MATHEMATICAL CREATIVITY IN MATHEMATICS EDUCATION: A BIBLIOMETRIC ANALYSIS OF SCOPUS-INDEXED PUBLICATIONS (2000–2025)

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ABSTRACT

Mathematical creativity has emerged as a pivotal construct in mathematics education, yet the rapid growth of related scholarship has resulted in a dispersed and conceptually layered research landscape. This study presents a bibliometric and science-mapping review of 504 Scopus-indexed documents published between 2000 and 2025, with the aim of systematically examining the intellectual structure, thematic evolution, and research trajectories of mathematical creativity in mathematics education. Using VOSviewer as the sole analytical tool, the study analyzes publication trends, document types, leading authors, institutions, countries, and sources, as well as co-authorship, citation, and keyword co-occurrence networks. The results reveal a pronounced increase in research output after 2013, with journal articles constituting the dominant publication format and social sciences and mathematics serving as the primary disciplinary anchors. Influential citation networks highlight a stable core of foundational scholars shaping theoretical and pedagogical discourse, while keyword co-occurrence mapping identifies interconnected thematic clusters centered on creative mathematical reasoning, problem solving, instructional practices, and emerging technology-mediated learning contexts. Notably, the field demonstrates a gradual shift from predominantly theoretical conceptualizations toward pedagogically grounded and application-oriented investigations. Taking a comprehensive, data-driven synthesis of 25 years of research, this study clarifies the knowledge structure of mathematical creativity scholarship and offers empirically grounded insights to inform future research directions, curriculum design, and instructional innovation in mathematics education.

Keywords: mathematical creativity; mathematics education; bibliometric analysis; science mapping; VOSviewer; Scopus

1.0 INTRODUCTION

Mathematical creativity has increasingly been recognized as a central construct in mathematics education, reflecting a global shift from procedural competence toward flexible, generative, and innovative mathematical thinking. Over the past two decades, research interest in mathematical creativity has grown steadily, driven by accumulating empirical evidence linking creative mathematical thinking to academic achievement, psychological well-being, equity, and long-term life success (e.g., Sebastian & Huang, 2016; Sternberg, 2006; Stolz et al., 2022). As education systems worldwide respond to the demands of the twenty-first century—characterized by uncertainty, complexity, and rapid technological change—creativity has become a core educational priority rather than an optional enrichment.

Within mathematics education, creativity has been conceptualized in diverse and sometimes competing ways. Early scholarship often framed mathematical creativity as a rare talent associated with giftedness and exceptional mathematical ability (Haylock, 1987; Ervynck, 1991). In contrast, more contemporary perspectives emphasize creativity as a developable competence that can be cultivated through instruction, problem solving, and problem posing (Silver, 1997; Sriraman, 2009). These perspectives align with broader creativity frameworks that view creativity not merely as an individual trait but as an interaction among person, process, product, and press or environment (Rhodes, 1961). As a result, mathematical creativity research has expanded to include cognitive processes (e.g., fluency, flexibility, originality), affective dimensions (e.g., self-confidence, self-efficacy), instructional practices, and learning environments that support creative mathematical engagement.

Recent bibliometric evidence confirms the rapid expansion and diversification of research on mathematical creativity in mathematics education. Saefudin, Wijaya, and Dwiningrum (2023) conducted a Scopus-based bibliometric analysis of mathematical creativity research from 2002 to 2022, revealing a substantial increase in publication output over time and identifying dominant research contributors, influential journals, and evolving thematic trends

Their findings demonstrate that mathematical creativity research has been shaped largely by discipline-specific instructional practices—particularly problem solving and problem posing—while also highlighting emerging attention to psychological constructs and learning environments. Importantly, their analysis suggests that although creativity has become a prominent keyword, research remains unevenly distributed across themes, educational levels, and geographic contexts.

Despite the significant contribution of this earlier bibliometric work, several critical gaps remain.

First, existing reviews—including Saefudin et al. (2023)—are temporally bounded and do not capture the most recent surge in publications observed after 2022, a period marked by intensified curricular reform, technology-mediated instruction, and renewed emphasis on creative competencies. Second, prior studies rely on relatively smaller datasets, limiting the granularity of science-mapping analyses and the ability to trace fine-grained thematic evolution. Third, much of the existing bibliometric literature focuses primarily on descriptive trends, with less emphasis on the structural relationships among themes, authors, and conceptual clusters over extended time spans.

Moreover, while prior bibliometric analyses have identified dominant instructional themes, there remains limited synthesis of how mathematical creativity research has transitioned from cognitively oriented and giftedness-centered frameworks toward more inclusive, classroom-embedded, and assessment-driven approaches. Saefudin et al. (2023) explicitly call for future research that moves beyond discipline-specific practices toward more holistic perspectives integrating person, process, product, and press/environment dimensions of creativity. Addressing this call requires updated, large-scale bibliometric evidence capable of capturing recent thematic shifts and emerging research fronts.

