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Tendencies in the Trends of Mathematics Teacher Knowledge: A Bibliometric Analysis

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Abstract. Despite growing scholarly interest in mathematics teacher knowledge over the past 25 years, no comprehensive systematic mapping has been conducted to examine its conceptual evolution, thematic structure, and developmental trajectory. This study aims to map publication trends; identify high impact works; uncover thematic associations and conceptual co-occurrences; trace the temporal evolution of dominant topics; and classify research themes by their developmental trajectory, distinguishing motor, basic, niche, and declining themes in mathematics teacher knowledge research. A total of 550 Scopus-indexed articles published between 1 January 2000, and 31 December 2025 were analysed using the bibliometrix R package, covering performance analysis, science mapping, and keyword co-occurrence network analysis. The results show a steady increase in publications, with a sharp rise after 2018 and a peak around 2025. Citation impact was highest during the formative period of 2005–2010, reflecting the field's consolidation around foundational frameworks of mathematical knowledge for teaching. Mathematical content knowledge, PCK, and MKT consistently constitute the field's conceptual core, with mathematical content knowledge serving as the central connecting node across all thematic clusters. Topic trends analysis reveals a clear trajectory from broad theoretical frameworks toward more specialised, practice-oriented, and technology-integrated topics from 2020 onward. Strategic diagram analysis classifies teaching quality and initial teacher education as current motor themes, indicating that the field has matured from defining teacher knowledge to operationalising it in classroom practice. Future research should prioritise cross-database validation and geographic network analysis and should examine how the depth of mathematical content knowledge conditions the development of technology-integrated teaching competencies such as TPACK.

Keywords: bibliometric analysis; bibliometrix R package; research trends; mathematics teacher knowledge; tendencies.

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1. Introduction

Mathematics teacher knowledge occupies a central position in mathematics education research, with decades of scholarship showing that what teachers know, and how they understand it, directly shapes instructional quality and student learning outcomes (Copur-Gencturk & Doleck, 2021; Mohr-Schroeder et al., 2017; Yang et al., 2021). Its theoretical foundations trace to Shulman's (1987) influential distinction between Content Knowledge (CK), Pedagogical Content Knowledge (PCK), and General Pedagogical Knowledge (GPK), a typology that foregrounded the idea that teaching demands a qualitatively distinct form of subject-matter understanding. While serving as a foundation for subsequent large-scale studies of teacher competence(König et al., 2014), Shulman's framework has been critiqued for its relatively static view of teacher knowledge, as it does not fully capture the dynamic and context-dependent nature of classroom practice (Hwang & Cho, 2021).

In response, mathematics education researchers have developed more specialised frameworks: Ball et al.'s (2008) Mathematical Knowledge for Teaching (MKT), which distinguishes common from specialised content knowledge; Rowland et al.'s (2005) Knowledge Quartet; Carrillo-Yañez et al.'s (2018) Mathematics Teacher's Specialised Knowledge (MTSK) model; and Davis & Simmt's (2006) collective and emergent conception of teachers' mathematics for teaching. Together, these frameworks reflect a field undergoing continuous theoretical development, with its conceptual boundaries and empirical priorities evolving substantially over time.

Despite this theoretical richness, existing reviews of the mathematics teacher knowledge literature remain relatively narrow in scope. Published syntheses have focused on specific sub-domains such as PCK development (Asvat, 2024; Grigaliūnienė, Lehtinen, et al., 2025; Kholid et al., 2023) and TPACK integration (Handayani, Hussin, & Helmi, 2023; Zou et al., 2022). offering valuable but partial perspectives. To date, no study has undertaken a longitudinal, field-wide mapping of how research themes have emerged, evolved, consolidated, or declined across the 25-year development of this literature. This gap limits a comprehensive understanding of the field's intellectual trajectory, including where it has come from and the directions in which it is likely to develop.

Bibliometric analysis is well positioned to address this gap unlike narrative reviews, it enables systematic, replicable mapping of publication patterns, citation impact, thematic co-occurrences, and the structural evolution of research clusters at scale (Dede & Ozdemir, 2022; Donthu et al., 2021; Wirzal et al., 2022). To address this gap, the present study poses the following research questions:
RQ1: What has been the trend in publications on mathematics teacher knowledge from 2000 to 2025?
RQ2: Which years and papers had the highest citation rates in research on mathematics teacher knowledge from 2000 to 2025?
RQ3: What have been the major topics in research on mathematics teacher knowledge from 2000 to 2025, and what are the most common associations among them?

RQ4: How have topic trends in mathematics content knowledge research developed from 2000 to 2025?
RQ5: What is the motor, basic, declining, and niche themes of mathematics teacher knowledge research?

2. Literature Review

Mathematics teacher knowledge has evolved into a prominent and increasingly important area of research within mathematics education(Ponte & Chapman, 2016). It plays a central role in mathematics education (Even & Ball, 2010; Fennema & Franke, 2006), attention to what characterizes this knowledge as "specialized" has also intensified. A defining characteristic of mathematics teacher knowledge is that it extends beyond mere mastery of mathematical content.

Bromme (1994) observed that school subjects carry "a life of their own," operating according to a logic that does not always align with academic disciplines, an insight implying that school mathematics must be understood on its own terms rather than merely as a simplified version of university mathematics. Buchholtz et al. (2013) This distinction was formalised through a bridging form of knowledge that connects school mathematics with advanced mathematics, drawing on Klein's notion of elementary mathematics from an advanced standpoint." Together, these perspectives establish that mathematics teacher knowledge is neither static nor unidirectional: it is cumulative, context-dependent, and continuously reconstructed throughout professional practice.

Building on this premise, scholars have conceptualised mathematics teacher knowledge as a multidimensional construct that encompasses at least three complementary aspects (Scheiner et al., 2019). First, teachers need knowledge beyond the content itself, which is demonstrated by anticipating students' misconceptions when teaching systems of linear equations (Marhami et al., 2026). Second, teachers must understand this content in qualitatively different ways, applying specialized content knowledge (SCK) to analyse student errors, interpret their mathematical reasoning, and recognise the approaches they use during instruction (özdemir et al., 2022).

Moreover, third, they must present material accessibly, transforming it through representations and explanations aligned with learning goals that are consistent with ambitious, discourse-rich teaching and the use of scaffolding for diverse learners (Dogbey, 2025; Johnson & Roy, 2026; Zahner et al., 2025). In practice, this means that a mathematics teacher must be able to judge the validity of a non-standard student algorithm, diagnose the reasoning underlying unfamiliar errors, and select representations that support conceptual understanding tasks that extend well beyond the demands of mathematical expertise alone (Lynch et al., 2025; Özdemir et al., 2022).

Empirical research has consistently substantiated the value of more specialised conceptions of mathematics teacher knowledge. Baumert et al. (2010) and Blömeke et al. (2014) demonstrated that teachers' mathematical knowledge predicts instructional quality and student outcomes in ways that general content knowledge does not, establishing that what teachers know mathematically translates measurably into classroom effectiveness. Building on this, Ijeh et al. (2025) found that stronger mathematical knowledge for teaching significantly influenced student achievement, retention, and attitude toward mathematics, while Sakaria et al. (2023) confirmed that such knowledge develops collectively through professional learning communities. These findings support a range of theoretical frameworks that, although developed in response to different research objectives, share a cumulative and hierarchical conceptual structure.

CK serves as the irreducible base upon which Shulman's (1987) PCK elaborates the transformation of content into pedagogically accessible forms; Ball et al. (2008) MKT operationalises PCK into measurable sub-domains for mathematics teaching (Hill et al., 2005; Kersting et al., 2012); Carrillo-Yañez et al.'s (2018) The MTSK framework integrates mathematical and pedagogical knowledge as inseparable domains, while uniquely positioning teachers' beliefs as a constitutive component of professional knowledge rather than a peripheral influence(Escudero-Ávila et al., 2021); and Koehler & Mishra's (2005) TPACK extends all prior frameworks by adding a technological dimension whose relevance has intensified in the post-pandemic context (Akpalu et al., 2025; Pérez Echeverría et al., 2025). Nevertheless, several dimensions remain underexamined, particularly the specialized knowledge deployed in instructional settings, such as evaluating alternative solution strategies (Eaves et al., 2025; Grigaliūnienė, Rutkienė, et al., 2025; Lee, 2017; Novikasari, 2023).

