

Problem posing in mathematics education: Research trends and global collaborations over four decades

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Abstract

Problem posing has become a central pedagogical and cognitive process in mathematics education, enhancing students' conceptual understanding, metacognitive regulation, and creativity. Despite its growing prominence, the literature remains fragmented and lacks integrative syntheses. This study analyzes 440 peer-reviewed articles published between 1984 and 2025 and indexed in the Web of Science, using the preferred reporting items for systematic reviews and meta-analyses-guided bibliometric and thematic analysis supported by VOSviewer and Bibliometrix. The analysis examines publication trends, keyword co-occurrences, thematic clusters, and patterns of international collaboration. The results show a sharp increase in problem posing research since 2010, with dominant themes related to teacher education, cognitive processes, instructional design, and mediated learning environments. Emerging lines of inquiry include technology-supported problem posing, gamified contexts, and creativity-oriented approaches, which appear alongside established pedagogical and theoretical frameworks. Grounded in constructivist, metacognitive, creative, and sociocultural perspectives, the study maps the intellectual structure of the field and outlines strategic directions for future research, curriculum development, and teacher education. The findings indicate that problem posing functions as a multidimensional and interdisciplinary approach to supporting mathematical thinking across diverse learning contexts.

Keywords: problem posing, mathematics education, bibliometric analysis, thematic mapping, instructional design

INTRODUCTION

In mathematics education, problem posing has gained increasing recognition as a central process that supports learners' cognitive development, creative thinking, and conceptual understanding (English, 1998; Silver & Cai, 1996). Beyond solving given problems, posing mathematical problems requires learners to restructure problem situations, generate alternative formulations, and explore multiple solution pathways, thereby fostering higher-order thinking and metacognitive engagement (Cai et al., 2020; Christou et al., 2005). From a constructivist perspective, problem posing enables learners to actively construct knowledge by transforming mathematical ideas rather than merely applying procedures, which contributes to deeper conceptual learning (Baumanns & Rott, 2021; Zhang et al., 2025a).

In recent years, research interest in problem posing has expanded beyond student learning outcomes to include teacher education, instructional design, and technology-enhanced learning environments. Studies increasingly emphasize the role of problem posing in developing teachers' pedagogical judgment and curriculum awareness, particularly in preservice teacher education contexts (Leavy & Hourigan, 2022). At the same time, digital pedagogies and artificial intelligence (AI)-supported learning environments have opened new possibilities for designing interactive and adaptive problem posing activities (Marco & Palatnik, 2024). These developments position problem posing as a multifaceted pedagogical practice that integrates cognitive, metacognitive, creative, and instructional dimensions.

Contribution to the literature

- This study presents a large-scale bibliometric and thematic synthesis of 440 peer-reviewed articles on mathematical problem posing published between 1984 and 2025, providing an overview of the field's development over time. By combining preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines with VOSviewer and Bibliometrix tools, the study maps the conceptual structure of problem posing research, identifies major thematic trends, and examines patterns of international and institutional collaboration.
- The study highlights emerging lines of inquiry, such as technology-supported problem posing, gamified contexts, and creativity-oriented approaches that appear alongside established instructional and theoretical themes.
- Integrating cognitive, metacognitive, creative, and sociocultural perspectives, the study frames problem posing as a multidimensional research domain and pedagogical practice relevant to future research and teacher education.

Despite the growing body of research, existing studies on problem posing are predominantly experimental or descriptive and often rely on limited samples or specific instructional settings. As a result, the field remains fragmented, with relatively few studies offering a comprehensive synthesis of its conceptual structure, thematic orientations, and long-term development. However, such a holistic perspective is essential for informing educational policy, curriculum development, and instructional innovation in mathematics education (Hwang et al., 2025; Ulusoy, 2025). Addressing this gap, the present study aims to systematically examine the literature on problem posing using bibliometric and thematic analysis methods to reveal the field's temporal development, dominant themes, and research trends. By mapping the intellectual structure of problem posing research over four decades, the study seeks to provide strategic insights for curriculum design, teacher education, and technology-supported learning environments from an interdisciplinary perspective.

LITERATURE REVIEW

Problem Posing in Mathematics Education

Problem posing is widely recognized as a core component of meaningful learning in mathematics, functioning both as a cognitive process and a pedagogical strategy. Rather than engaging only with pre-formulated problems, learners who pose problems actively reformulate or generate new mathematical situations, which supports deeper conceptual understanding as well as creative and metacognitive engagement (English, 1998; Silver & Cai, 1996; Singer & Voica, 2015). Through this process, students explore mathematical structures, test assumptions, and consider multiple representations and solution pathways.

Historically, problem posing has emerged as an instructional approach that emphasizes student agency and inquiry. Early work by Brown and Walter (1983) highlighted learners' capacity to generate meaningful

mathematical questions, positioning problem posing as a catalyst for exploration and sense-making. Subsequent research linked problem posing to creativity and mathematical meaning-making (English, 1998; Silver, 1994). Over time, the field has evolved from a peripheral classroom activity into a multifaceted research domain central to learning, teaching, and assessment in mathematics education. Several conceptual models describe the structure of the problem posing process. Leung (2025) aligned problem posing with Polya's problem-solving cycle, emphasizing its iterative nature. Christou et al. (2005) further identified four interrelated phases: understanding, organizing, representing, and formulating, highlighting the cognitive and metacognitive regulation involved. These models have informed research on both student learning and teacher development.

Contemporary research reflects increasing theoretical integration. Studies have examined the links between problem posing and modeling competencies (Hartmann et al., 2024), metacognitive regulation (Kontorovich, 2024), and task variables that influence problem quality (Cai et al., 2024). Interdisciplinary perspectives drawing on creativity research, sociocultural theory, and cognitive psychology further enrich the field (Cai et al., 2015; Singer & Voica, 2015). Overall, the literature can be organized into three interconnected strands: student-centered studies focusing on creativity and engagement (Baumanns & Rott, 2024), research in teacher education emphasizing pedagogical reasoning and curriculum alignment (Cai & Hwang, 2020; Leavy & Hourigan, 2022), and emerging work on technology-enhanced environments that support interactive and individualized problem posing (Kim et al., 2025; Segal & Biton, 2024; Shao & Tang, 2025). This evolution underscores the need for systematic syntheses to capture the field's conceptual trajectory and research dynamics.

Theoretical Framework

Problem posing is a multifaceted construct informed by multiple theoretical traditions in mathematics

education. It is best understood through the integration of constructivist, metacognitive, creative, and sociocultural perspectives, which together capture how learners generate, regulate, and interpret mathematical problems. From a constructivist viewpoint, problem posing supports active knowledge construction by engaging learners in transforming mathematical ideas rather than merely applying procedures (English, 1998; Silver & Cai, 1996). While Piagetian perspectives emphasize individual cognitive development, Vygotskian concepts such as mediation and the zone of proximal development highlight the social and dialogic dimensions of learning, particularly in collaborative problem posing contexts (Bosra et al., 2025; Ghasempour & Baker, 2012).

Metacognitive perspectives emphasize learners' regulation of thinking during problem posing. Generating mathematical problems requires planning, monitoring, and evaluating cognitive actions, as learners assess the coherence and complexity of the problems they create. Christou et al. (2005) conceptualized this process through four interrelated stages: understanding, organizing, representing, and formulating, illustrating how metacognitive control operates throughout problem generation (Hartmann et al., 2024). Creativity-based frameworks position problem posing as a means of fostering divergent thinking in mathematics. By generating original and varied problem situations, learners develop fluency, flexibility, and originality, key components of mathematical creativity (Leung, 2025; Singer & Voica, 2015). Empirical studies suggest that such creative engagement fosters cognitive flexibility and enhances deeper mathematical insight (Baumanns & Rott, 2024; Bicer et al., 2025).

Sociocultural perspectives situate problem posing within instructional contexts shaped by classroom norms, curricular expectations, and teacher mediation. Frameworks such as F-PosE illustrate how teachers can structure problem posing tasks to balance learner agency with curricular alignment (Leavy & Hourigan, 2022). Integrative accounts further synthesize these perspectives into cognitive, pedagogical, and creative strands, reinforcing the multidimensional nature of problem posing (Papadopoulos et al., 2022). This framing provides a foundation for examining the field's conceptual development, consistent with the aims of the present study.