In response to these gaps, the present study conducts a comprehensive bibliometric and science-mapping analysis of Scopus-indexed research on mathematical creativity in mathematics education published between 2000 and 2025. By analyzing a substantially larger dataset and extending the temporal scope beyond previous reviews, this study aims to provide an updated and more detailed mapping of the field's intellectual structure, thematic evolution, and global research dynamics. Using advanced bibliometric techniques, including keyword co-occurrence and thematic clustering, the study seeks to clarify how mathematical creativity research has developed over time and to identify emerging directions that can inform future theory, research, and instructional practice. Specifically, this study addresses the following research questions:

1. How has the volume of Scopus-indexed research on mathematical creativity in mathematics education evolved from 2000 to 2025?
2. What subject areas and document types characterize the scholarly literature on mathematical creativity?
3. Which countries, institutions, authors, and publication sources have contributed most significantly to the development of mathematical creativity research?
4. What major conceptual themes and thematic clusters structure the field, and how have these themes evolved over time?

Situating its contribution in dia-

logue with existing bibliometric scholarship—particularly the work of Saefudin et al. (2023)—this study advances a more comprehensive and current understanding of mathematical creativity in mathematics education, offering evidence-based insights for researchers, educators, and curriculum designers.

2.0 Methodology

2.1 Research Design

This study employed a bibliometric research design to systematically examine the evolution, intellectual structure, and thematic orientation of scholarly literature on mathematical creativity in mathematics education. Bibliometric analysis is a well-established quantitative approach that applies statistical and network-based techniques to bibliographic metadata in order to identify publication patterns, influential contributors, and conceptual relationships within a research domain (Zupic & Čater, 2015; Donthu et al., 2021).

Bibliometric methods are particularly appropriate for fields characterized by rapid growth, conceptual plurality, and interdisciplinary influences, such as mathematical creativity, where traditional narrative reviews may be constrained by subjectivity and limited scope. By combining descriptive performance indicators with science-mapping techniques, bibliometric analysis enables a replicable and macro-level synthesis of knowledge production and intellectual development (Aria & Cuccurullo, 2017).

Consistent with best practices in bibliometric research and with the methodological structure used in recent Scopus-based bibliometric studies in education and educational technology, this study integrates performance analysis (e.g., publication growth, productive authors, countries, and sources) with relational science-mapping analysis (e.g., keyword co-occurrence). This dual approach allows both the quantitative expansion and the conceptual organization of mathematical creativity research to be examined comprehensively.

2.2 Data Source and Search Strategy

The Scopus database was selected as the sole data source due to its broad coverage of peer-reviewed journals, strong representation of education, psychology, and mathematics research, and standardized citation metadata. Scopus has been widely recognized as a reliable and authoritative database for bibliometric studies, particularly in interdisciplinary educational research contexts (Mongeon & Paul-Hus, 2016).

An advanced search strategy was developed to retrieve publications explicitly addressing mathematical creativity within educational contexts. The search was applied to the title, abstract, and author keyword fields and combined key terms related to creativity and mathematics education, including *mathematical creativity,*

creativity in mathematics education, creative problem solving in mathematics, mathematical problem posing. This was the search string used TITLE-ABS-KEY (mathematical creativity) AND PUBYEAR > 2001 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "MATH")) AND (LIMIT-TO (LANGUAGE , "English"))

Boolean operators were used to enhance retrieval precision while maintaining conceptual breadth. The search was limited to English-language publications published between 2000 and 2025, a time span selected to capture both the early conceptualization of mathematical creativity and its more recent expansion following global curricular reforms emphasizing creativity, problem solving, and higher-order thinking.

2.3 Inclusion and Exclusion Criteria

To ensure conceptual relevance and data consistency, a set of explicit inclusion criteria was applied during the screening process. Only publications indexed in the Scopus database were considered, as Scopus provides standardized and reliable bibliographic metadata suitable for bibliometric analysis. Eligible studies were required to explicitly address mathematical creativity within a mathematics education or instructional context, thereby ensuring alignment with the conceptual focus of the review. In addition, only recognized scholarly document types—namely journal articles, conference papers, review articles, and book chapters—were included to maintain academic rigor and comparability. Finally, publications were limited to those released between 2000 and 2025, a temporal range selected to capture both the early conceptual development and the recent expansion of research on mathematical creativity in mathematics education.

Publications were excluded if they focused solely on creativity outside mathematics education, addressed mathematics without a creativity dimension, or lacked sufficient bibliographic metadata for analysis. Applying these criteria aligns with established bibliometric guidelines that emphasize thematic relevance and data quality over sheer document volume (Zupic & Čater, 2015; Donthu et al., 2021).