3. Methodology

This study adopts a bibliometric approach, a systematic and transparent method for mapping and analysing the scholarly literature within a research field(Batanero et al., 2019; Hallinger & Kovačević, 2021; Hudha et al., 2020). The method is well-suited to uncovering trends in article and journal performance, collaboration patterns, and research community characteristics, typically through three components: performance evaluation, indicators of scholarly behavior, and network visualization (Dede & Ozdemir, 2022; Donthu et al., 2021; Utami et al., 2024; Wirzal et al., 2022). The analysis was conducted in three sequential stages: data collection, screening, and analysis, all of which were guided by the PRISMA protocol (Page et al., 2021) to ensure transparency and reproducibility, the study followed procedures consistent with established bibliometric research practices (Pham et al., 2023; Wei et al., 2022).

3.1 Data Collection

A bibliometric analysis was conducted to examine research trends and thematic developments related to mathematics teacher knowledge. Since the validity of bibliometric findings depends strongly on the quality and coverage of the bibliographic data, Scopus was selected as the sole data source. While both Scopus and Web of Science are widely recognized as premier scholarly databases (Chadegani et al., 2013; Mongeon & Paul-Hus, 2016) within the social sciences, including mathematics education, Scopus provides a greater number of documents compared to Web of Science under identical search conditions (Martín-Martín et al., 2021; Narong & Hallinger, 2024; Nguyen et al., 2022). Scopus

is highly compatible with widely used bibliometric software, including Biblioshiny, Gephi, and VOSviewer, making it a suitable source for comprehensive bibliometric analysis (Tomaszewski, 2023).
The search was conducted on 4 April 2026 using the query TITLE-ABS-KEY("mathematics teacher knowledge"), which was applied to the titles, abstracts, and keywords of records indexed in Scopus. This umbrella phrase was selected as the most representative term encompassing the breadth of the field while maintaining conceptual precision. The search results were subsequently refined using Scopus's built-in filters for subject area, document type, source type, and language to ensure the relevance and quality of the dataset (Narayanan et al., 2025), as shown in Table 1.

Table 1: Inclusion and exclusion criteria

	Inclusion Criteria	Exclusion Criteria
Subject area	Social science and mathematics	Other subject area
Document type	Articles	Conference paper, book chapter,
Source type	Journal	Conference proceedings, books, book series, trade journals, and undefined
Language	English	Languages other than English

3.2 Data Screening
The screening process followed the PRISMA flow diagram presented in Figure 1. The initial search yielded 10,001 records, which were subsequently exported in BibTeX format for further analysis. During the first screening stage, 4,468 records were excluded for not meeting the inclusion criteria in Table 1, leaving 5,533 records for eligibility assessment. In the eligibility phase, each remaining record was evaluated against three criteria: (1) alignment with the research scope, (2) conceptual relevance to mathematics teacher knowledge, assessed through examination of titles, abstracts, and full texts, and (3) exclusion of records outside the defined scope or publication timeframe.

To ensure the reliability of these judgements, a two-stage review process was employed, whereby each document was independently examined twice by the authors. Consequently, formal inter-rater reliability was not calculated. Discrepancies between the two review stages were resolved through re-examination and discussion until consensus was reached. This stage removed a further 4,983 records, yielding a final dataset of 550 articles for bibliometric analysis.

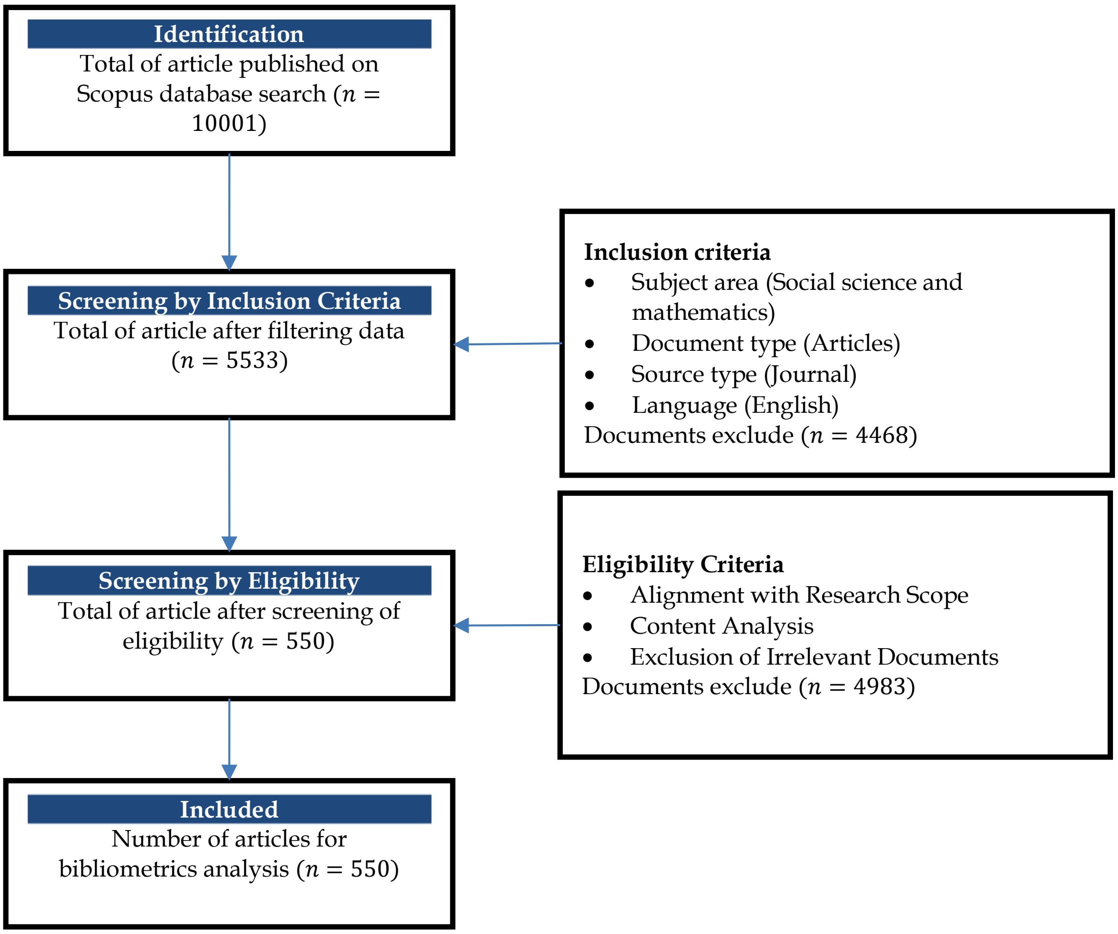

Figure 1: Results of Article Search Using PRISMA

Prior to analysis, the dataset was normalised to improve consistency and accuracy. Only author-supplied keywords were retained for the co-occurrence and thematic analyses, whereas Keywords Plus terms were excluded because they are algorithmically generated and may not accurately reflect the conceptual focus of individual articles. Conceptually equivalent terms (e.g., "PCK" and "pedagogical content knowledge") were merged into single keyword strings so that co-occurrence patterns reflected genuine conceptual relationships. Duplicate records were removed during the Scopus export process and subsequently verified using the bibliometrix deduplication function, which identified no additional duplicates in the dataset.

3.3 Data Analysis

This study employed three types of bibliometric analyses to address the research questions: network analysis, science mapping, and performance analysis. Performance analysis assessed the prominence of research topics over time by examining citation counts and publication counts. Science mapping was employed to identify the most prominent research themes in the dataset using a tree map and to examine their evolution over time with trend-topic plots. Network analysis involved constructing a keyword co-occurrence network to explore interconnections among keywords within individual documents; the resulting clusters highlighted central research themes. Furthermore, a strategic diagram, another science mapping technique, was constructed to distinguish between basic, emerging, declining, niche, and motor themes based on two dimensions: centrality, which reflects the strength of connections between a keyword cluster and other clusters, and density, which indicates the internal cohesion of the keywords within a cluster) (Yu et al., 2021). All analyses were performed using the Bibliometrix package in RStudio (version 4.2.3). It was used for its flexibility, scalability, and compatibility with various statistical R packages, making it particularly effective for science mapping, especially in fields characterized by extensive, fragmented, and sometimes contested bodies of empirical research (Aria & Cuccurullo, 2017).

4. Results and Findings

This section presents the main findings derived from the bibliometric analysis. The results offer a comprehensive overview of how research on mathematics teacher knowledge has evolved and been conceptualized over time.