Current Trends and Empirical Directions in Problem Posing Research

Recent research in mathematics education increasingly conceptualizes problem posing not merely as an instructional technique but as a holistic learning practice that integrates cognitive, metacognitive, affective, and pedagogical dimensions. This shift reflects a growing recognition of problem posing as a complex

activity that supports meaningful engagement with mathematical ideas across diverse learning contexts.

From a cognitive and metacognitive perspective, studies demonstrate that problem posing enhances conceptual understanding and supports learners' regulation of their own thinking. Research highlights how structured problem posing tasks activate planning, monitoring, and reflection processes, enabling deeper engagement with mathematical concepts (Baumanns & Rott, 2021; Hartmann et al., 2024; Zhang et al., 2025a). Advanced methodological tools, including eye-tracking and process-based analyses, have further revealed how non-routine and unexpected student responses provide insight into diverse cognitive pathways during problem posing (Kontorovich, 2024; Ran et al., 2025).

Affective and motivational dimensions have also received increasing attention. Empirical studies indicate that engaging learners in problem posing activities can enhance self-efficacy, task value, and sustained motivation, particularly when tasks are embedded in meaningful modeling or real-world contexts (Krawitz et al., 2025). These findings underscore the importance of considering emotional and motivational factors in conjunction with cognitive outcomes.

Within teacher education, problem posing has been positioned as a key mechanism for developing pedagogical judgment and mathematical reasoning among preservice teachers. Research shows that engaging future teachers in problem posing activities supports their ability to evaluate task quality, align instruction with curricular goals, and reflect on students' thinking (Marco & Palatnik, 2024; Ulusoy, 2025). Frameworks such as F-PosE provide structured criteria that guide teachers in designing and assessing problem posing tasks, promoting reflective and intentional instructional practice (Leavy & Hourigan, 2022).

Finally, a growing body of work examines how curriculum materials and instructional designs can be adapted to support the posing of problems. Studies demonstrate that transforming traditional resources, such as textbooks, into problem posing opportunities fosters student inquiry and creativity while bridging theoretical insights with classroom practice (Hwang et al., 2025). Collectively, these trends indicate a shift toward more integrated and context-sensitive approaches to problem posing, underscoring the need for research designs that capture the cognitive, affective, and pedagogical complexity of this process.

Focus of This Study

Although problem posing has received growing scholarly attention in mathematics education, existing research remains fragmented across specific populations, instructional contexts, and narrowly defined subthemes. Recent studies have highlighted advances in task design, instructional strategies, and

learning outcomes; however, they also point to the need for integrative syntheses that capture the field's conceptual evolution, methodological diversity, and interdisciplinary connections (Cai et al., 2024; Wang et al., 2022; Zhang et al., 2024a, 2025a). In particular, comprehensive reviews that systematically map research trends, thematic structures, and collaboration patterns over extended periods remain limited.

To address this gap, the present study employs bibliometric and thematic analysis techniques to examine the development of problem posing research over a four-decade span (1984-2025). Drawing on publications indexed in the Web of Science (WoS), the study aims to reveal the intellectual structure of the field by identifying dominant themes, emerging topics, and patterns of scholarly collaboration. By integrating bibliometric indicators with thematic mapping, the study moves beyond descriptive summaries to offer a structured interpretation of how problem posing research has evolved conceptually and methodologically over time.

The study is guided by four research questions, each serving a distinct analytical purpose within the bibliometric framework:

1. What keywords and trending topics characterize the literature on problem posing, and how do they reflect evolving research priorities?
2. How are studies on problem posing clustered thematically or methodologically, and what subfields emerge from these clusters?
3. What thematic structures and relationships can be identified through thematic mapping of the literature?
4. What patterns of geographical and institutional collaboration shape the global research landscape on problem posing?

The academic contribution of this study lies in its systematic integration of bibliometric and thematic analyses, providing a comprehensive overview of problem posing research across mathematics education and related fields. Unlike prior reviews that focus on specific instructional approaches or learner populations, this study captures long-term trends, conceptual linkages, and research gaps on a global scale. By organizing dispersed findings into a coherent intellectual map, the study offers strategic insights for future research, curriculum development, teacher education, and interdisciplinary applications in mathematics education.

METHODOLOGY

This study employs a systematic literature review and bibliometric analysis to explore the conceptual structure, research trends, and thematic orientations of studies on mathematical problem posing. The systematic

review establishes a transparent and replicable corpus, while bibliometric techniques serve as the primary analytical approach for examining patterns of knowledge development within the field.

The research design is informed by the PRISMA framework (Moher et al., 2009), ensuring transparency, replicability, and methodological rigor in the identification and screening of relevant studies. Rather than examining individual learning outcomes or instructional interventions, this study focuses on how research on mathematical problem posing has evolved over time in terms of dominant concepts, themes, and methodological orientations. The review process consisted of four phases:

- (1) defining inclusion and exclusion criteria,
- (2) conducting a comprehensive literature search,
- (3) applying systematic data screening procedures, and
- (4) performing bibliometric and thematic analyses using VOSviewer and Bibliometrix tools.

Inclusion and Exclusion Criteria

To ensure a focused and rigorous review, inclusion and exclusion criteria were defined with respect to publication type, timeframe, database scope, and relevance to the research topic. The inclusion criteria comprised peer-reviewed journal articles published between January 1984 and July 2025 that explicitly addressed problem posing within mathematics education or closely related educational fields. Only studies indexed in the WoS core collection and available in full-text English were considered. Exclusion criteria involved conference proceedings, book chapters, theses, editorials, and other forms of grey literature, as well as studies in which problem posing was mentioned only peripherally or without a substantive analytical focus. Documents without accessible full texts were also excluded.

The decision to rely exclusively on the WoS database is grounded in its curated journal selection, citation tracking, and metadata standardization, which make it a widely accepted source for bibliometric research (Mongeon & Paul-Hus, 2016; Zupic & Čater, 2015). Restricting the corpus to WoS-indexed journal articles allows for a consistent and comparable representation of how knowledge on mathematical problem posing has been constructed, validated, and disseminated within high-impact academic outlets. Excluding non-journal literature further aligns with common practice in systematic reviews (Falagas et al., 2008) and enhances the internal consistency of the dataset.

Literature Search and Study Identification

The literature search was conducted in July 2025 using the WoS core collection. A topic search (TS) was

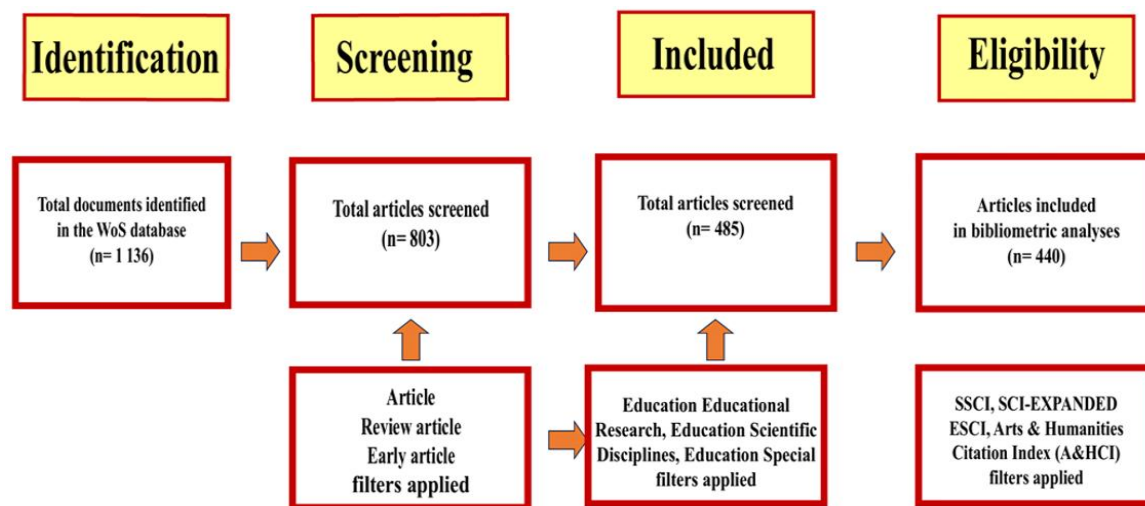


Figure 1. PRISMA flow diagram illustrating the article selection process (Source: Author's own elaboration, based on PRISMA)

performed using the following keyword string: TS = ("problem posing" OR "problem generation" OR "student-generated problems" OR "mathematical problem posing" OR "problem posing"). This search strategy was designed to capture both terminological variations and shifts in the conceptual framing of problem posing across different educational contexts and time periods. Although the term *problem generation* is used across multiple disciplines, subsequent category-based and content-based screening ensured that only studies situated within mathematics education and closely related educational fields were retained. The initial query returned to 1,136 records. After removing duplicates, the remaining studies were screened in two stages.