Following screening and data cleaning procedures, a final dataset of 504 Scopus-indexed documents was retained for analysis.

2.4 Data Analysis Procedures

Bibliometric analyses were conducted using VOSviewer, a specialized software tool designed for constructing and visualizing bibliometric networks. VOSviewer is widely used in high-impact bibliometric studies due to its ability to process large datasets and generate interpretable visualizations of co-authorship, co-citation, and keyword co-occurrence networks (van Eck & Waltman, 2010).

The analysis proceeded in two stages. First, descriptive bibliometric indicators were generated to examine annual publication trends,

document types, subject-area distribution, and the most productive countries, institutions, authors, and publication sources. These indicators provide a macro-level overview of research productivity and dissemination patterns.

Second, keyword co-occurrence analysis was conducted to explore the conceptual structure of mathematical creativity research. Keyword co-occurrence analysis is a widely accepted science-mapping technique used to identify dominant and emerging research themes by examining how frequently and closely concepts appear together within the literature (Cobo et al., 2011; van Eck & Waltman, 2010). Minimum occurrence thresholds were applied to enhance analytical clarity and reduce noise, consistent with established bibliometric practices.

This analytical strategy mirrors the methodological rigor observed in recent Scopus-based bibliometric studies in education and educational technology while extending the analysis to a longer time span and a larger dataset.

2.5 Reliability and Validity Considerations

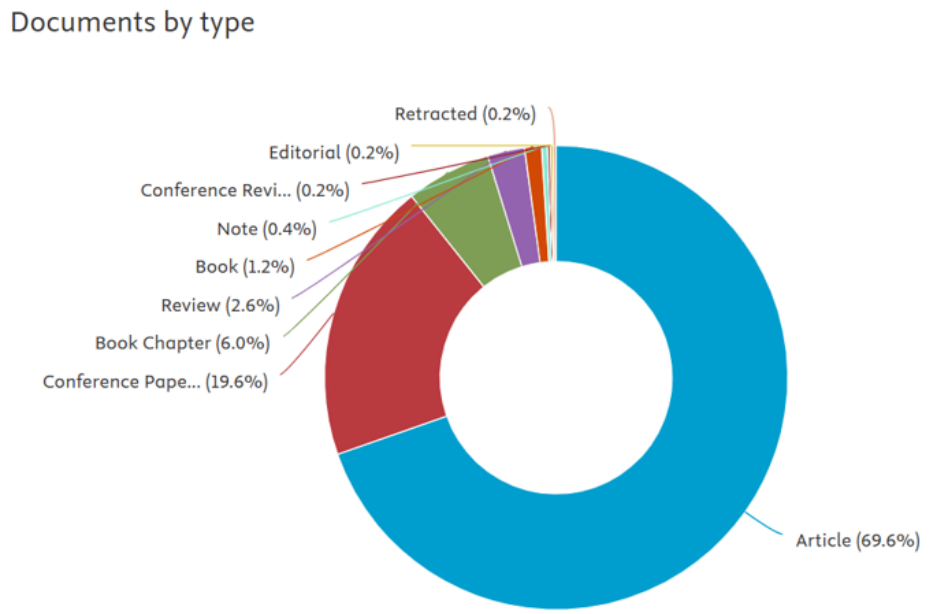
Methodological rigor was ensured through transparent reporting of the search strategy, inclusion criteria, and analytical procedures, enabling replicability and comparison with related bibliometric studies. The exclusive use of a single, high-quality database minimized inconsistencies in bibliographic metadata and citation records. While bibliometric analysis does not evaluate the methodological quality of individual studies, it provides a reliable macro-level representation of research development, scholarly influence, and thematic orientation within a field (Donthu et al., 2021).

2.6 Ethical Considerations

This study relied exclusively on publicly available bibliographic metadata and did not involve human participants, personal data, or identifiable information. Consequently, formal ethical approval was not required. All analyses were conducted in accordance with accepted standards for research integrity and responsible use of scholarly data.

3.0 Results and Discussion

3.1 Document Types in Mathematical Creativity Research



Analysis of document types indicates that journal articles dominate the corpus, accounting for 69.6% of all Scopus-indexed publications on mathematical creativity in mathematics education. This is followed by conference papers (19.6%), book chapters (6.0%), and review articles (2.6%). Other document types—such as books (1.2%), notes (0.4%), editorials (0.2%), conference reviews (0.2%), and retracted documents (0.2%)—constitute only marginal proportions of the dataset.