4.1 RQ 1: Publication Trends

Research output remained minimal between 2000 and 2004, increased gradually from 2005 to 2008, and then accelerated markedly from 2010 onward. Periodic declines around 2014 and 2017 interrupted the upward trajectory but did not reverse it. Growth became considerably more pronounced after 2018, recovering quickly from a brief dip in 2021 and reaching its highest point in 2025, with approximately 60 articles. Despite intermittent fluctuations, the overall trend indicates strong and accelerating scholarly interest in this area of research.

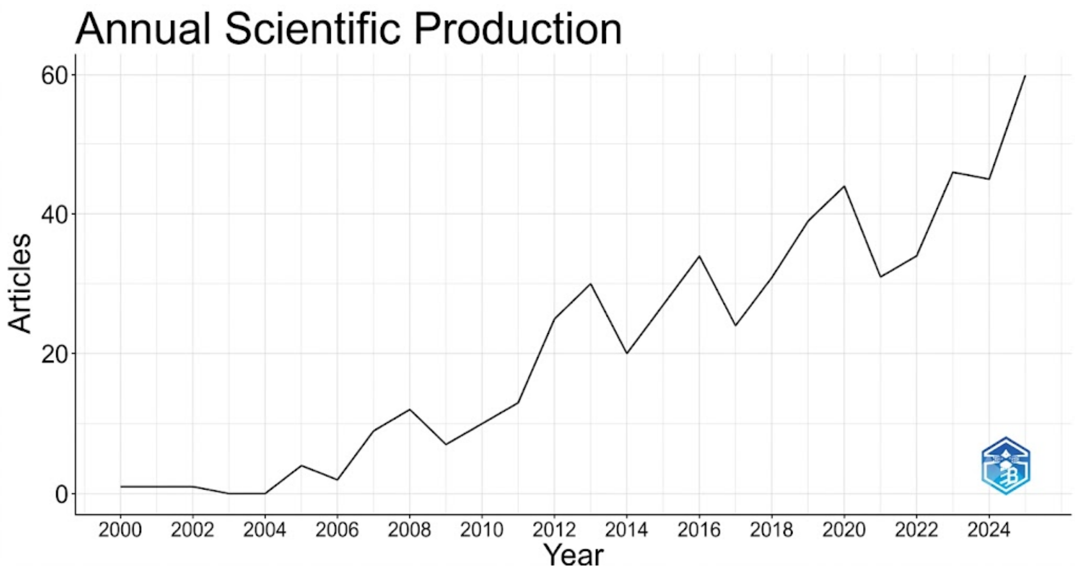

Figure 2: Annual Scientific Production

4.2 RQ 2: Citation Impact and Most Cited Papers

The Average Citations per Year graph (Figure 3) exhibits a fluctuating pattern, marked by a prominent peak around 2005 and a smaller secondary increase around 2010. From 2011 onward, averages stabilized at a lower level, including the most recent period (2020–2025). This pattern should not be read as a decline in scholarly impact. The peaks observed in 2005 and 2010 correspond to the publication of several field-defining studies, whose foundational contributions have continued to attract substantial scholarly attention and sustained citation over the past two decades. The comparatively low averages for recent years reflect citation lag: newly published articles have not yet had time to accumulate citations, a well-documented artifact of citation-based metrics rather than evidence of diminishing influence. The concentration of citation impact during the field's formative period therefore highlights the enduring influence and scholarly authority of its foundational theoretical frameworks.

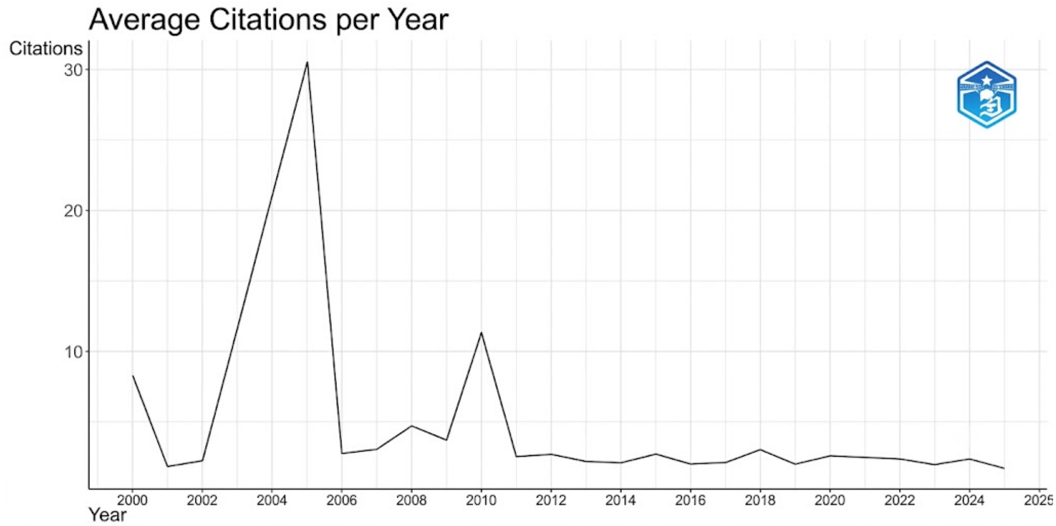

Figure 3: Average Citation per Year

The ten most-cited works (Table 2) are clustered around three thematic foci. The empirical foundation was established by Hill et al. (2005), the most-cited work with 1,576 citations, which provided the first large-scale evidence linking MKT to student achievement, along with the COACTIV studies (Baumert et al., 2010; Kleickmann et al., 2013; Krauss et al., 2008), which demonstrated that pedagogical content knowledge (PCK) is a stronger predictor of instructional quality than content knowledge alone. Framework development is represented by Rowland et al. (2005), Carrillo-Yañez et al. (2018), and Niess (2005), the last offering an early conceptualization of TPACK. Assessment and application are represented by Kersting et al. (2012) and Tirosh (2000). The dominance of framework-defining studies and large-scale empirical validations among the most-cited works suggests that the field has placed greater value on theoretical consolidation and robust measurement frameworks than on isolated empirical contributions.

Table 2: The 10 Most Cited Papers by Total Citation Number

No	Document title	Authors	Source	Citations
1.	Effects of teachers' mathematical knowledge for teaching on student achievement	(Hill et al., 2005)	American Educational Research Journal	1576
2.	Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress	(Baumert et al., 2010)	American Educational Research Journal	1345
3.	Preparing teachers to teach science and mathematics with technology: developing a technology pedagogical content knowledge	(Niess, 2005)	Teaching And Teacher Education	780
4.	Teachers' content knowledge and pedagogical content knowledge: the role of structural differences in teacher education	(Kleickmann et al., 2013)	Journal of Teacher Education	374
5.	Elementary teachers' mathematics subject knowledge: the knowledge quartet and the case of Naomi	(Rowland et al., 2005)	Journal of Mathematics Teacher Education	323
6.	Pedagogical content knowledge and content knowledge of secondary mathematics teachers	(Krauss, Brunner, et al., 2008)	Journal of Educational Psychology	321
7.	Measuring usable knowledge: teachers' analyses of mathematics classroom videos predict teaching quality and student learning	(Kersting et al., 2012)	American Educational Research Journal	295
8.	The mathematics teacher's specialized knowledge (MTSK) model	(Carrillo-Yañez et al., 2018)	Research in Mathematics Education	295
9.	Enhancing prospective teachers' knowledge of children's conceptions: the case of division of fractions	(Tirosh, 2000)	Journal For Research In Mathematics Education	225
10.	Secondary mathematics teachers' pedagogical content knowledge and content knowledge: validation of the COACTIV constructs	(Krauss, Baumert, et al., 2008)	ZDM	192

4.3 RQ 3: Dominant Topics and Their Associations

The treemap of the top 25 keywords (Figure 4) highlights both the dominant themes and the evolving relationships among research topics that have shaped the field over the past 25 years. At the theoretical core, *mathematical content knowledge* (21%), *pedagogical content knowledge* (17%), and *mathematical knowledge for teaching* (10%) form an interrelated cluster reflecting the field's sustained effort to define and differentiate the knowledge teachers need. These constructs are closely linked to teacher education (13%) and *pre-service mathematics teachers* (5%), suggesting that investigations of teacher knowledge have been consistently situated within teacher preparation and professional training contexts. A second cluster centers on technology integration, where technological pedagogical content knowledge (7%) emerges as a growing extension of traditional PCK discourse, reflecting growing research attention to how digital tools reshape teaching demands.