In the first stage, titles, abstracts, and keywords were examined for relevance to the research focus. In the second stage, the full texts of selected studies were assessed against the predefined inclusion criteria. Reference management and screening were conducted using Zotero software. Inclusion decisions were made independently by two researchers, and any disagreements were resolved through discussion until consensus was reached.

Data Screen

To ensure transparency and methodological rigor, the data screening process followed the PRISMA framework (Moher et al., 2009). In this study, PRISMA was employed as a structured protocol for identifying, screening, and refining the literature corpus prior to bibliometric analysis. A four-stage filtering procedure was applied to narrow the initial pool of publications to a dataset suitable for examining the development and structure of research on mathematical problem posing (see **Figure 1**).

In the *identification stage*, 1,136 records were retrieved from the WoS core collection using topic-based search

terms. During the *screening stage*, document-type filters (e.g., article, review article, and early access) were applied, resulting in 803 retained articles. In the *inclusion stage*, additional filtering restricted the sample to WoS subject categories directly related to education and learning sciences, including *education educational research*, *education scientific disciplines*, and *education special*, yielding 485 articles. Finally, in the *eligibility stage*, database indexing filters (SSCI, SCI-Expanded, ESCI, and A&HCI) were applied to ensure academic quality and relevance, resulting in a final dataset of 440 articles included in the bibliometric analysis.

During this process, bibliographic data (e.g., author names, publication year, institutional affiliations, countries, number of citations, keywords, and abstracts) were extracted. The dataset was formatted as plain text and imported into the Bibliometrix R-package interface (Biblioshiny) for analysis (Aria & Cuccurullo, 2017). All records were manually checked for inconsistencies and standardized to ensure accuracy and comparability across bibliometric indicators.

Data Analysis

The bibliometric analysis was conducted using the Bibliometrix R-package via the Biblioshiny interface, enabling a systematic examination of publication trends, conceptual structures, and collaboration patterns in problem posing research (Aria & Cuccurullo, 2017). The analysis incorporated both performance indicators and relational metrics.

Descriptive indicators, including annual publication output, number of sources, citation averages, and co-authorship patterns, were first calculated to provide an overview of the dataset (see **Table 1**) and to illustrate the dynamics of productivity and dissemination over time. Subsequently, several bibliometric techniques were applied. Keyword co-occurrence analysis was used to identify dominant themes and emerging research trends,

Table 1. Bibliometric summary of selected studies on problem posing (1984-2025)

Description	Results
Timespan	1984:2025 (July)
Sources	184
Documents	440
Annual average number of publications	10.73
Average citations per doc	14
Total references	13,809
Keywords plus (ID)	388
Author’s keywords (DE)	1,082
Authors	797
Co-authors per documents	2.41
International co-authorships (%)	15.68

co-citation analysis to reveal intellectual linkages and influential references, conceptual mapping (based on multiple correspondence analysis) to uncover thematic clusters, and collaboration network analysis to examine institutional and international research partnerships.

Thematic maps and strategic diagrams were generated to visualize the internal organization and longitudinal development of the field. In particular, theme positioning was interpreted using density and centrality measures to distinguish between core, emerging, and peripheral research themes. Within this framework, the development of knowledge in problem posing research was examined through shifts in thematic prominence, diversification of research foci, and increasing interdisciplinary orientations. The descriptive statistics of the reviewed corpus are summarized in **Table 1**, providing context for the subsequent presentation of thematic findings.

RESULTS

As a first step in examining the development of the field, the annual volume of publications on problem posing was analyzed. **Figure 2** presents the distribution of scientific output from 1984 to July 2025.

Between 1984 and 2000, publication activity remained limited, with most years yielding zero or one study. A gradual increase in output is observed after 2005, followed by a more pronounced rise after 2010. From 2018 onward, the number of publications increased substantially, reaching a peak of 63 articles in 2024. Overall, the data indicate a sustained upward trend in scholarly production on problem posing, particularly during the last decade.

As part of the bibliometric analysis, the 25 most globally cited documents related to problem posing were identified to examine the intellectual foundations of the field. **Table 2** presents these highly cited publications along with their citation counts.

An examination of these documents reveals that highly cited studies primarily address themes related to the cognitive aspects of problem posing, teacher education and pedagogical practices, student learning outcomes, creativity, and the development of conceptual or theoretical frameworks. Early influential works primarily focus on the cognitive processes involved in problem posing and their relationship with problem solving, while later highly cited studies increasingly emphasize teacher education, creativity, and instructional design. Collectively, the most cited publications reflect a concentration on understanding problem posing as a cognitive activity, a pedagogical

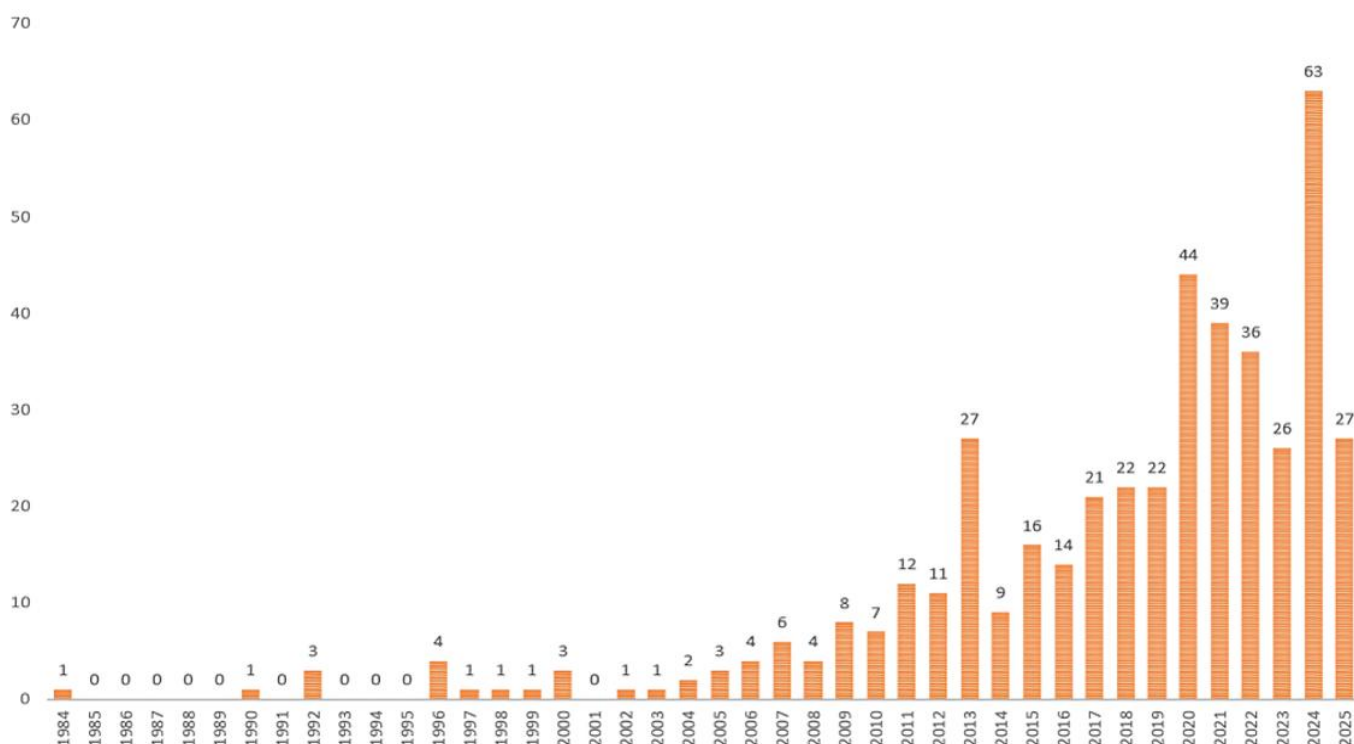


Figure 2. Annual scientific production (Source: Author’s own elaboration, based on Web of Science data using Bibliometrix)

