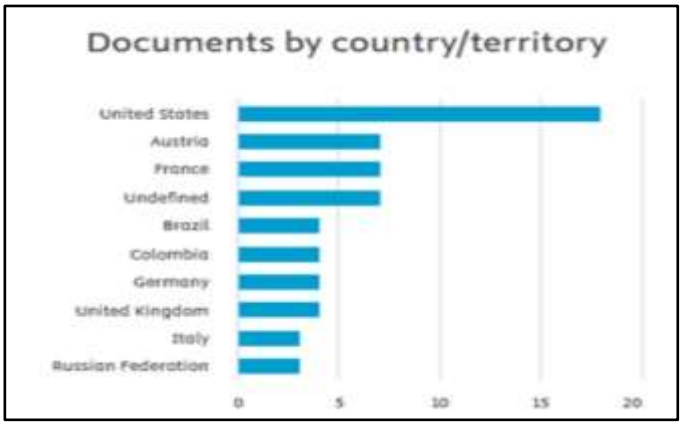


Figure 5. Distribution of Publications by Country

The dominance of these countries indicates that research on mathematical intuition has developed strongly in regions with long-standing traditions in the philosophy of mathematics and mathematics education. The prominence of European countries and North America as major centers of publication can be attributed to the strength of epistemological discourse on mathematical intuition as well as robust institutional support for research in mathematics education. Meanwhile, contributions from countries in Latin America and other regions suggest that studies on mathematical intuition are beginning to attract broader global attention, although the overall distribution remains uneven.

This geographical distribution highlights substantial opportunities for the development of cross-national and cross-cultural research, particularly in examining how mathematical intuition is conceptualized and fostered within different educational contexts. The limited contributions from developing countries also point to significant research gaps that can be further explored, either through international collaborations or through contextual studies that relate mathematical intuition to the characteristics of local education systems.

In addition to the distribution of publications by country, the analysis also examined patterns of international collaboration among countries, as illustrated in Figure 4.5. The visualization represents cross-country collaboration networks among authors, where nodes correspond to countries and connecting lines indicate co-authorship relationships. The thickness of the links reflects the intensity of collaboration, while the size of the nodes represents the relative level of each country's involvement within the collaboration network.

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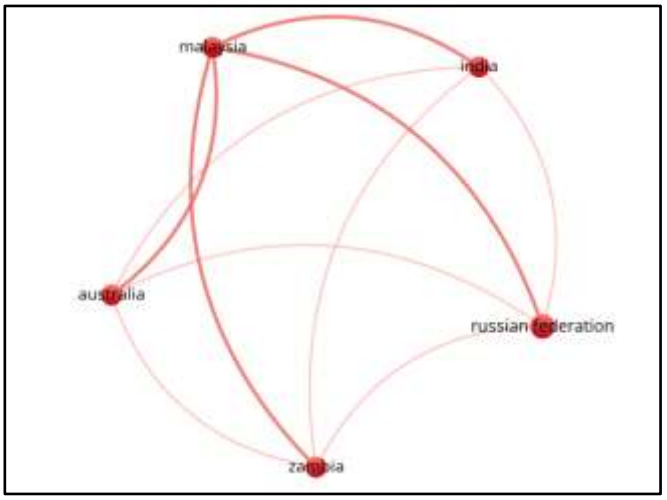


Figure 6. International Collaboration Network among Countries in Research on Mathematical Intuition

The visualization results indicate that international collaboration in research on mathematical intuition is still organized within relatively limited networks, with strong connections among a small number of countries. Countries such as Malaysia, Australia, India, and the Russian Federation appear to play central roles in the collaboration network, exhibiting several relatively strong collaborative ties. The presence of Zambia within the network suggests that collaboration in research on mathematical intuition is not exclusively dominated by Western countries, although the number and intensity of such collaborations remain relatively modest.

Overall, these findings indicate that although research on mathematical intuition has developed on a global scale, international collaboration remains sporadic and has not yet formed a broad and dense network. This condition highlights significant opportunities to strengthen cross-national collaboration, particularly between countries with high publication outputs and those that are still emerging in the field of mathematical intuition research. Enhancing international collaboration has the potential to enrich theoretical and pedagogical perspectives and to promote the development of more contextualized and globally inclusive research on mathematical intuition.