Meanwhile, content-specific terms such as algebra, fractions, and geometry, together with conceptual and procedural knowledge, indicate that teacher knowledge is frequently examined within particular mathematical domains, reflecting a sustained interest in how teachers understand and teach specific mathematical concepts. Finally, *the professional development, assessment, and knowledge quartet serves as a methodological and practical thread*, focusing on how teacher knowledge is evaluated and developed in applied settings.

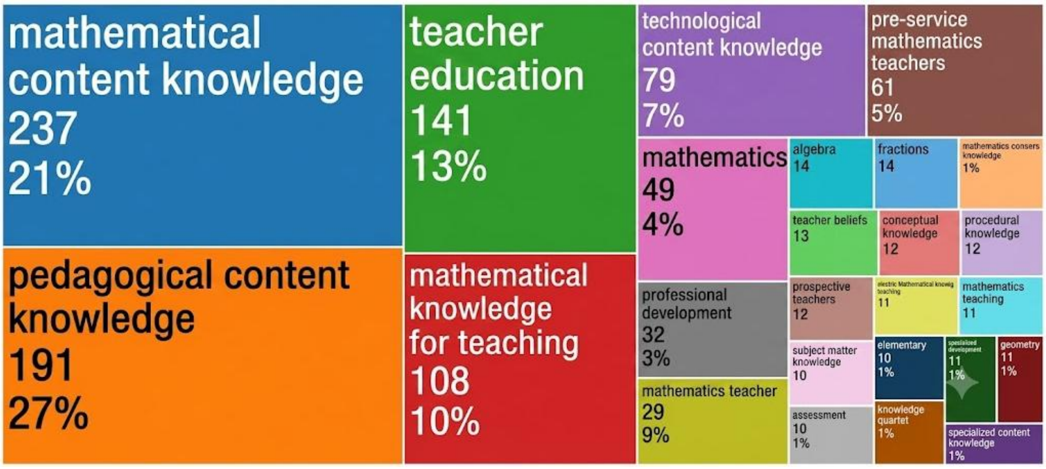

Figure 4: Tree Map

The keyword co-occurrence network visualizes the relationships among keywords, with spatial proximity representing stronger thematic connections and node size indicating the relative prominence of each keyword within the literature. ***Mathematical content knowledge*** is the most central and dominant node, serving as the primary hub that links the field's major themes. It is closely connected to terms such as ***teacher education, mathematical knowledge for teaching, algebra, assessment,*** and ***pre-service mathematics teachers***, reflecting a strong focus on teacher preparation and knowledge development. The network is organized into three distinct clusters.

The green cluster is centered on pedagogical content knowledge and is connected to themes such as teachers' ***beliefs, mathematics teaching, student achievement, lesson study, and initial teacher education***. This cluster highlights the pedagogical dimension of teacher knowledge and its close relationship with instructional practice and classroom learning outcomes. The red cluster centers on ***technological pedagogical content knowledge, grouping technology integration,***

teacher professional development, STEM, and ***GeoGebra*** into a distinct line of research on digital competencies. The blue cluster acts as a bridge, connecting ***teaching quality, professional development, knowledge quartet, proof***, and ***geometry*** across the pedagogical, content, and technological dimensions. Peripheral nodes such as ***conceptual knowledge, fractions***, and ***procedural knowledge*** appear more specialized and less integrated into the main streams. Overall, the network indicates that research continues to be strongly anchored in mathematical content knowledge, while maintaining substantial connections with pedagogical knowledge and increasingly incorporating technology-related themes into the broader research landscape

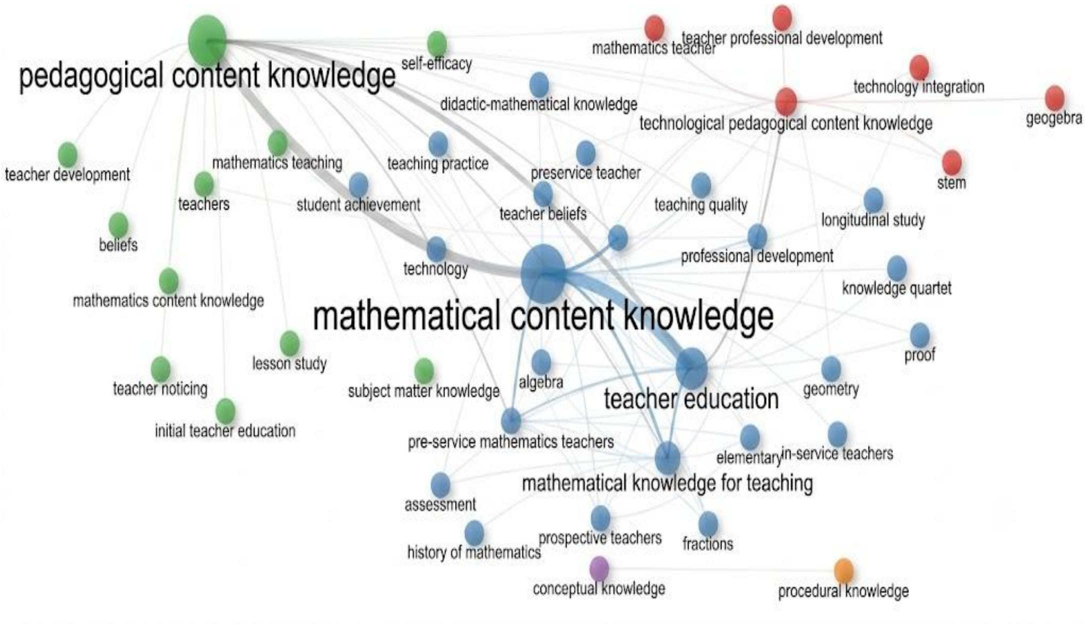

Figure 5: Keyword Co-Occurrence Network

The dominance of the MCK–PCK reflects the field's enduring concern with defining and distinguishing the forms of knowledge that make teaching mathematics fundamentally different from merely knowing mathematics. On the other hand, the three-cluster structure of the co-occurrence network reflects an ongoing tension between knowledge-oriented and practice-oriented research traditions. The tight association between these constructs and teacher-preparation keywords indicates that this question has been pursued primarily in pre-service contexts, where knowledge can be measured and developed systematically.

4.4 RQ 4: Topic Trend

To examine how research interests have evolved over time, a trend topic plot (Figure 6) was generated. In this visualization, the length of each line represents the period during which a keyword remained active in the literature, while the size of each dot reflects the frequency with which the term appeared. The plot shows that foundational constructs such as pedagogical content knowledge, teacher education, content knowledge, and mathematical knowledge for teaching have remained consistently influential over multiple years, anchoring the field's intellectual core. In contrast, recent terms such as *GeoGebra, technology integration,* *and technological pedagogical content knowledge* saw their visibility surge, signaling a decisive turn toward digital tools and technological competencies in teaching. Consistent with the preceding visualizations, the timeline reveals a clear thematic progression, moving from broad pedagogical foundations toward increasingly specialized and technology-enhanced approaches in mathematics teacher education.