Table 2. Most globally cited documents

Authors	DOI	R	Article
Silver and Cai (1996)	10.2307/749846	226	An analysis of arithmetic problem posing by middle school students
Chang et al. (2012)	10.1016/j.compedu.2011.10.002	156	Embedding game-based problem-solving phase into problem-posing system for mathematics learning
English (1998)	10.2307/749719	148	Children's problem posing within formal and informal contexts
Akom (2009)	10.1080/10665680802612519	136	Critical hip hop pedagogy as a form of liberatory praxis
Crespo and Sinclair (2008)	10.1007/s10857-008-9081-0	119	What makes a problem mathematically interesting? Inviting prospective teachers to pose better problems
Horn and Kane (2015)	10.1080/10508406.2015.1034865	111	Opportunities for professional learning in mathematics teacher workgroup conversations: Relationships to instructional expertise
Christou et al. (2005)	10.1007/s11858-005-0004-6	101	An empirical taxonomy of problem posing processes
Silver et al. (1996)	10.2307/749366	94	Posing mathematical problems: An exploratory study
Cognition and Technology Group at Vanderbilt (1992)	10.1007/BF02296707	91	The Jasper experiment: An exploration of issues in learning and instructional design
Toluk-Uçar (2009)	10.1016/j.tate.2008.08.003	84	Developing pre-service teachers understanding of fractions through problem posing
Cai et al. (2013)	10.1007/s10649-012-9429-3	82	Mathematical problem posing as a measure of curricular effect on students' learning
Singer et al. (2013)	10.1007/s10649-013-9478-2	79	Problem-posing research in mathematics education: New questions and directions
Cai and Hwang (2020)	10.1016/j.ijer.2019.01.001	73	Learning to teach through mathematical problem posing: Theoretical considerations, methodology, and directions for future research
Van Harpen and Sriraman (2013)	10.1007/s10649-012-9419-5	70	Creativity and mathematical problem posing: An analysis of high school students' mathematical problem posing in China and the USA
Koballa et al. (2000)	10.1080/095006900289967	70	Prospective gymnasium teachers' conceptions of chemistry learning and teaching
Lijnse (2004)	10.1080/09500690310001614753	69	Didactical structures as an outcome of research on teaching-learning sequences?
Ellerton (2013)	10.1007/s10649-012-9449-z	68	Engaging pre-service middle-school teacher-education students in mathematical problem posing: Development of an active learning framework
Bonotto (2013)	10.1007/s10649-012-9441-7	67	Artifacts as sources for problem-posing activities
Kontorovich et al. (2012)	10.1016/j.jmathb.2011.11.002	63	An exploratory framework for handling the complexity of mathematical problem posing in small groups
Voica et al. (2020)	10.1007/s10649-020-10005-0	56	How are motivation and self-efficacy interacting in problem-solving and problem-posing?
Cai and Leikin (2020)	10.1007/s10649-020-10008-x	56	Affect in mathematical problem posing: Conceptualization, advances, and future directions for research
Barlow and Cates (2020)	10.1007/s10649-020-10008-x	56	The impact of problem posing on elementary teachers' beliefs about mathematics and mathematics teaching
Bicer et al. (2020)	10.1007/s10649-020-09995-8	53	Considering mathematical creative self-efficacy with problem posing as a measure of mathematical creativity
Cai and Jiang (2017)	10.1007/s10763-016-9758-2	52	An analysis of problem-posing tasks in Chinese and US elementary mathematics textbooks
Singer and Voica (2013)	10.1007/s10649-012-9422-x	52	A problem-solving conceptual framework and its implications in designing problem-posing tasks

Note. R: Reference

practice, and a theoretical construct within mathematics education. These themes form the core intellectual references that have shaped subsequent research in the field.

Following the analysis of the most cited documents (see **Table 2**), a thematic network was generated to synthesize their conceptual focus and visualize relationships among key themes (**Figure 3**).

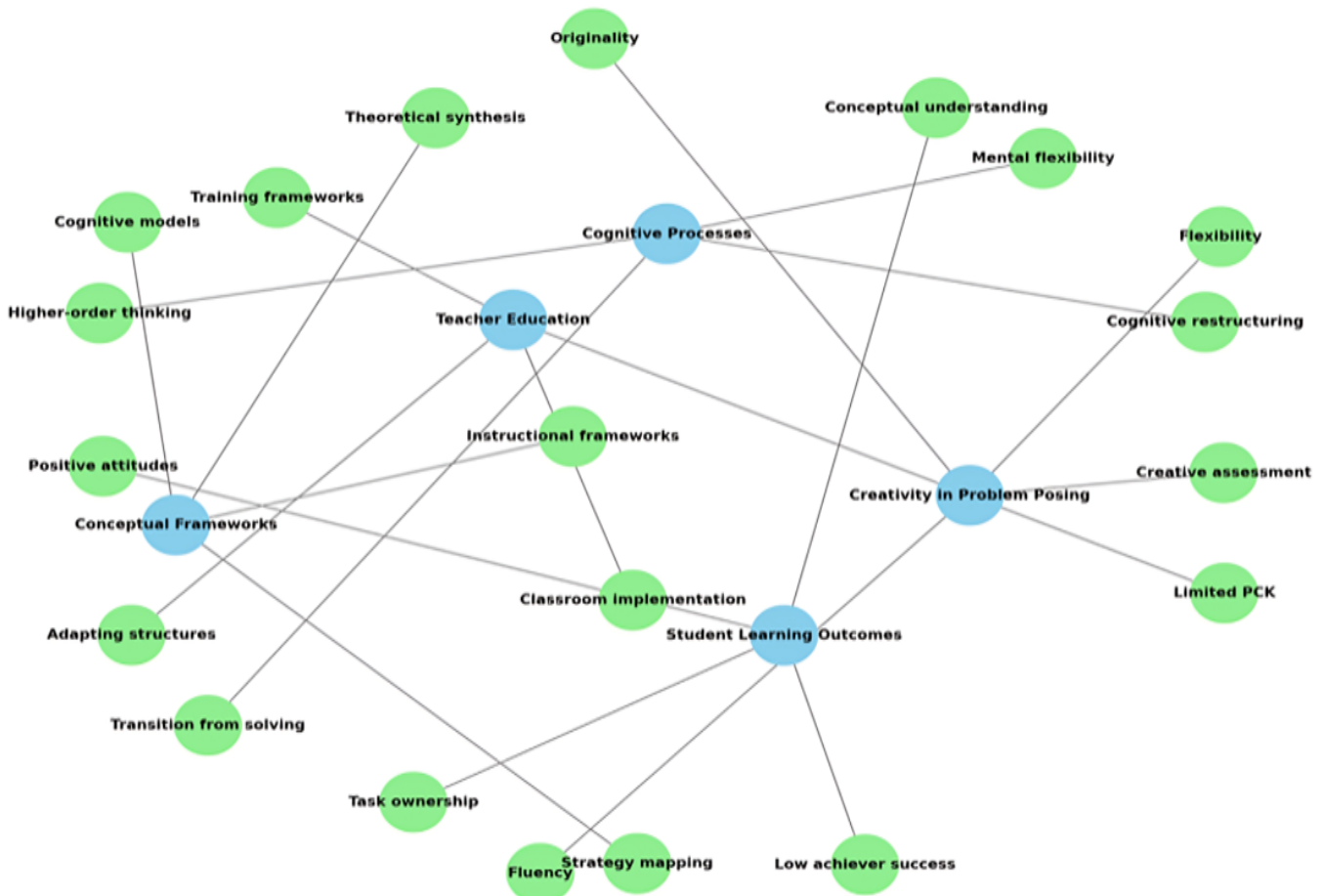


Figure 3. Thematic network of highly cited problem-posing studies (Source: Author’s own elaboration, based on Web of Science data)

As shown in **Figure 3**, five major thematic clusters are evident in the problem posing literature: cognitive processes, teacher education, student learning outcomes, creativity in problem posing, and conceptual frameworks. The network structure indicates that cognitive processes and teacher education occupy central positions, with multiple connections to other themes. Student learning outcomes and creativity-related themes are closely linked to classroom implementation and instructional practices, while conceptual frameworks connect theoretical models with pedagogical applications. Overall, the thematic network illustrates how research on problem posing is organized around interconnected cognitive, pedagogical, and theoretical dimensions, reflecting the multidimensional structure of the field.