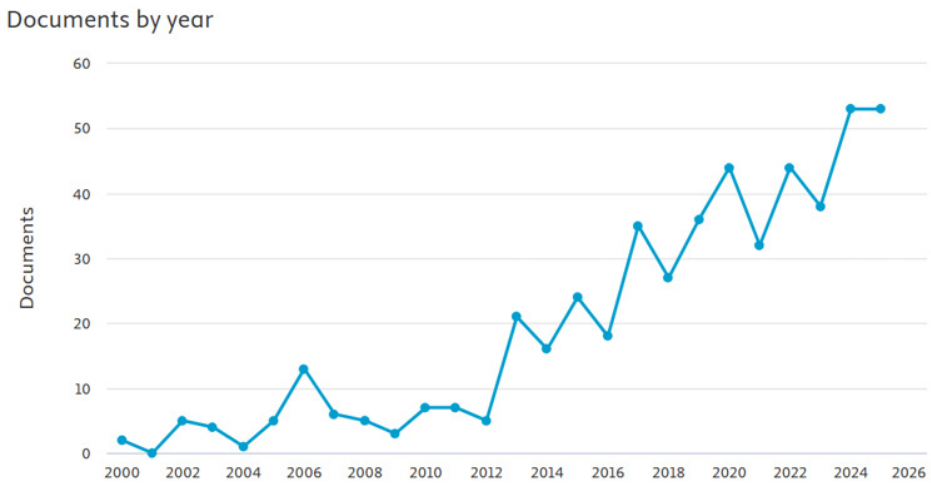
The overwhelming prevalence of journal articles suggests that research on mathematical creativity is largely disseminated through peer-reviewed outlets, reflecting an emphasis on validated empirical and theoretical contributions rather than preliminary or informal scholarly communication.

The dominance of journal articles is indicative of a field that has reached a level of conceptual consolidation and scholarly legitimacy, as journal publication is typically associated with mature theoretical framing and methodological rigor (Donthu et al., 2021). This pattern contrasts with emerging research areas, which often rely more heavily on conference proceedings.

The substantial proportion of conference papers nevertheless signals continued innovation and methodological exploration, particularly in relation to instructional design, task development, and technology-enhanced creativity. The relatively small proportion of

review articles suggests that while synthesis efforts exist, the field may still benefit from additional integrative and theory-building reviews that consolidate diverse conceptual strands (Zupic & Čater, 2015).

3.2 Temporal Trends in Publication Output



The temporal analysis reveals a clear upward trajectory in the volume of research on mathematical creativity from 2000 to 2025. In the early period (2000–2005), annual publication counts remained low, ranging from 0 to 5 documents per year. Between 2006 and 2012, output increased modestly, fluctuating between 3 and 13 publications annually.

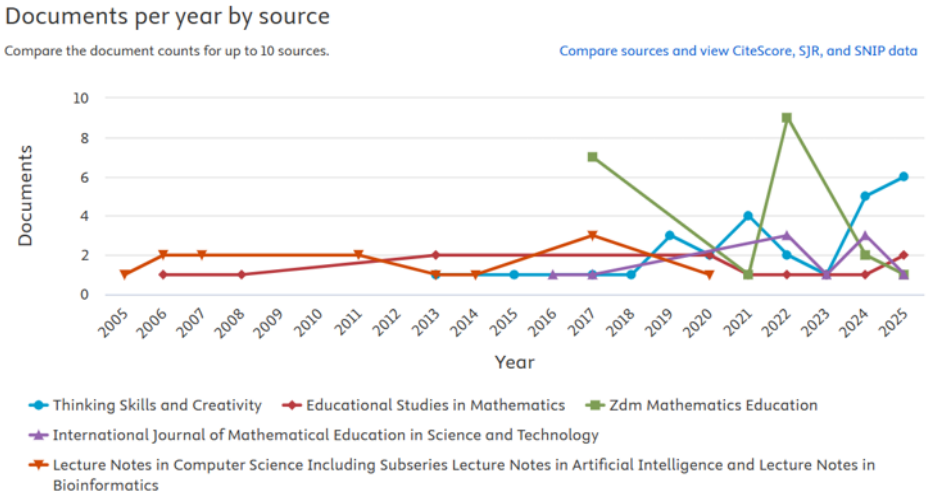
A marked acceleration is evident from 2013 onward, with annual production consistently exceeding 15 documents per year. The most pronounced growth occurs after 2017, culminating in peak outputs of over 50 publications per year in 2024 and 2025.

This growth pattern reflects the typical developmental trajectory of a research field, progressing from an exploratory phase to consolidation and rapid expansion (Zupic & Čater, 2015). Early low publication rates suggest that creativity was initially treated as an implicit component of problem solving or gifted education rather than a distinct construct.