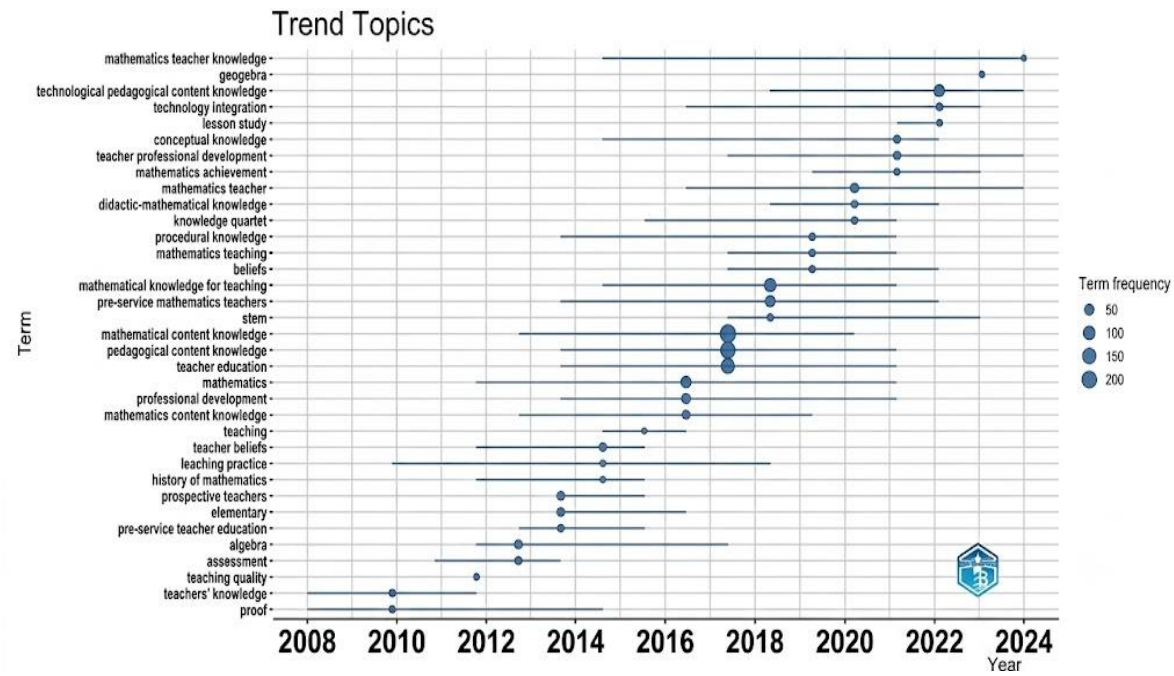

Figure 6: Topic Trends

4.5 RQ 5: Strategic Theme

To address the fifth research question, Figure 7 presents a strategic diagram that categorizes themes in mathematics teacher knowledge research into four groups: motor, basic, niche, and emerging or declining themes based on their levels of centrality and density. Motor themes, including *mathematics*, *teaching quality*, and *initial teacher education*, are highly developed and strongly connected, making them the main drivers of the field.

Basic themes, such as *mathematical content knowledge*, *mathematical knowledge for teaching (MKT)*, *pedagogical content knowledge (PCK)*, *TPACK*, and *teacher education*, form the conceptual foundation but require further development. Niche themes, including *geometry, dynamic geometry, and peer teaching*, are highly specialized but exhibit limited connections to the broader research field. In contrast, emerging or declining themes, such as *Knowledge Quartet, contingency*, and *horizon content knowledge*, occupy a peripheral position, suggesting that they may either represent developing research directions or areas experiencing a decline in scholarly attention.

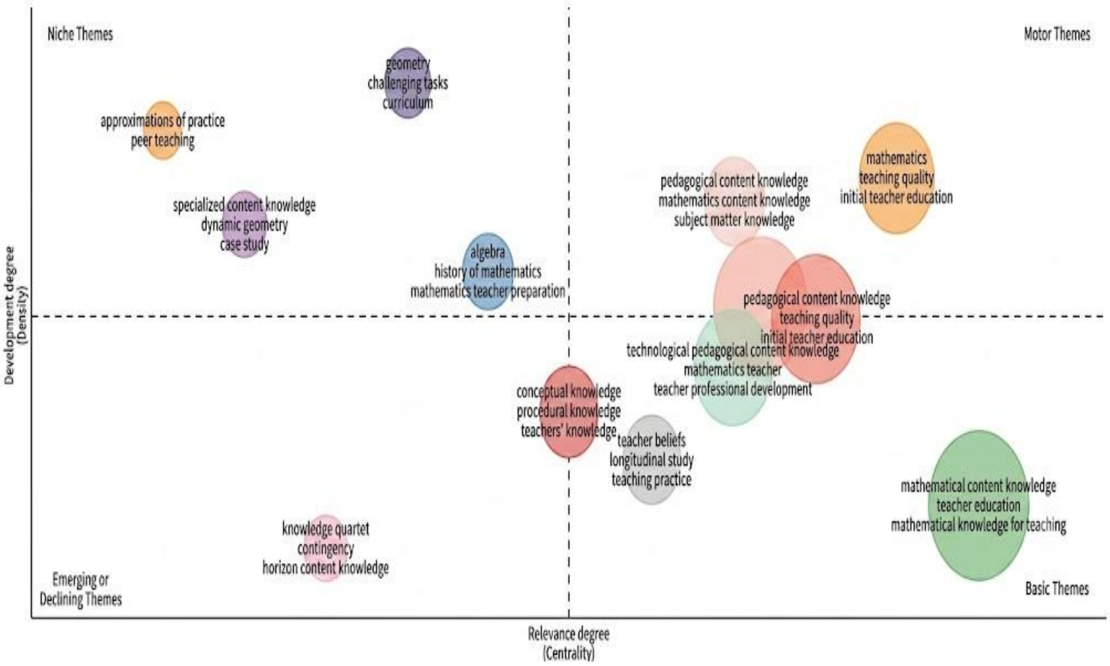

Figure 7: Thematic Map

5. Discussion

5.1 A Field in Accelerated Expansion

The publication trajectory (RQ1) reflects not only growing interest but also intellectual consolidation. The sharp increase after 2010 coincided with the wider diffusion of shared theoretical vocabularies, particularly MKT and the Knowledge Quartet, which provided researchers with common constructs for empirical investigation. At the same time, increasing policy attention to teacher quality positioned teacher knowledge as a measurable factor influencing student outcomes. The post-2018 acceleration is most plausibly the compounding product of field maturation, the expansion of dedicated outlets, and broadening international participation.

The rapid global transition to digital learning during the COVID-19 pandemic contributed to this momentum by foregrounding the demands of remote instruction (Atweh et al., 2023). Studies published between 2019 and 2023 highlight sustained professional development, together with teaching experience, as key factors influencing the development and enhancement of mathematics teachers' pedagogical content knowledge (Sakaria et al., 2023). Furthermore, the necessity for digital instruction bolstered interest in frameworks such as Technological Pedagogical Content Knowledge (TPACK), as educators adapted to remote teaching environments (Akpalu et al., 2025; Pérez Echeverría et al., 2025).

5.2 Citation Concentration and the Maturity Paradox

The concentration of citation impact in the field's formative years (RQ2) does not indicate a decline in influence; rather, it reflects the enduring relevance of foundational studies that continue to shape contemporary research and theoretical development. The peaks correspond to field-defining works whose authority has sustained citation over two decades, and the lower averages of recent years are best understood through two mechanisms. First, citation cycles inherently lag, so recently published work has not yet accumulated citations (Alimohammadi, 2009; Cai et al., 2023). Second, the field has reached a level of theoretical maturity in which its core constructs are well established. As a result, newer studies tend to build incrementally on a consolidated knowledge base rather than producing the landmark works typically associated with an emerging field(Ishmuradova et al., 2024). That the most-cited works are predominantly framework-defining or large-scale empirical validations indicates a field that has rewarded theoretical consolidation and rigorous measurement.

5.3 A Centralized Conceptual Core

The dominance of mathematical content knowledge, PCK, and MKT (RQ2, RQ3, and RQ4) reflects the field's enduring central concern: defining and differentiating the forms of knowledge that distinguish teaching mathematics from mere knowledge of mathematics. The centrality of mathematical content knowledge as the principal connecting node is significant, as teacher educators must themselves possess the specialized "meta-knowledge" required to prepare others to teach (Escudero-Ávila et al., 2021). The close association between these constructs and teacher-preparation keywords suggests that this question has been examined predominantly within pre-service teacher education contexts. This structure is corroborated by recent bibliometric work that confirms PCK as the link between content mastery and pedagogy and validates MKT as a multidimensional framework (Alka et al., 2023; Asvat, 2024; Handayani, Hussin, & Norman, 2023; Hwang & Cho, 2021; Ijeh et al., 2025).

5.4 The Integration of Technology

The surge in technology-related themes (RQ3, RQ4, and RQ5), such as GeoGebra, technology integration, and TPACK, positions digital pedagogical competence as a defining concern in contemporary mathematics teacher education (Akpalu et al., 2025; Koehler & Mishra, 2005; Lachner et al., 2021; Ning et al., 2022). However, these themes occupy peripheral positions in the co-occurrence network, indicating that technology has entered the research agenda faster than it has been absorbed into the field's theoretical core.

This peripheral position is significant because the effective use of digital tools depends not merely on their adoption, but on their alignment with sound pedagogical and didactic principles (Bray & Tangney, 2017; Bretscher, 2014; Drijvers, 2019; Jankvist et al., 2019). Teachers with strong TPACK integrate tools such as GeoGebra into instructional design meaningfully rather than as superficial additions (Yildiz & Arpaci, 2024; Yuan et al., 2023), and the theoretical integration of technology into established knowledge frameworks remains a productive direction for future research. The implication for the field is that integrating technological and traditional knowledge frameworks, rather than allowing them to develop in parallel, represents a more pressing theoretical challenge for future research

5.5 From Defining to Operationalizing Knowledge

The thematic map (RQ5) reveals the maturation of the field's epistemic priorities. Earlier scholarship focused on establishing and defining broad constructs, whereas recent studies have increasingly operationalized these constructs through practice-oriented themes. This shift moves the central question from what teacher knowledge is to how it functions in classroom practice. Crucially, foundational frameworks are refined rather than displaced: their sustained prominence across the timeline signals a cumulative rather than substitutive trajectory (Depaepe et al., 2013; Shulman, 1986). The strategic diagram positions teaching quality and initial teacher education as motor themes, while foundational constructs such as MKT, PCK, and TPACK remain in the basic quadrant. This pattern reveals a displacement between the field's conceptual center and its developmental frontier. This shift aligns with global trends in evidence-informed professional development (Darling-Hammond, 2017; Lee & Vongkulluksn, 2023).