To provide an overview of the conceptual landscape of problem posing research, the frequency distribution of author keywords was examined and is presented in **Figure 4**.

As shown in **Figure 4**, the most frequently occurring keywords include *teachers*, *students*, *knowledge*, *mathematics*, *education*, and *performance*. In addition, terms such as *creativity*, *thinking*, *skills*, *beliefs*, *achievement*, and *curriculum* appear with notable

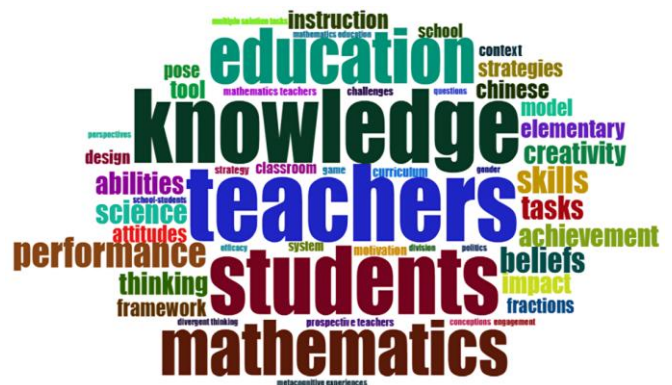


Figure 4. Keyword frequency word cloud in problem-posing studies (Source: Author’s own elaboration, based on Web of Science data using Bibliometrix)

frequency. Overall, the keyword frequency distribution indicates that research on problem posing spans a broad range of cognitive, pedagogical, and curricular topics, reflecting the diversity of concepts addressed in the literature.

To further examine the structural relationships among frequently occurring themes, a thematic mapping analysis was conducted, and the results are presented in **Figure 5**.

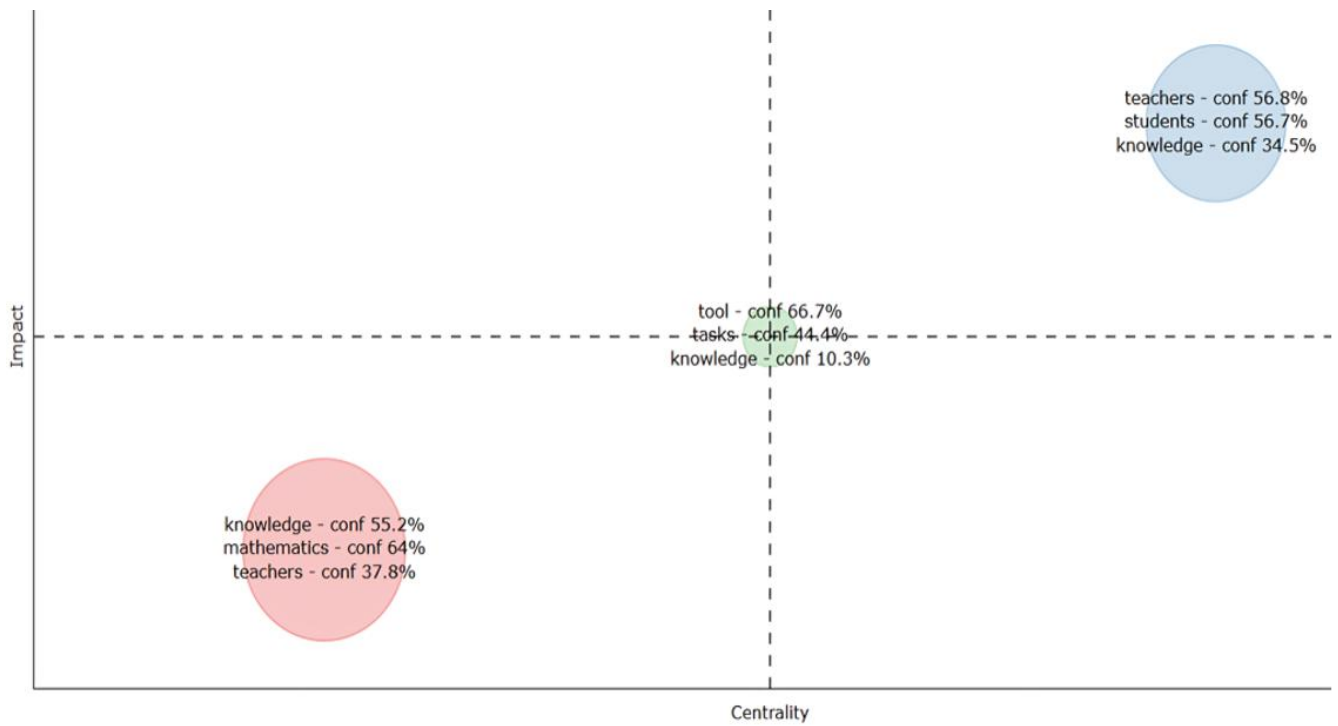


Figure 5. Thematic map of problem-posing research based on keyword centrality and density (Source: Author’s own elaboration, based on Web of Science data using Bibliometrix)

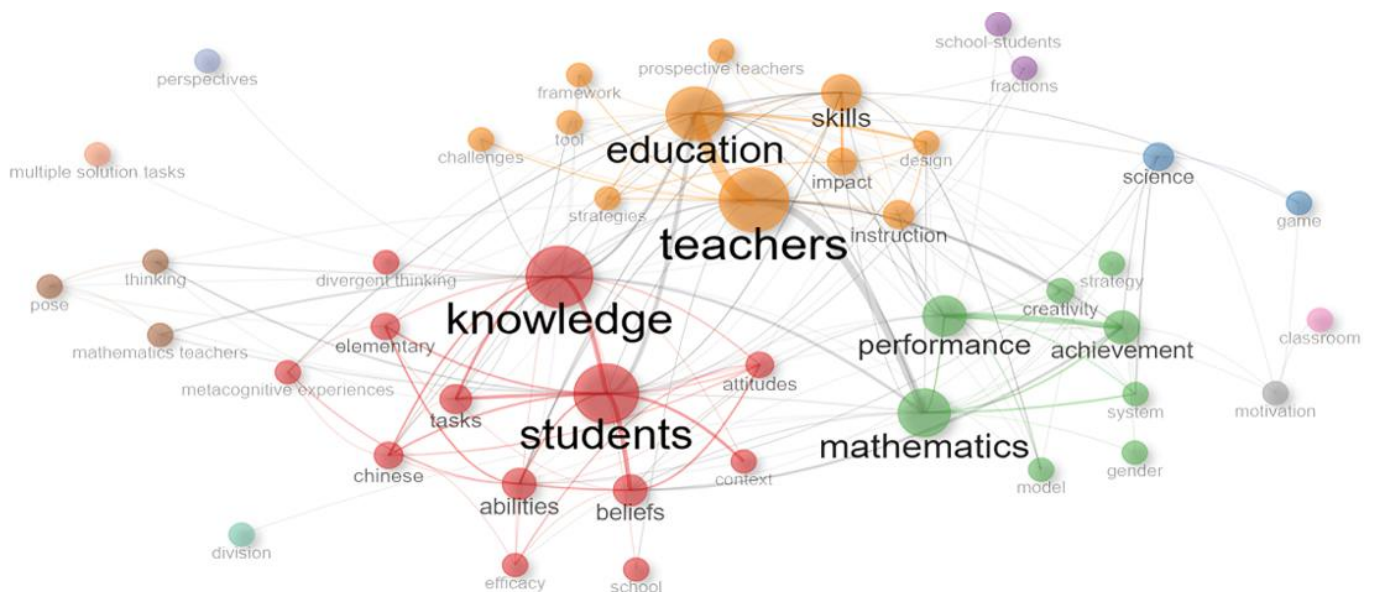


Figure 6. Keyword co-occurrence network in problem-posing research (Source: Author’s own elaboration, based on Web of Science data using Bibliometrix)

Figure 5 illustrates the thematic structure of problem posing research, organized by the centrality and density of key themes into four quadrants. Themes located in the upper-right quadrant exhibit both high centrality and high density, indicating well-developed and influential research areas. In contrast, themes in the lower-left quadrant display lower levels of development and peripheral positioning. The map shows a cluster containing *teachers*, *students*, and *knowledge* positioned in the upper-right quadrant, reflecting themes with strong internal cohesion and high relevance within the literature.