The observed surge after 2008 coincides with influential theoretical contributions, particularly Lithner's (2008) formulation of creative mathematical reasoning and Sriraman's (2009) conceptual synthesis of mathematical creativity. The steep rise after 2017 aligns with global educational reforms emphasizing creativity, higher-order thinking, and problem posing as core outcomes of mathematics instruction (Silver, 1997; Leikin, 2020). Collectively,

these trends indicate that mathematical creativity has become a sustained and central research focus within mathematics education.

3.3 Leading Publication Sources

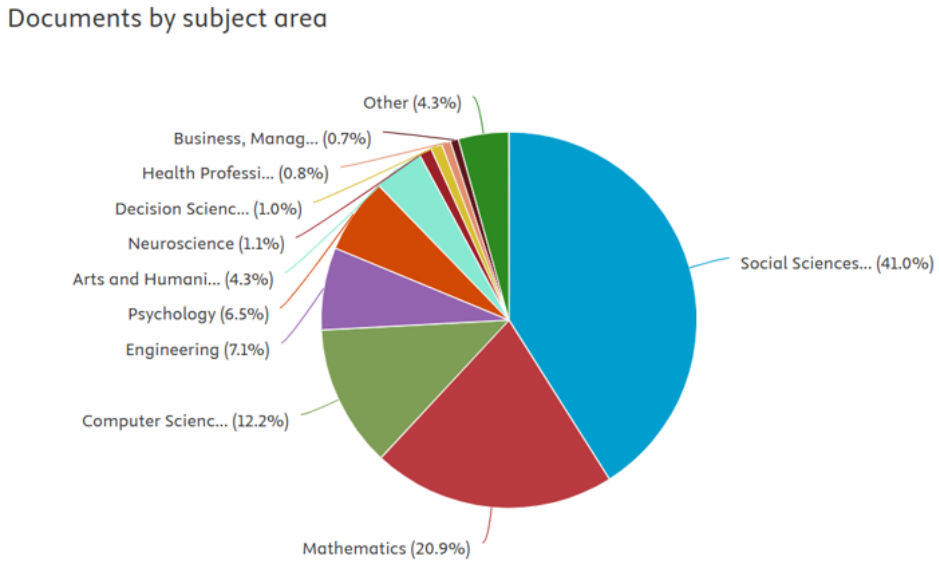


Source-level analysis shows that a limited number of journals contribute disproportionately to annual publication output. Thinking Skills and Creativity, Educational Studies in Mathematics, ZDM Mathematics Education, and the International Journal of Mathematical Education in Science and Technology emerge as the most consistent publication venues.

Notably, ZDM Mathematics Education exhibits episodic spikes, including a peak of approximately nine publications in a single year, suggesting the presence of special issues or focused thematic calls. Thinking Skills and Creativity demonstrates a steady increase in output in recent years, particularly after 2019. The concentration of publications in a small set of high-impact journals suggests that research on mathematical creativity is being shaped within well-defined scholarly communities. Journals such as *ZDM and Educational Studies in Mathematics* are known for their emphasis on theoretical depth and methodological rigor, indicating that creativity research is increasingly integrated into mainstream mathematics education discourse.

The growth of publications in Thinking Skills and Creativity reflects the field's alignment with broader creativity research, supporting interdisciplinary dialogue between mathematics education and cognitive creativity studies (Sriraman, 2009; Leikin & Pitta-Pantazi, 2013).

3.4 Subject Area Distribution

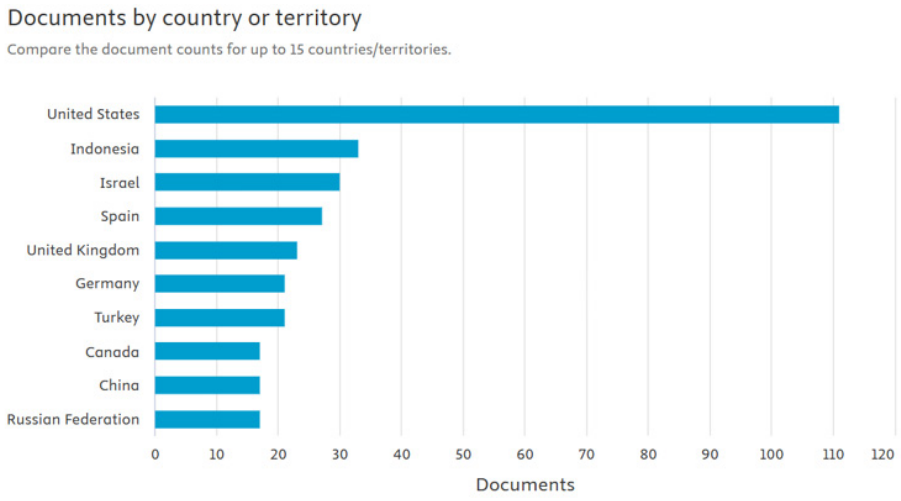


The subject-area classification reveals that Social Sciences account for 41.0% of publications, followed by Mathematics (20.9%) and Computer Science (12.2%). Additional contributions originate from Engineering (7.1%), Psychology (6.5%), and Arts and Humanities (4.3%), with smaller shares distributed across Neuroscience, Decision Sciences, Health Professions, and Business and Management.