5.6 A Maturing Field and Its Future Trajectory

The observed patterns suggest that the field has reached a level of theoretical maturity in which newer studies build cumulatively upon an established knowledge base rather than replacing existing frameworks (Depaepe et al., 2013; Ishmuradova et al., 2024). Such maturity is a strength, but it also carries a risk: a consolidated field can mistake refinement for progress and leave its foundational tensions unexamined. The present mapping suggests three priorities for the next phase of research. First, greater conceptual clarity among foundational constructs such as MKT, PCK, and TPACK would help reduce the terminological fragmentation revealed by the bibliometric mapping.

Second, the niche and peripheral themes, including the Knowledge Quartet and horizon content knowledge, merit reintegration into mainstream inquiry rather than abandonment; their peripheral position may reflect the labour-intensive observational approaches their investigation requires, or their gradual absorption into more comprehensive frameworks such as MTSK, rather than diminished conceptual value. Third, and perhaps most importantly, the field would benefit from theoretical efforts that more closely integrate its rapidly expanding technological strand with its established conceptual core, enabling pedagogical expertise, content mastery, and technology-enhanced teaching to develop into a coherent framework for effective instruction in technology-rich learning environments.

5.7 Limitations

Several limitations should be acknowledged. First, the analysis relies exclusively on the Scopus database, thereby excluding studies indexed in other databases and potentially introducing indexing bias. Second, the single search term ("mathematics teacher knowledge") may omit relevant studies that use alternative terminology, prioritizing conceptual precision over exhaustive recall. Third, keyword co-occurrence reflects terminology rather than underlying conceptual relationships, potentially fragmenting related themes. Fourth, the exclusion of non-English publications underrepresents several active communities in mathematics education. Finally, the reliance on author-supplied keywords, without incorporating co-citation or bibliographic coupling analyses, may limit the depth and granularity of the thematic mapping.

6. Conclusion

This bibliometric analysis provides a comprehensive overview of the development of research on mathematics teacher knowledge from 2000 to 2025. Publications increased steadily over this period, moving from minimal output in the early 2000s to accelerated growth after 2018, with a peak around 2025. This growth was driven by theoretical consolidation, broader international participation, and the post-pandemic expansion of digital mathematics teaching. Citation impact was strongest during the field's formative period of 2005–2010, reflecting the enduring authority of foundational works on MKT and PCK rather than any decline in scholarly influence; this pattern is best explained by citation lag rather than diminishing relevance. Mathematical content knowledge, pedagogical content knowledge (PCK), and mathematical knowledge for teaching (MKT) have consistently formed the conceptual core of the field.

Among these constructs, mathematical content knowledge serves as the central connecting node across thematic clusters, while teacher education remains its primary context of application. The strategic diagram further indicates that teaching quality and initial teacher education have emerged as the field’s motor themes, suggesting that the field has progressed from defining the nature of teacher knowledge to examining how it is enacted and applied in classroom practice. At the same time, foundational constructs such as MKT, PCK, and TPACK remain structurally central yet conceptually unsettled. Niche and declining themes, including the Knowledge Quartet and horizon content knowledge, retain conceptual value that the field risks overlooking. Future research should pursue cross-database validation and geographic network analysis and should examine whether and how the depth of mathematical content knowledge conditions the progressive development of technology-integrated competencies such as TPACK, a question that this mapping surfaces but that bibliometric methods alone cannot resolve.

7. Conflict of Interest

The author affirms that there are no conflicts of interest in the composition and dissemination of this study.

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9. References

Akpalu, R., Boateng, P. A., Owusu, J., & Ayisi, E. (2025). Digital Transformation in Mathematics Education: Strategic Responses to E-Learning Challenges. *International Journal of Research and Innovation in Social Science*, *IX*(II), 1188–1200. https://doi.org/10.47772/IJRISS.2025.9020096

Alimohammadi, D. (2009). Correlation between references and citations. *Webology, 6*(2), Article 62.

Alka, Muh., Bancong, H., Sukmawati, Muzaini, M., & Ernawati. (2023). Bibliometric Analysis of Pedagogical Content Knowledge (PCK) Publication Trends in Scopus Database from 2018 to 2022. *Studies in Learning and Teaching*, *4*(2), 306–318. https://doi.org/10.46627/silet.v4i2.222

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics, 11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Asvat, Z. J. (2024). Pedagogical Content Knowledge Development within Pre-Service Mathematics Teacher Education: A Bibliometric Analysis. *Journal of Educational Studies*, *23*(4), 182–213. https://doi.org/10.59915/jes.2024.23.4.8

Atweh, B., Kaur, B., Nivera, G., Abadi, A., & Thinwiangthong, S. (2023). Futures for Post-Pandemic Mathematics Teacher Education: responsiveness and responsibility in the Face of a Crisis. *ZDM – Mathematics Education*, *55*(1), 65–77. https://doi.org/10.1007/s11858-022-01394-y

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Batanero, J. M. F., Reyes Rebollo, M. M., & Rueda, M. M. (2019). Impact of ICT on students with high abilities. Bibliographic review (2008–2018). *Computers & Education*, *137*, 48–58. https://doi.org/10.1016/j.compedu.2019.04.007

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., Klusmann, U., Krauss, S., Neubrand, M., & Tsai, Y. M. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, *47*(1), 133–180. https://doi.org/10.3102/0002831209345157

Beswick, K., Callingham, R., & Watson, J. (2012). The nature and development of middle school mathematics teachers' knowledge. *Journal of Mathematics Teacher Education*, *15*(2), 131–157. https://doi.org/10.1007/s10857-011-9177-9

Blömeke, S., Hsieh, F.-J., Kaiser, G., & Schmidt, W. H. (Eds.). (2014). *International perspectives on teacher knowledge, beliefs and opportunities to learn: TEDS-M results*. Springer. https://doi.org/10.1007/978-94-007-6437-8

Bray, A., & Tangney, B. (2017). Technology usage in mathematics education research – A systematic review of recent trends. *Computers & Education*, *114*, 255–273. https://doi.org/10.1016/j.compedu.2017.07.004

Bretscher, N. (2014). Exploring the quantitative and qualitative gap between expectation and implementation: A survey of English mathematics teachers' uses of ICT. In A. Clark-Wilson, O. Robutti, & N. Sinclair (Eds.), *The mathematics teacher in the digital era* (pp. 43–70). Springer. https://doi.org/10.1007/978-94-007-4638-1_3

Bromme, R. (1994). Beyond subject matter: A psychological topology of teachers'professional knowledge. In R. Biehler, R. W. Scholz, R. Strässer, & B. Winkelmann (Eds.), *Mathematics didactics as a scientific discipline: The state of the art* (pp. 73–88). Kluwer.