A separate cluster, including *knowledge*, *mathematics*, and *teachers*, appears in a lower-centrality region, while another cluster, composed of *tools*, *tasks*, and *knowledge*, is positioned closer to the central boundary of the map. These configurations illustrate how frequently used themes are distributed across different levels of development and centrality within the field.

To further examine the conceptual structure of problem posing research, a co-occurrence analysis of author keywords was conducted, and the results are presented in Figure 6.

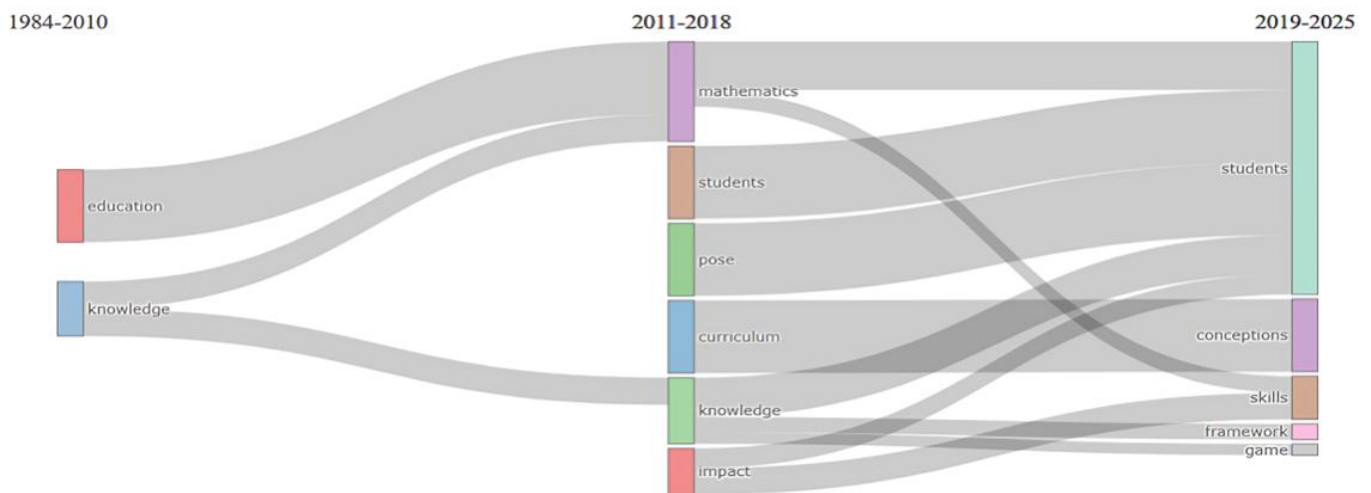


Figure 7. Thematic evolution of problem-posing research based on author keywords (Source: Author's own elaboration, based on Web of Science data using Bibliometrix)

Figure 6 illustrates the keyword co-occurrence network, where node size represents the frequency of each keyword and link thickness indicates the strength of co-occurrence relationships. Frequently used keywords such as *teachers*, *students*, *knowledge*, *education*, *performance*, and *mathematics* occupy central positions within the network.

Several clusters are evident. One cluster is centered on student-related themes, including *students*, *tasks*, *attitudes*, and *beliefs*. Another cluster focuses on teacher education and instructional design, featuring keywords such as *teachers*, *education*, *skills*, and *framework*. A further cluster includes performance- and outcome-related terms such as *performance*, *achievement*, and *creativity*, while additional smaller clusters represent more peripheral or contextual topics. Overall, the network illustrates the clustering and interconnections among frequently used keywords in the problem posing literature. To examine changes in thematic emphasis over time in the problem posing literature, a longitudinal keyword analysis was conducted, and the results are presented in **Figure 7**.

Figure 7 illustrates the evolution of keywords across three time periods: 1984-2010, 2011-2018, and 2019-2025. During the 1984-2010 period, the most prominent themes were *education* and *knowledge*. In the subsequent period (2011-2018), these broad themes give rise to more specific keywords, including *mathematics*, *students*, *pose*, *curriculum*, and *impact*. In the most recent period (2019-2025), the theme of *students* remains central, while additional keywords such as *conceptions*, *skills*, *framework*, and *game* appear. Overall, the thematic evolution map illustrates both continuity and diversification in the keywords employed in problem posing research over time.

To visualize international research partnerships in the field of problem posing, a country-level collaboration network was generated and is presented in **Figure 8**. The

network is based on co-authorship relationships derived from publications indexed between 1984 and 2025. Node size represents the total publication output of each country, while link thickness indicates the volume of collaborative publications between countries.

As shown in **Figure 8**, the USA and China occupy central positions within the collaboration network, displaying extensive co-authorship links with multiple countries. Strong collaborative connections are observed between the USA and countries such as China, Canada, Australia, and the UK. In addition, several countries form more regionally clustered patterns of collaboration. For example, Türkiye, Iran, Egypt, and Bahrain are connected primarily within a regional cluster, with fewer links to the central nodes of the network. Overall, the collaboration map illustrates both highly connected international hubs and more localized patterns of research collaboration within the problem posing literature.

To visualize institutional-level academic partnerships in the field of problem posing, a university collaboration network was generated and is presented in **Figure 9**. The network is based on inter-institutional co-authorships derived from publications indexed between 1984 and 2025. Node size represents each university's publication output, while link thickness indicates the extent of joint research activity.

As shown in **Figure 9**, the University of Delaware occupies a central position in the institutional collaboration network, displaying multiple co-authorship links with universities in different regions, including Beijing Normal University, Southwest University (China), and the University of Münster. In addition to this central node, several clusters of institutional collaboration are visible. These include networks among USA-based institutions, an internal collaboration structure within Kent State University campuses, a bilateral partnership between the

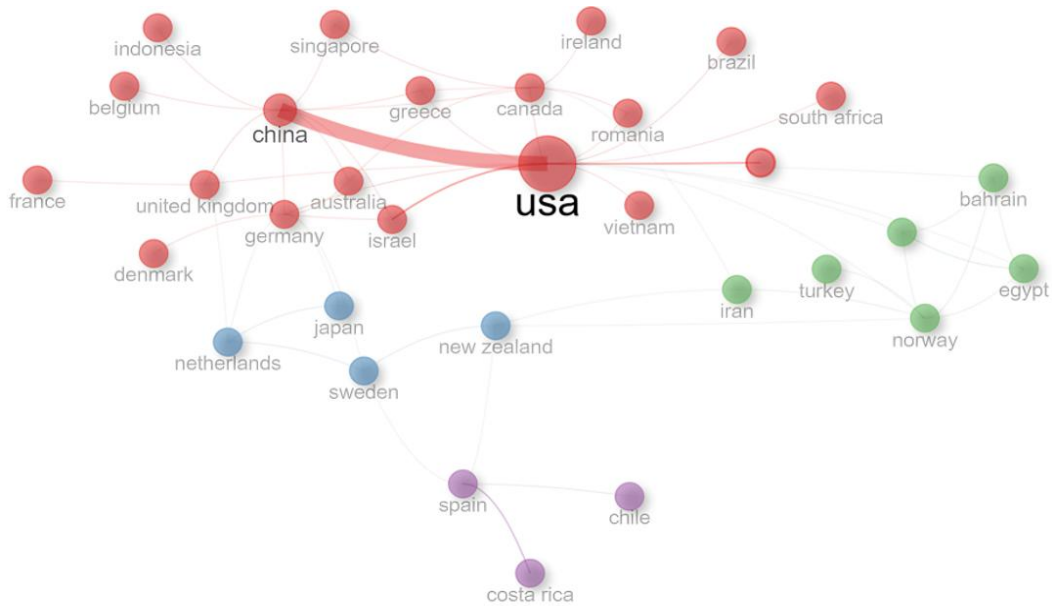


Figure 8. Country-level collaboration network in problem-posing research (Source: Author’s own elaboration, based on Web of Science data using Bibliometrix)