Keyword Analysis and Research Focus

This section presents an analysis of keywords used in research publications on mathematical intuition to identify the main research foci and the thematic structure of the field.

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The analysis was conducted through keyword co-occurrence mapping, which enables the exploration of relationships among concepts and the identification of dominant research themes. The results indicate that mathematical intuition functions as a core concept that connects a wide range of themes, including philosophical, mathematical, and pedagogical domains.

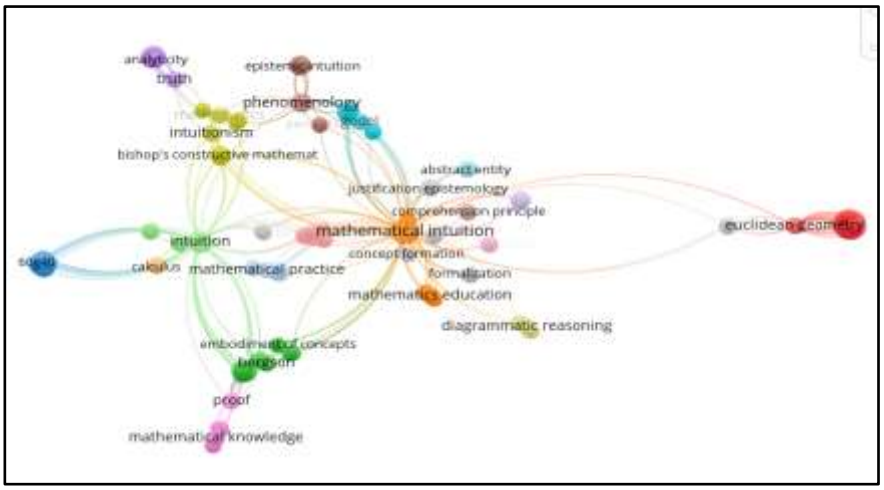


Figure 7. Keyword Co-occurrence Network and Research Foci in Mathematical Intuition

Figure 7 illustrates the keyword co-occurrence network representing the thematic structure and research foci in studies of mathematical intuition. It is evident that mathematical intuition occupies a central position within the network and is connected to several distinct thematic clusters, indicating its role as a unifying concept across approaches and disciplines. This extensive interconnectedness suggests that mathematical intuition is not understood as a single, isolated concept, but rather as a complex construct examined from multiple philosophical, mathematical, and pedagogical perspectives.

One prominent cluster is related to the philosophy and epistemology of mathematics, as indicated by keywords such as intuitionism, phenomenology, epistemic intuition, truth, analyticity, and references to thinkers such as Gödel and Bishop's constructive mathematics. This cluster reflects a research focus that positions mathematical intuition as an epistemological foundation for understanding truth, proof, and the justification of mathematical knowledge. The presence of terms such as justification epistemology and abstract entity further indicates that a substantial body of research remains deeply rooted in philosophical debates concerning the ontological and epistemic status of mathematical objects.

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Another cluster is oriented toward mathematical practice and mathematics education, characterized by keywords such as mathematics education, mathematical practice, concept formation, formalization, and diagrammatic reasoning. This focus highlights a shift in research attention toward examining how mathematical intuition functions in learning processes, concept development, and the transition from intuitive understanding to formal mathematical thinking. The association with terms such as Euclidean geometry and calculus indicates that mathematical intuition is also frequently investigated within specific mathematical topics that require visualization and intuitive reasoning.

In addition, a cluster emphasizing cognitive and embodied perspectives emerges, marked by keywords such as embodiment of concepts, intuition, and references to Bergson. This cluster underscores a strand of research that conceptualizes mathematical intuition as a cognitive process grounded in experience, perception, and human interaction with mathematical representations. The connections between this cluster and mathematics education suggest integrative efforts to bridge cognitive studies with instructional practice.