Buchholtz, N., Leung, F. K. S., Ding, L., Kaiser, G., Park, K., & Schwarz, B. (2013). Future mathematics teachers' professional knowledge of elementary mathematics from an advanced standpoint. *ZDM*, *45*(1), 107–120. https://doi.org/10.1007/s11858-012-0462-6

Cai, X., Lyu, X., & Zhou, P. (2023). The relationship between interdisciplinarity and citation impacts a novel perspective on citation accumulation. *Humanities and Social Sciences Communications*, *10*(1), 945. https://doi.org/10.1057/s41599-023-02475-3

Campbell, P. F., Nishio, M., Smith, T. M., Clark, L. M., Conant, D. L., Rust, A. H., DePiper, J. N., Frank, T. J., Griffin, M. J., & Choi, Y. (2014). The Relationship Between Teachers' Mathematical Content and Pedagogical Knowledge, Teachers' Perceptions, and Student Achievement. *Journal for Research in Mathematics Education*, *45*(4), 419–459. https://doi.org/10.5951/jresematheduc.45.4.0419

Carrillo-Yañez, J., Climent, N., Montes, M., Contreras, L. C., Flores-Medrano, E., Escudero-Ávila, D., Vasco, D., Rojas, N., Flores, P., Aguilar-González, Á., Ribeiro, M., & Muñoz-Catalán, M. C. (2018). The mathematics teacher's specialised knowledge (MTSK) model*. *Research in Mathematics Education*, *20*(3), 236–253. https://doi.org/10.1080/14794802.2018.1479981

Chadegani, A. A., Salehi, H., Yunus, M. M., Farhadi, H., Fooladi, M., Farhadi, M., & Ebrahim, N. A. (2013). A Comparison between Two Main Academic Literature Collections: Web of Science and Scopus Databases. *Asian Social Science*, *9*(5). https://doi.org/10.5539/ass.v9n5p18

Copur-Gencturk, Y. (2015). The Effects of Changes in Mathematical Knowledge on Teaching: A Longitudinal Study of Teachers' Knowledge and Instruction. *Journal for Research in Mathematics Education*, *46*(3), 280–330. https://doi.org/10.5951/jresematheduc.46.3.0280

Copur-Gencturk, Y., & Doleck, T. (2021). Strategic competence for multistep fraction word problems: an overlooked aspect of mathematical knowledge for teaching. *Educational Studies in Mathematics*, *107*(1), 49–70. https://doi.org/10.1007/s10649-021-10028-1

Darling-Hammond, L. (2017). Teacher education around the world: What can we learn from international practice? *European Journal of Teacher Education*, *40*(3), 291–309. https://doi.org/10.1080/02619768.2017.1315399

Davis, B., & Simmt, E. (2006). Mathematics-for-Teaching: an Ongoing Investigation of the Mathematics that Teachers (Need to) Know. *Educational Studies in Mathematics*, *61*(3), 293–319. https://doi.org/10.1007/s10649-006-2372-4

Dede, E., & Özdemir, E. (2022). *Mapping and performance evaluation of mathematics education research in Turkey: A bibliometric analysis from 2005 to 2021*. *Journal of Pedagogical Research*. https://doi.org/10.33902/JPR.202216829

Depaepe, F., Verschaffel, L., & Kelchtermans, G. (2013). Pedagogical content knowledge: A systematic review of the way in which the concept has pervaded mathematics educational research. *Teaching and Teacher Education*, *34*, 12–25. https://doi.org/10.1016/j.tate.2013.03.001

Dogbey, J. (2025). Supporting elementary school teachers enhance their mathematics instruction through invented strategies and classroom discourse. *Asian Journal for Mathematics Education*, *4*(1), 3–30. https://doi.org/10.1177/27527263251318090

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Drijvers, P. (2019). Head in the clouds, feet on the ground: A realistic view on using digital tools in mathematics education. In *Vielfältige Zugänge zum Mathematikunterricht* (pp. 163–176). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-24292-3_12

Eaves, J., Attridge, N., & Gilmore, C. (2025). Misconceptions of the order of operations and associativity use. *Learning and Instruction*, *97*, 102074. https://doi.org/10.1016/j.learninstruc.2024.102074

Escudero-Ávila, D., Montes, M., & Contreras, L. C. (2021). *What Do Mathematics Teacher Educators Need to Know? Reflections Emerging from the Content of Mathematics Teacher Education* (pp. 23–40). https://doi.org/10.1007/978-3-030-62408-8_2

Even, R., & Ball, D. L. (2010). *The Professional Education and Development of Teachers of Mathematics* (R. Even & D. L. Ball, Eds.; Vol. 11). Springer US. https://doi.org/10.1007/978-0-387-09601-8

Fennema, E., & Franke, M. L. (2006). Teachers' Knowledge and Its Impact. In *Handbook of Research on Mathematics Teaching and Learning* (pp. 147–164). Emerald Publishing Limited. https://doi.org/10.1108/978-1-60752-874-620251011

Grigaliūnienė, M., Lehtinen, E., Verschaffel, L., & Depaepe, F. (2025). Systematic Review of Research on Pedagogical Content Knowledge in Mathematics: Insights from a Topic-Specific Approach. *ZDM – Mathematics Education*, *57*(4), 777–794. https://doi.org/10.1007/s11858-025-01684-1

Hallinger, P., & Kovačević, J. (2021). Science Mapping the knowledge base in educational leadership and management: A longitudinal bibliometric analysis, 1960 to 2018. *Educational Management Administration & Leadership*, *49*(1), 5–30. https://doi.org/10.1177/1741143219859002

Handayani, S., Hussin, M., & Helmi. (2023). Technological Pedagogical Content Knowledge (TPACK) Model in teaching: A Review and Bibliometric Analysis. *Pegem Journal of Education and Instruction*, *13*(3). https://doi.org/10.47750/pegegog.13.03.19

Handayani, S., Hussin, M., & Norman, H. (2023). *Technological Pedagogical Content Knowledge (TPACK) Model in Teaching: A Review and Bibliometric Analysis*. *Pegem Journal of Education and Instruction*, *13*(3). https://doi.org/10.47750/pegegog.13.03.19

Harris, J., Mishra, P., & Koehler, M. (2009). Teachers' Technological Pedagogical Content Knowledge and Learning Activity Types. *Journal of Research on Technology in Education*, *41*(4), 393–416. https://doi.org/10.1080/15391523.2009.10782536

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement. *American Educational Research Journal*, *42*(2), 371–406. https://doi.org/10.3102/00028312042002371

Hudha, M. N., Hamidah, I., Permanasari, A., Abdullah, A. G., Rachman, I., & Matsumoto, T. (2020). Low Carbon Education: A Review and Bibliometric Analysis. *European Journal of Educational Research, 9*(1), 319–329. https://doi.org/10.12973/eu-jer.9.1.319

Hwang, S., & Cho, E. (2021). Exploring Latent Topics and Research Trends in Mathematics Teachers' Knowledge Using Topic Modeling: A Systematic Review. *Mathematics*, *9*(22), 2956. https://doi.org/10.3390/math9222956

Ijeh, S. B., Akpomedaye, J. F. O., Njoseh, I. N., Igabari, J. N., & Enakpoya, E. E. (2025). Exploring Teachers' Mathematical Knowledge for Teaching and Its Influence on Students Achievement, Retention and Attitude towards Mathematics in Secondary Schools in Nigeria. *International Journal of Social Science and Education Research Studies*, *05*(1), 84-93. https://doi.org/10.55677/ijssers/V05I01Y2025-13

Ishmuradova, I. I., Chistyakov, A. A., Chudnovskiy, A. D., Grib, E. V., Kondrashev, S. V., & Zhdanov, S. P. (2024). A cross-database bibliometrics analysis of blended learning in higher education: Trends and capabilities. *Contemporary Educational Technology*, *16*(2), ep508. https://doi.org/10.30935/cedtech/14478

Jankvist, U. T., Misfeldt, M., & Aguilar, M. S. (2019). What happens when CAS procedures are objectified? —the case of "solve" and "desolve." *Educational Studies in Mathematics*, *101*(1), 67–81. https://doi.org/10.1007/s10649-019-09888-5

Johnson, F., & Roy, F. G. (2026). Mathematics Teachers' Pedagogical Content Knowledge in Strengthening Conceptual Understanding in Students with Learning

Disabilities: A Practice-Based Conceptual Synthesis. *Education Sciences*, *16*(2), 176. https://doi.org/10.3390/educsci16020176

Kholid, M. N., Hendriyanto, A., Sahara, S., Muhaimin, L. H., Juandi, D., Sujadi, I., Kuncoro, K. S., & Adnan, M. (2023). A systematic literature review of Technological, Pedagogical and Content Knowledge (TPACK) in mathematics education: Future challenges for educational practice and research. *Cogent Education*, *10*(2). https://doi.org/10.1080/2331186X.2023.2269047

Koehler, M. J., & Mishra, P. (2005). Teachers learning technology by design. *Journal of Computing in Teacher Education*, *21*(3), 94–102.