The dominance of Social Sciences underscores the pedagogical orientation of mathematical creativity research, emphasizing teaching, learning, curriculum, and assessment. The strong representation of Mathematics confirms that creativity is studied within discipline-specific practices such as reasoning, problem solving, and task structure (Lithner, 2008).

The growing presence of Computer Science and Engineering reflects increasing interest in computational thinking, programming, and technology-mediated creativity. This trend aligns with contemporary STEM and STEAM frameworks, where creativity is conceptualized as a cross-disciplinary competence rather than a domain-isolated skill (Leikin, 2020).

3.5 Country-Level Research Contributions

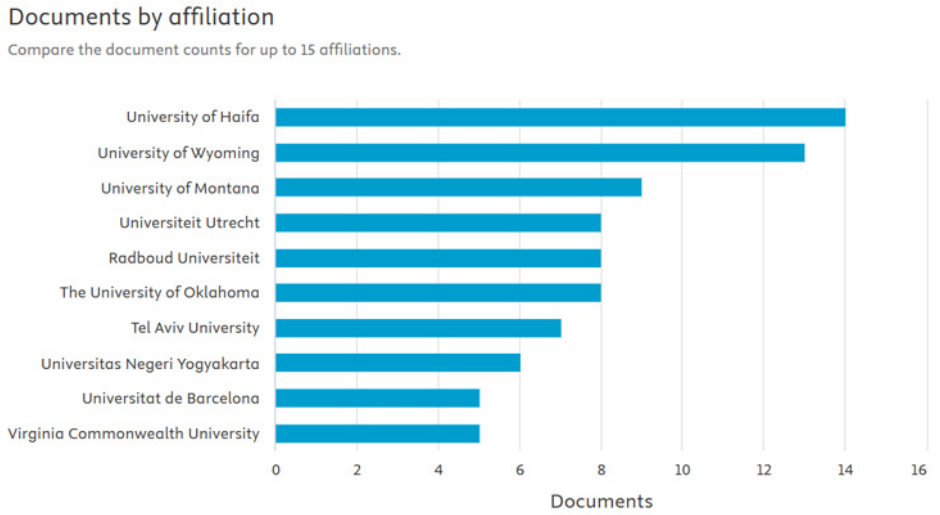


At the country level, the United States is the most prolific contributor, with over 110 documents, followed by Indonesia (approximately 35), Israel (around 30), Spain (approximately 27), and the United Kingdom (around 23). Other notable contributors include Germany, Turkey, Canada, China, and the Russian Federation, each producing between 15 and 20 publications.

The dominance of the United States reflects its extensive research infrastructure and leadership in mathematics education scholarship. Israel's strong contribution aligns with its long-standing tradition of research on problem posing, multiple-solution tasks, and creativity-focused teacher education (Leikin & Pitta-Pantazi, 2013).

Indonesia's substantial output signals rapid growth in creativity-oriented mathematics education research in Southeast Asia, often driven by curriculum reforms emphasizing higher-order thinking skills. However, the concentration of output in a limited number of countries suggests uneven global participation, highlighting the need for more culturally responsive and cross-national studies of mathematical creativity (Mongeon & Paul-Hus, 2016).

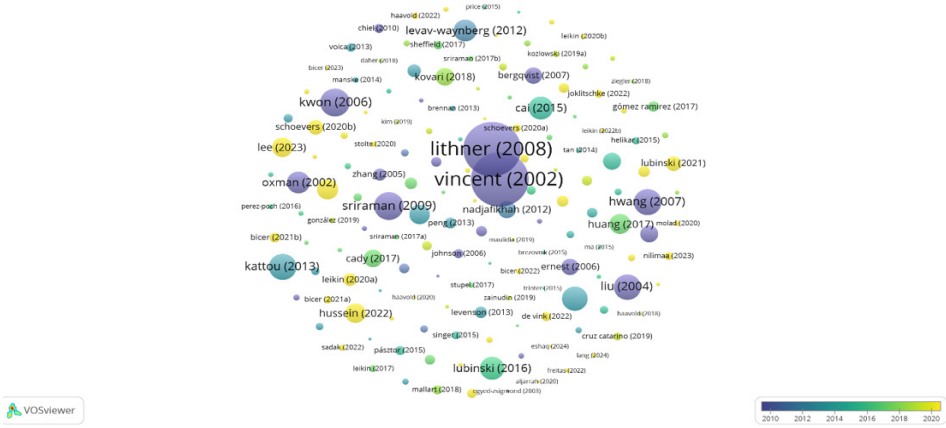
3.6 Institutional Productivity



Institutional analysis identifies the University of Haifa as the most productive affiliation, followed by the University of Wyoming and the University of Montana. Other leading institutions include Utrecht University, Radboud University, The University of Oklahoma, Tel Aviv University, Universitas Negeri Yogyakarta, Universitat de Barcelona, and Virginia Commonwealth University, each contributing between 5 and 8 publications.