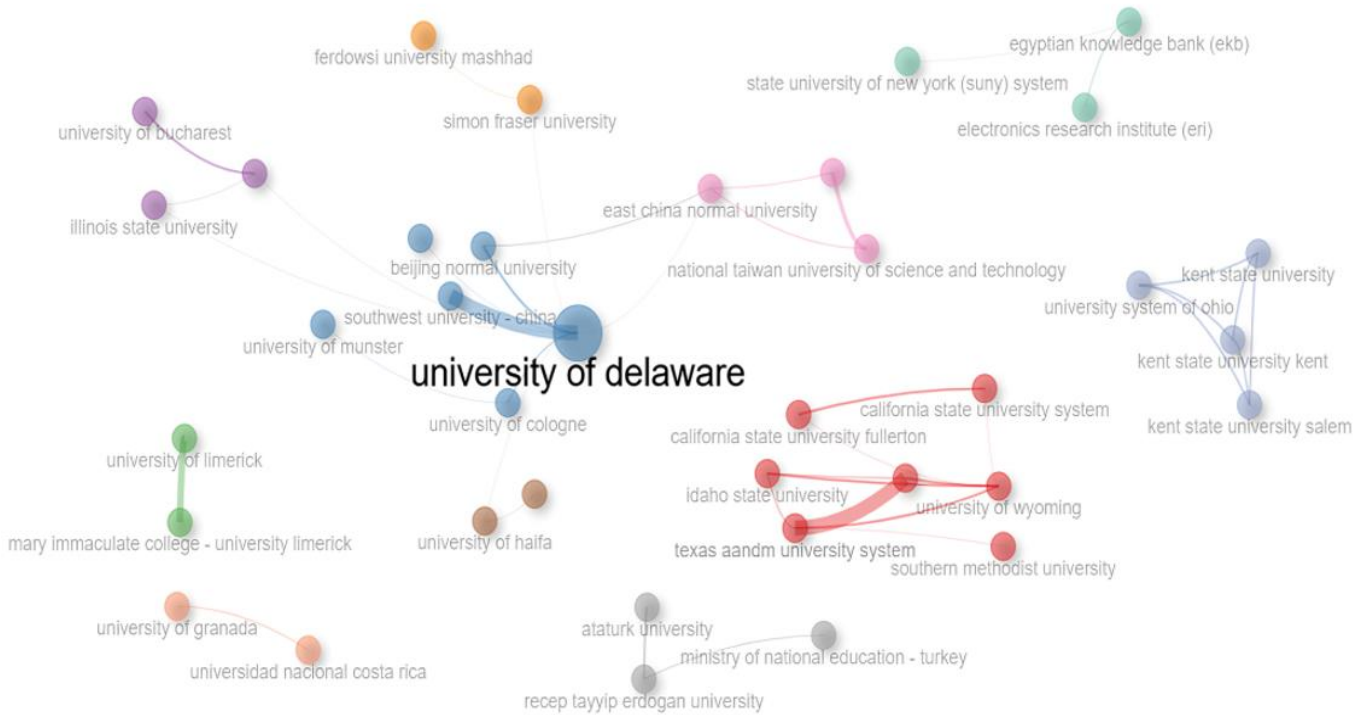


Figure 9. Institutional collaboration network in problem-posing research (Source: Author’s own elaboration, based on Web of Science data using Bibliometrix)

University of Limerick and Mary Immaculate College, and collaborative links among East Asian universities such as East China Normal University and the National Taiwan University of Science and Technology.

To examine the global distribution of research collaborations in problem posing studies, a country-level analysis of collaborations was conducted, and the results are presented in **Figure 10**. The map visualizes international co-authorship relationships based on publications indexed between 1984 and 2025.

As shown in **Figure 10**, several bilateral collaborations are evident within the global network. Notable partnerships include collaborations between the USA and China, the USA, and Israel, Spain, and Costa Rica, China, and the UK, and Egypt and Saudi Arabia. Overall, more than 40 countries contribute to the problem posing literature, although the extent and intensity of collaboration vary considerably across regions.

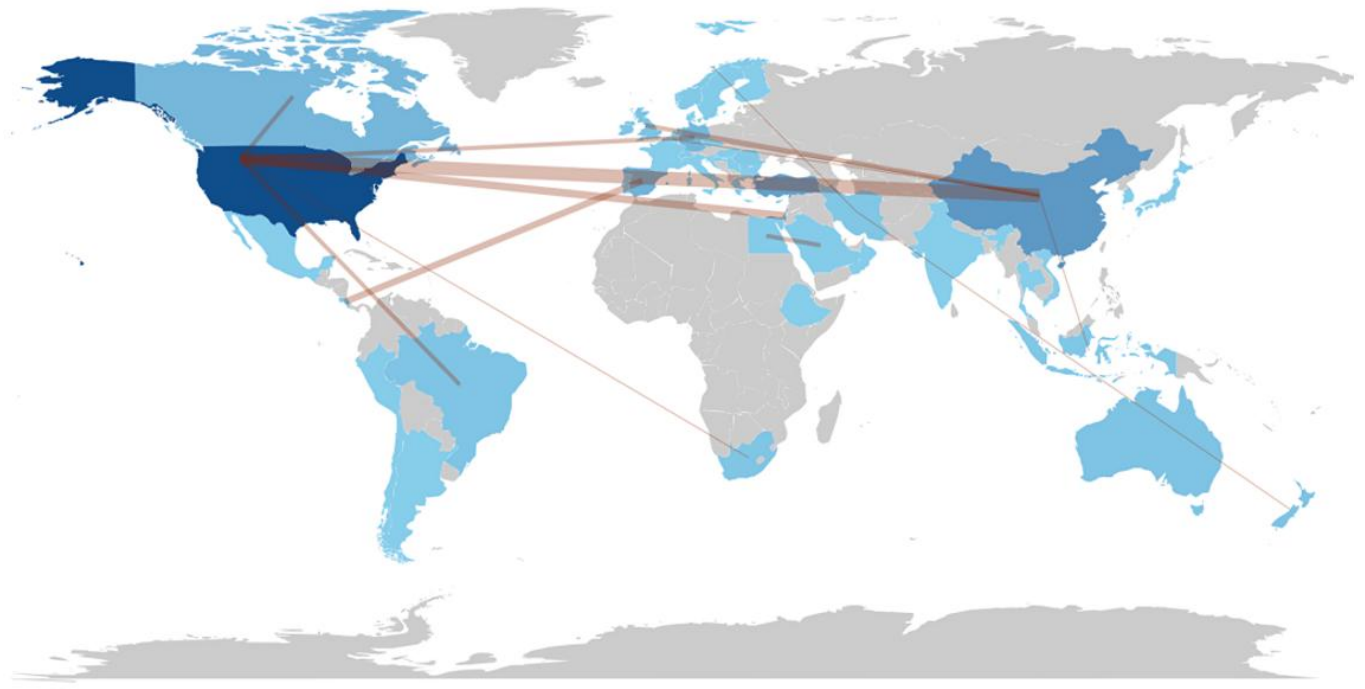


Figure 10. Global map of country-level research collaborations in problem-posing studies (Source: Author's own elaboration, based on Web of Science data using Bibliometrix)

DISCUSSION

The results of this study provide a systematic overview of how research on mathematical problem posing has developed over time in terms of productivity, thematic focus, and collaboration patterns. The bibliometric evidence indicates not only a substantial increase in scholarly attention but also a gradual diversification and structuring of research themes across different periods. Rather than indicating isolated trends, the identified patterns suggest a broader transformation in how problem posing is conceptualized, studied, and situated within the field of mathematics education research. In the following sections, these findings are examined in greater detail by first discussing the empirical patterns revealed through bibliometric analyses, then interpreting these patterns through relevant theoretical perspectives, and finally considering their implications for instructional practice, teacher education, and future research.

Empirical Insights

Building on the bibliometric patterns identified in the Results section, this study provides empirical evidence of how research on mathematical problem posing has evolved in scope and thematic orientation. The sustained increase in publication volume after 2010, and more prominently after 2018, indicates that problem posing has shifted from a relatively specialized topic to a more established area within mathematics education research. This growth reflects both increased scholarly attention and a widening of research agendas across different educational contexts.

Thematic analyses reveal a clear transformation in the conceptual focus of problem posing research. Early studies predominantly emphasized broad constructs, such as education and knowledge, often foregrounding individual cognitive engagement and the relationship between problem posing and problem-solving. In more recent work, these emphases have given way to more differentiated themes related to students, curriculum, instructional frameworks, skills, and learning outcomes. This pattern suggests a movement toward understanding problem posing as a pedagogically situated practice shaped by instructional design and curricular considerations.