Overall, the keyword analysis demonstrates that research on mathematical intuition is multidimensional and multidisciplinary, organized around three main axes: epistemology and philosophy of mathematics, mathematical practice and mathematics education, and cognitive as well as embodied cognition perspectives. The dominance and interconnections among these clusters indicate that research on mathematical intuition has not developed in isolation but through an ongoing dialogue between philosophical theory and educational practice. These findings reinforce the position of mathematical intuition as a central and evolving concept that remains highly relevant in contemporary mathematics education.

Evolution of Research Themes in Mathematical Intuition

This section discusses the evolution of research themes in mathematical intuition based on the dynamics of keyword emergence and interconnections over time, as shown in the overlay visualization of the keyword co-occurrence network in Figure 7 below. The colour gradient of each node represents the average year of publication, where darker colours indicate themes that emerged in earlier periods and progressively lighter colours denote themes that have developed more recently. The visualization reveals a clear and gradual shift in research focus, moving from philosophical of epistemological inquiries toward more pedagogical, cognitive, and contextual approaches within mathematics education.

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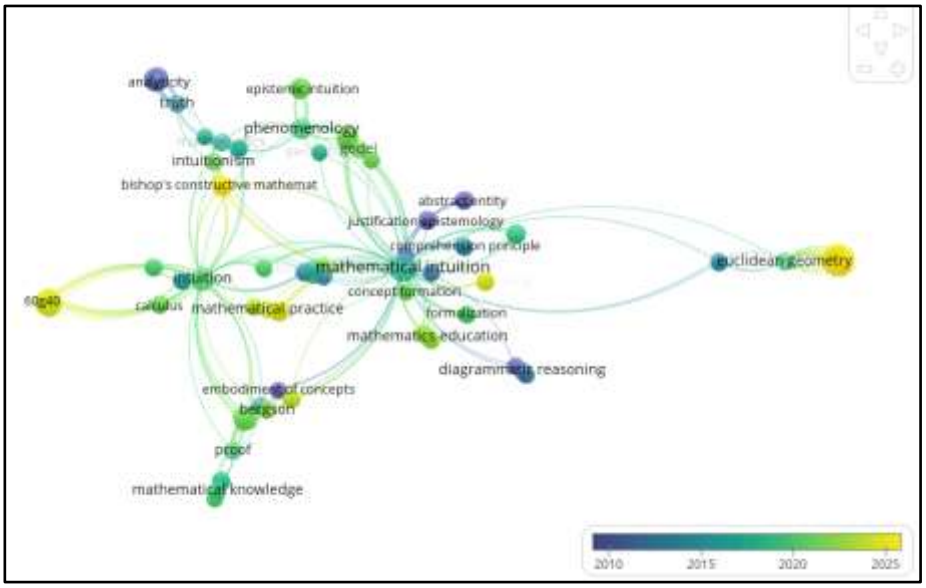


Figure 8. Overlay Visualization of the Evolution of Research Themes in Mathematical Intuition by Year of Publication

DISCUSSION

During the early period of the review (approximately 2010–2014), research themes were dominated by philosophical and epistemological discourses in mathematics. This is reflected in the appearance of keywords displayed in darker colours, such as truth, analyticity, intuitionism, phenomenology, and epistemic intuition, as well as references to influential figures and schools of thought, including Gödel and Bishop's constructive mathematics. In this phase, mathematical intuition was primarily understood as an epistemological foundation related to issues of truth, knowledge justification, and the ontological status of mathematical objects, as indicated by its associations with keywords such as justification epistemology and abstract entity.

Entering the transitional period (approximately 2015–2019), the node colours begin to shift toward green, signaling an expansion of research focus into the domains of mathematical practice and learning. Keywords such as intuition, mathematical practice, concept formation, and formalization show increasingly strong connections with mathematical intuition as the central node. This shift indicates that mathematical intuition was no longer positioned solely as a philosophical construct, but began to be conceptualized as a cognitive process that plays a role in concept formation and in the transition from intuitive understanding to formal mathematical structures.