The concentration of output within a small number of institutions suggests the presence of research hubs that sustain long-term inquiry into mathematical creativity. Such clustering is characteristic of maturing research domains, where cumulative knowledge production is supported by stable research groups and mentorship networks (van Eck & Waltman, 2010).

3.7 Influential Authors and Citation Structure



The figure presents the author co-citation network visualization generated using VOSviewer, illustrating the intellectual structure of mathematical creativity research in mathematics education. Node size represents citation frequency, link strength reflects co-citation intensity, spatial proximity indicates conceptual relatedness, and node color corresponds to the average publication year.

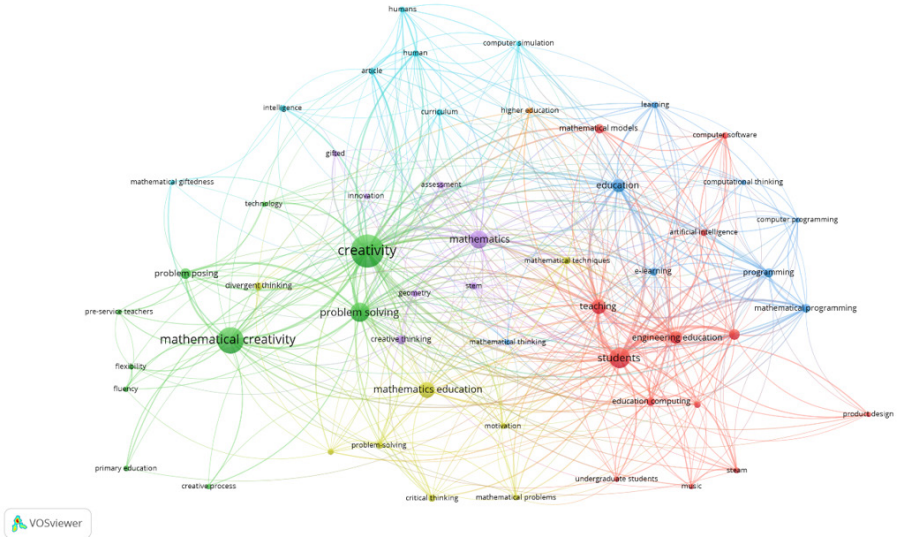
The network is highly centralized, with a small number of dominant nodes exerting substantial influence. Among these, Lithner (2008) and Vincent (2002) emerge as the most prominent nodes, indicating their foundational role in shaping subsequent scholarship. These authors occupy central positions within the network, with dense co-citation links to both early conceptual works and more recent empirical studies.

Closely connected to this central core are Sriraman (2009), Leikin (multiple years), and Hwang (2007), whose works bridge theoretical, pedagogical, and cognitive dimensions of mathematical creativity. The spatial clustering of these authors suggests a shared conceptual orientation centered on creative reasoning, problem solving, and instructional design.

Peripheral but still influential clusters include authors such as Kattou (2013), Lubinski (2016, 2021), Cai (2015), and Kwon (2006), who contribute specialized perspectives on creativity, giftedness, multiple-solution tasks, and mathematical problem posing. More recent contributors (e.g., publications post-2018) appear in lighter colors, indicating ongoing expansion and diversification of the field.

The prominence of Lithner (2008) within the co-citation network underscores the enduring influence of the creative mathematical reasoning (CMR) framework. Lithner's distinction between algorithmic and creative reasoning has become a conceptual anchor for research examining how students generate novel solution strategies, justify mathematical ideas, and engage in non-routine problem solving. The dense co-citation links surrounding Lithner's work indicate that CMR has been widely adopted across empirical, instructional, and theoretical studies, positioning it as a unifying construct within the field.

3.8 Thematic Structure of Mathematical Creativity Research



The keyword co-occurrence network positions "mathematical creativity" as the central organizing node, strongly connected to problem solving, creativity, mathematics education, teaching, students, and computational thinking. The clustering pattern suggests at least four interpretable thematic areas, reflecting how the field conceptualizes, operationalizes, and extends mathematical creativity across educational contexts.