Highly cited publications and keyword networks further point to sustained attention to higher-order learning processes, including abstraction, transformation, reflection, and metacognitive regulation. These empirical patterns are consistent with findings from intervention and meta-analytic studies reporting associations between structured problem posing activities and outcomes such as mathematical performance, self-efficacy, and learner engagement, while also highlighting variation linked to task design, levels of guidance, and instructional context (Christou et al., 2005; Wang et al., 2022; Zhang et al., 2024b).

Recent empirical work also shows increasing attention to instructional design and support mechanisms in problem posing activities. The emergence of keywords such as framework, skills, tools, and game reflects growing interest in how problem posing is structured and scaffolded in practice. This shift is consistent with recent syntheses emphasizing the role of task variables, particularly problem situations and

prompts, in shaping problem posing products and processes across individual, group, and classroom settings (Cai et al., 2024). Studies focusing on design-sensitive approaches report more consistent outcomes than minimally guided implementations, underscoring the role of intentional task design in shaping empirical findings (Krawitz et al., 2025; Walkington et al., 2024). Technology-related themes appear within this context as developing lines of inquiry, often examined in relation to interaction, feedback, and collaborative learning environments rather than as standalone research foci (Hwang et al., 2025). This pattern is consistent with systematic evidence indicating that problem posing interventions incorporating explicit scaffolding, task structuring, and interactive support tend to produce more stable outcomes than minimally guided approaches (Zhang et al., 2025b).

Theoretical Insights

The bibliometric patterns identified in this study can be interpreted through theoretical perspectives that conceptualize problem posing as a multidimensional pedagogical practice rather than a discrete instructional technique. The prominence of themes such as teachers, students, and knowledge across thematic maps suggests that problem posing is increasingly framed as an activity embedded within instructional relationships. This orientation aligns with constructivist views of learning, which emphasize meaning-making through engagement, interaction, and the transformation of mathematical ideas (Ghasempour & Baker, 2012).

From this perspective, problem posing is commonly understood as a generative process involving multiple cognitive and metacognitive phases. Christou et al. (2005) describe this process through stages, including understanding, transformation, organization, and formulation, highlighting its recursive nature. The continued visibility of cognitive constructs such as abstraction and transformation in highly cited publications indicates that these process-oriented models remain influential, while being increasingly situated within pedagogically structured learning environments.

Recent theorizing emphasizes that problem posing tasks are constituted by problem situations and prompts, and that variations in these task variables shape both products and processes (Cai et al., 2024). Complementary theoretical work has highlighted the affective and creative dimensions of problem posing. Bibliometric evidence indicating an increased attention to beliefs, attitudes, and engagement aligns with frameworks that integrate cognitive and affective processes. Cai and Leikin (2020) emphasize the interaction between emotion, motivation, and reasoning in problem posing, while creativity is commonly operationalized through fluency, flexibility, and originality (Bicer et al., 2020; Elgrably & Leikin, 2021).

This multidimensional framing is further illustrated in studies that integrate problem posing with proof-related reasoning and creativity in teacher education contexts, demonstrating how these creative dimensions can be systematically supported through structured investigative tasks (Leikin & Elgrably, 2020). Together, these perspectives position creativity as a context-dependent capacity shaped by task design and instructional support.

The emergence of themes related to frameworks and conceptions further reflects growing theoretical interest in structuring problem posing practices, particularly in teacher education. Models emphasizing guided reflection and pedagogical judgment position problem posing as a teachable and assessable component of instruction (Cai & Hwang, 2020), while context-sensitive approaches highlight the role of epistemological assumptions and instructional norms across educational settings (Papadopoulos et al., 2022; Possamai & Allevato, 2024). Within this landscape, AI-supported environments emerge as potential pedagogical mediators that can facilitate feedback and scaffolding when integrated into established instructional frameworks (Serin & Kepceoglu, 2025).

Practical Implications

The findings of this study suggest several implications for instructional design, teacher education, and the integration of digital tools in mathematics education. The centrality of themes related to teachers, students, and knowledge suggests that problem posing is primarily situated within pedagogical decision-making processes, rather than being treated as an isolated classroom activity. This emphasis aligns with research highlighting the role of structured frameworks in supporting teachers' analysis, selection, and design of problem posing tasks aligned with curricular goals and students' thinking (Leavy & Hourigan, 2022).

From a teacher education perspective, the bibliometric patterns underscore the importance of scaffolded and design-sensitive approaches to problem posing. Prior research indicates that interventions incorporating explicit guidance and reflective criteria tend to produce more consistent learning outcomes than minimally guided implementations, particularly in preservice teacher contexts (Zhang et al., 2024a). These findings underscore the importance of integrating problem posing into teacher education through structured models that support pedagogical judgment and task quality. Evidence from recent systematic reviews further suggests that effective problem posing interventions typically combine structured task design, guided support, and opportunities for interaction, while also highlighting ongoing challenges in measuring affective and process-related outcomes (Zhang et al., 2025a).

The emergence of technology-related themes in recent studies further underscores the growing interest in digitally mediated problem posing environments. Research on interactive and technology-supported learning contexts suggests that digital tools can facilitate feedback, collaboration, and iterative refinement when embedded within coherent instructional designs (Hwang et al., 2025; Walkington et al., 2024). Emerging work on generative AI similarly conceptualizes AI-supported environments as resources for pedagogical reflection and adaptation in problem posing, particularly in teacher education settings (Kim et al., 2025; Serin & Kepceoglu, 2025).

Patterns of international and institutional collaboration also highlight the value of cross-contextual exchange in the development of problem posing practices. Expanding collaboration across educational systems may contribute to refining context-sensitive instructional approaches that account for differences in curriculum structures, pedagogical traditions, and access to technology (Cai & Hwang, 2020). These implications point toward future research and practice that foreground instructional design, teacher learning, and mediated environments within theoretically grounded frameworks.

CONCLUSION

This study provides a comprehensive overview of research on mathematical problem posing by examining its conceptual foundations, thematic structures, and development over time through bibliometric and thematic analyses. The findings suggest that problem posing extends beyond a single instructional technique and functions as a multidimensional pedagogical practice, encompassing cognitive, metacognitive, creative, and instructional components. By tracing long-term publication trends and thematic evolution, the study demonstrates how problem posing has become an increasingly structured and theoretically grounded area within the field of mathematics education research.

By synthesizing fragmented research into a coherent thematic structure, this study highlights the central roles of students, teachers, and knowledge in shaping problem posing practices. The results further show that recent research places growing emphasis on instructional frameworks, task design, and mediated learning environments, reflecting a shift toward more intentional and application-oriented approaches. In this respect, the study provides a conceptual framework for researchers and educators seeking to situate problem posing within broader discussions of curriculum, pedagogy, and teacher education.

Based on the identified bibliometric patterns, several directions for future research can be outlined. First, future studies may further investigate the interaction between metacognitive regulation and creative

processes in problem posing by combining product- and process-oriented assessment approaches. Second, research in teacher education contexts may benefit from examining how structured instructional frameworks support the design, implementation, and evaluation of problem posing tasks aligned with curricular goals and students' thinking. Third, comparative and cross-cultural studies could explore how curricular structures, pedagogical traditions, and cultural contexts shape problem posing practices across educational systems. Finally, growing interest in digitally mediated environments suggests the need for research examining how digital and AI-supported tools can support feedback, scaffolding, and reflective engagement in problem posing when integrated within coherent instructional designs.

Limitations and Future Directions

This study is limited by its reliance on peer-reviewed journal articles indexed in a single database, which excludes grey literature and may underrepresent classroom-based qualitative research. Additionally, bibliometric indicators are less sensitive to micro-level learning processes and recent innovations that have not yet garnered citations. Future research should therefore adopt longitudinal and context-sensitive designs to examine how problem posing develops across age groups, instructional settings, and cultural contexts. Prior research indicates that the effectiveness of problem posing interventions varies according to learner characteristics, task structure, and instructional duration (Wang et al., 2022; Zhang et al., 2024b). Further studies should focus on designing structured supports that address both cognitive and affective dimensions of learning, particularly in teacher education contexts (Baumanns & Rott, 2024; Cai & Hwang, 2020). Expanding cross-cultural and interdisciplinary collaboration will also be essential for developing more inclusive and theoretically grounded models of problem posing in mathematics education.

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