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In the more recent period (approximately 2020–2025), the overlay visualization is characterized by the dominance of lighter colours, particularly for keywords directly related to mathematics education and cognitive–pedagogical aspects. The emergence of keywords such as mathematics education, diagrammatic reasoning, embodiment of concepts, and mathematical knowledge reflects a strengthening of research that emphasizes the role of mathematical intuition in learning processes, visual representation, and learners' experiential engagement. Moreover, the connections with specific topics such as calculus and Euclidean geometry indicate that mathematical intuition is increasingly examined within the context of particular mathematical subjects that demand visualization and intuitive reasoning.

Overall, the evolution of research themes in mathematical intuition, as illustrated by this overlay visualization, reveals a progressive and adaptive developmental trajectory aligned with the needs of contemporary mathematics education. The consistent central position of mathematical intuition across all time periods underscores its role as a bridging concept between early philosophical foundations and more recent pedagogical orientations. These findings suggest that research on mathematical intuition is moving toward more contextualized, empirical, and practice-oriented investigations, while still maintaining strong connections to its theoretical and epistemological roots.

The bibliometric findings indicating a shift in research on mathematical intuition from predominantly philosophical perspectives toward pedagogical and cognitive orientations are consistent with developments in contemporary philosophy of mathematics and mathematics education. Within the philosophical tradition, intuition has been understood as an initial epistemic mechanism that enables access to mathematical objects and truths prior to formalization through proof and axiomatic systems. This view is evident in intuitionism, phenomenology, and epistemological reflections on mathematical justification, which position intuition as an integral component of knowledge formation rather than as an infallible or purely perceptual faculty (Peña-Páez, 2021, 2023; Tieszen, 2002; Wrigley, 2022). In this framework, mathematical intuition emerges from conceptual understanding that evolves through sustained engagement with mathematical practice.

Concurrently, contemporary studies highlight the strong cognitive and pedagogical dimensions of mathematical intuition. Empirical research in mathematics education demonstrates that intuition plays a crucial role in problem solving, concept formation, and the development of logical reasoning, particularly in learning environments that move beyond procedural memorization (Fischbein, 1999, 2002; Popova et al., 2022). In this context, mathematical intuition

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is understood as the capacity to grasp mathematical structures and meanings rapidly and meaningfully, which can subsequently be transformed into formal reasoning through reflective and representational activities.

Moreover, recent philosophical and epistemological literature emphasizes the dynamic and normative character of mathematical intuition, viewing it as a bridge between experience, social mathematical practice, and the construction of rationally validated knowledge (Chudnoff, 2014; Fischbein, 1999; John & Kuiper, 2004; Kitcher, 1985; Maddy, 1980). This perspective aligns with the bibliometric evidence showing increased attention to themes such as mathematical practice, diagrammatic reasoning, and embodiment of concepts, which signal a growing integration of intuition, visual representation, and experiential learning in mathematics education.

CONCLUSION

This bibliometric analysis provides a comprehensive overview of the development of research on mathematical intuition in mathematics education over the past decade. The findings reveal that mathematical intuition has evolved from a research focus predominantly grounded in philosophical and epistemological discourse toward a more pedagogical, cognitive, and practice-oriented orientation. Despite this thematic shift, mathematical intuition has consistently remained a central and integrative concept, bridging foundational theories of mathematical knowledge with contemporary concerns in mathematics teaching and learning. Based on the bibliometric findings, several research directions emerge as particularly relevant and impactful for advancing the study of mathematical intuition in mathematics education. One of the recomendation is about Intuition and Visual–Diagrammatic Reasoning. The strong presence of diagrammatic reasoning and embodiment of concepts points to the importance of visual and embodied approaches. Future research could examine how visual representations, gestures, and digital simulations support the development of mathematical intuition, especially in technology-enhanced learning environments. Potential contribution is Integrates cognitive theory with innovative instructional design.

FUTURE DIRECTIONS

Mathematical intuition is increasingly conceptualized as a cross-disciplinary construct that connects philosophical foundations, cognitive processes, and pedagogical practices. This development opens new avenues for future research that are more empirical, contextualized, and

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oriented toward instructional design, while remaining firmly grounded in robust theoretical frameworks from the philosophy of mathematics.

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