Cluster A: Cognitive foundations of mathematical creativity

A dense cluster links *mathematical creativity, creativity, problem posing, divergent thinking, fluency,* and *flexibility.* This cluster indicates that the dominant conceptualization of mathematical creativity remains grounded in cognitive and problem-solving processes, particularly the generation of multiple, novel, and mathematically valid solutions. The prominence of problem posing and divergent thinking aligns with long-standing theoretical positions that frame creativity as a form of advanced mathematical reasoning rather than mere originality (Silver, 1997; Lithner, 2008).

The presence of primary education and pre-service teachers within this cluster suggests that these cognitive constructs are not treated as abstract psychological traits but are increasingly examined as instructionally cultivable competencies, especially in early schooling and teacher education contexts (Leikin, 2009; Sriraman, 2009).

Cluster B: Pedagogical and curricular integration

A second cluster centers on *mathematics education, teaching, curriculum, assessment, learning,* and *motivation.* This pattern indicates that

mathematical creativity is widely studied as an embedded pedagogical outcome, shaped by classroom practices, curricular design, and assessment strategies. Rather than treating creativity as peripheral enrichment, this cluster reflects a mainstreaming of creativity within mathematics education discourse.

This finding resonates with scholarship arguing that creativity must be structurally supported through task design, classroom norms, and evaluative practices to become sustainable in mathematics instruction (Cai et al., 2015; Leikin & Lev, 2013). The strong linkage between creativity and assessment further suggests ongoing tensions in operationalizing and measuring creative mathematical thinking within standardized educational systems.

Cluster C: Technology, computational thinking, and digital mathematics

Another prominent cluster connects *computational thinking, programming, computer software, artificial intelligence,* and *mathematical programming*. This cluster reflects a growing body of work situating mathematical creativity within digital, computational, and algorithmic environments. The co-occurrence of these terms with learning and education suggests that technology is not merely a tool but a conceptual context in which new forms of mathematical creativity are explored, particularly through modeling, simulation, and code-based problem solving. This aligns with recent literature emphasizing that computational environments can expand the space of creative mathematical activity by enabling experimentation, visualization, and iterative refinement of ideas (Wing, 2006; Leikin, 2020). Importantly, the strong connectivity between this cluster and core creativity nodes indicates integration rather than fragmentation, suggesting that computational approaches are extending—not replacing—traditional creativity frameworks.

Cluster D: Learners, interdisciplinarity, and applied contexts

A fourth cluster emphasizes s*tudents, engineering education, STEAM, education computing, and product design.* This cluster highlights the application-oriented and interdisciplinary turn in mathematical creativity research, where creativity is examined in authentic problem contexts that bridge mathematics with engineering, technology, and design.

The prominence of *students* as a central node within this cluster reflects a learner-centered orientation, emphasizing how students enact creativity when mathematics is embedded in real-world or design-based challenges. This pattern supports arguments that interdisciplinary and STEAM contexts provide fertile ground for creative mathematical thinking by situating mathematics as a functional and generative tool rather than an abstract discipline (Sriraman et al., 2017).

Overall, the thematic struc-

ture suggests that research on mathematical creativity is moving toward a multidimensional and integrated agenda, where cognitive processes, pedagogy, and technology converge. Creativity is no longer framed solely as an individual cognitive capacity but as a phenomenon shaped by instructional design, digital environments, and interdisciplinary application. At the same time, the centrality of problem solving and reasoning indicates strong theoretical continuity, suggesting that newer themes are layered onto established foundations rather than displacing them.

This configuration reflects a mature and evolving field in which how mathematical creativity is taught, supported, and enacted has become as important as how it is defined—positioning pedagogy and learning contexts as core, rather than peripheral, concerns in future research trajectories.

4.0 Conclusion and Implication

This bibliometric and science-mapping review synthesizes 25 years (2000–2025) of Scopus-indexed research on mathematical creativity in mathematics education, revealing a field that is both theoretically cohesive and dynamically evolving. The results show that scholarship remains anchored in foundational frameworks emphasizing creative mathematical reasoning, problem solving, and divergent thinking, while simultaneously expanding toward pedagogical enactment, computational thinking, and interdisciplinary STEAM contexts. Importantly, this thematic diversification reflects conceptual integration rather than fragmentation, positioning mathematical creativity as a multidimensional construct shaped by cognition, instruction, and digital environments. The increasing prominence of technology-oriented themes underscores emerging opportunities—and challenges—for examining how computational tools and artificial intelligence reshape creative mathematical activity, highlighting the need for empirically grounded, pedagogy-driven inquiry. For practice and policy, the findings affirm that mathematical creativity should be treated as a core curricular and instructional outcome rather than an enrichment add-on, requiring intentional task design, teacher preparation, and assessment alignment. Collectively, this review suggests that the future advancement of the field depends on bridging theory with classroom implementation, broadening global research participation, and sustaining a human-centered, pedagogically grounded approach to fostering creativity in mathematics education.

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