König, J., Blömeke, S., Klein, P., Suhl, U., Busse, A., & Kaiser, G. (2014). Is teachers' general pedagogical knowledge a premise for noticing and interpreting classroom situations? A video-based assessment approach. *Teaching and Teacher Education*, *38*, 76–88. https://doi.org/10.1016/j.tate.2013.11.004

Krauss, S., Baumert, J., & Blum, W. (2008). Secondary mathematics teachers' pedagogical content knowledge and content knowledge: validation of the COACTIV constructs. *ZDM*, *40*(5), 873–892. https://doi.org/10.1007/s11858-008-0141-9

Lachner, A., Fabian, A., Franke, U., Preiß, J., Jacob, L., Führer, C., Küchler, U., Paravicini, W., Randler, C., & Thomas, P. (2021). Fostering pre-service teachers' technological pedagogical content knowledge (TPACK): A quasi-experimental field study. *Computers & Education*, *174*, 104304. https://doi.org/10.1016/j.compedu.2021.104304

Lee, H.-J., & Vongkulluksn, V. W. (2023). Enhancing mathematics teacher professional learning through a contextualized professional development program. *Teacher Development*, *27*(1), 92–115. https://doi.org/10.1080/13664530.2022.2134195

Lee, M. Y. (2017). Pre-service teachers' flexibility with referent units in solving a fraction division problem. *Educational Studies in Mathematics*, *96*(3), 327–348. https://doi.org/10.1007/s10649-017-9771-6

Lynch, K., Gonzalez, K., Hill, H., & Merritt, R. (2025). A Meta-Analysis of the Experimental Evidence Linking Mathematics and Science Professional Development Interventions to Teacher Knowledge, Classroom Instruction, and Student Achievement. *AERA Open*, *11*. https://doi.org/10.1177/23328584251335302

Maher, N., Muir, T., & Chick, H. (2022). Analysing senior secondary mathematics teaching using the Knowledge Quartet. *Educational Studies in Mathematics*, *110*(2), 233–249. https://doi.org/10.1007/s10649-021-10125-1

Marhami, Afgani Dahlan, J., & Dasari, D. (2026). Pedagogical Content Knowledge In Teaching Systems of Linear Equations: A Case of Secondary School Mathematics Teachers. *EduMatSains : Jurnal Pendidikan, Matematika Dan Sains*, *10*(3), 252–266. https://doi.org/10.33541/edumatsains.v10i3.7712

Marks, R. (1990). Pedagogical Content Knowledge: From a Mathematical Case to a Modified Conception. *Journal of Teacher Education*, *41*(3), 3–11. https://doi.org/10.1177/002248719004100302

Martín-Martín, A., Thelwall, M., Orduna-Malea, E., & Delgado López-Cózar, E. (2021). Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and OpenCitations' COCI: a multidisciplinary comparison of coverage via citations. *Scientometrics*, *126*(1), 871–906. https://doi.org/10.1007/s11192-020-03690-4

Mohr-Schroeder, M., Ronau, R. N., Peters, S., Lee, C. W., & Bush, W. S. (2017). Predicting Student Achievement Using Measures of Teachers' Knowledge for Teaching Geometry. *Journal for Research in Mathematics Education*, *48*(5), 520–566. https://doi.org/10.5951/jresematheduc.48.5.0520

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: a comparative analysis. *Scientometrics*, *106*(1), 213–228. https://doi.org/10.1007/s11192-015-1765-5

Narayanan, B., G Kumar, A., Gunasekaran, D., Vengayil, R., Maduvegadde, K., & Alampady, N. (2025). Perspectives of Socio-Scientific Issues in Educational Research: A Bibliometric Analysis. *Journal of Teaching and Learning*, *19*(1), 50–84. https://doi.org/10.22329/jtl.v19i1.8985

Narong, D. K., & Hallinger, P. (2024). The evolution of service learning in engineering education: a bibliometric review of research (1995–2023). *European Journal of Engineering Education*, *49*(5), 834–855. https://doi.org/10.1080/03043797.2024.2368148

Nguyen, N., Guerin, C., Barbieri, W., Palmer, E., & Pugsley, P. (2022). The role of technological knowledge in the pedagogical integration of film in disciplinary teaching at universities. *Journal of University Teaching & Learning Practice, 19*(3), Article 9. https://doi.org/10.53761/1.19.3.09

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509–523. https://doi.org/10.1016/j.tate.2005.03.006

Ning, Y., Zhou, Y., Wijaya, T. T., & Chen, J. (2022). Teacher Education Interventions on Teacher TPACK: A Meta-Analysis Study. *Sustainability*, *14*(18), 11791. https://doi.org/10.3390/su141811791

Novikasari, I. (2023). *Knowledge of mathematical pedagogy and sustainability consciousness through exploration of local culture-based mathematical modelling*. 020013. https://doi.org/10.1063/5.0155185

Özdemir Baki, G., Özkaya, M., & Konyalioglu, A. C. (2022). Teachers' approaches to student errors in mathematics teaching and noticing of their approaches. *Acta Didactica Napocensia*, *15*(2), 209–229. https://doi.org/10.24193/adn.15.2.14

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Pérez Echeverría, M. del P., Cabellos, B., & Pozo, J.-I. (2025). The use of ICT in classrooms: The effect of the pandemic. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-13124-w

Pham, H. T., Vu, T. C., Nguyen, L. T., Vu, N.-T. T., Nguyen, T. C., Pham, H.-H. T., Lai, L. P., Le, H.-C. T., & Ngo, C. H. (2023). Professional development for science teachers: A bibliometric analysis from 2001 to 2021. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(5), em2260. https://doi.org/10.29333/ejmste/13153

Ponte, J. P., & Chapman, O. (2016). Prospective mathematics teachers' learning and knowledge for teaching. In L. D. English & D. Kirshner (Eds.), *Handbook of international research in mathematics education* (3rd ed., pp. 275–296). Routledge. https://doi.org/10.4324/9780203448946-12

Rowland, T., Huckstep, P., & Thwaites, A. (2005). Elementary Teachers' Mathematics Subject Knowledge: the Knowledge Quartet and the Case of Naomi. *Journal of Mathematics Teacher Education*, *8*(3), 255–281. https://doi.org/10.1007/s10857-005-0853-5

Sakaria, D. A. L., Maat, S. M. Bin, & Matore, M. E. E. B. M. (2023). Factors influencing mathematics teachers' pedagogical content knowledge: A systematic review. *Pegem Journal of Education and Instruction*, *13*(2), 1-14. https://doi.org/10.47750/pegegog.13.02.01

Scheiner, T., Montes, M. A., Godino, J. D., Carrillo, J., & Pino-Fan, L. R. (2019). What Makes Mathematics Teacher Knowledge Specialized? Offering Alternative Views.

International Journal of Science and Mathematics Education, *17*(1), 153–172. https://doi.org/10.1007/s10763-017-9859-6

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Sosa, L., & Almaraz, C. (2026). Design and Implementation of a teaching proposal of the Fundamental Theorem of Calculus to explore the conjunction of Mathematics Teacher´s Specialized Knowledge and Teaching for Robust Understanding. *Annales de Didactique et de Sciences Cognitives*, *Thématique 4*, 187–213. https://doi.org/10.4000/15rjd

Tomaszewski, R. (2023). Visibility, impact, and applications of bibliometric software tools through citation analysis. *Scientometrics*, *128*(7), 4007–4028. https://doi.org/10.1007/s11192-023-04725-2

Utami, A., Sujarwo, S., Fauziyah, P. Y., Mustadi, A., Hidayat, R., & Rofiki, I. (2024). Bibliometric Analysis of Research Developments on Differentiated Instruction. *European Journal of Educational Research, 13(3), 1421–1439.* https://doi.org/10.12973/eu-jer.13.3.1421

Wei, T., Liu, W., Zheng, Z., Chen, Y., Shen, M., & Li, C. (2022). Bibliometric Analysis of Research Trends on 3-Monochloropropane-1,2-Diol Esters in Foods. *Journal of Agricultural and Food Chemistry*, *70*(49), 15347–15359. https://doi.org/10.1021/acs.jafc.2c06067

Wirzal, M. D. H., Nordin, N. A. H. M., Bustam, M. A., & Joselevich, M. (2022). Bibliometric Analysis of Research on Scientific Literacy between 2018 and 2022: Science Education Subject. *International Journal of Essential Competencies in Education*, *1*(2), 69–83. https://doi.org/10.36312/ijece.v1i2.1070

Yang, X., Kaiser, G., König, J., & Blömeke, S. (2021). Relationship Between Chinese Mathematics Teachers’ Knowledge and Their Professional Noticing. *International Journal of Science and Mathematics Education*, *19*(4), 815–837. https://doi.org/10.1007/s10763-020-10089-3

Yildiz, E., & Arpaci, I. (2024). Understanding pre-service mathematics teachers’ intentions to use GeoGebra: The role of technological pedagogical content knowledge. *Education and Information Technologies*, *29*(14), 18817–18838. https://doi.org/10.1007/s10639-024-12614-1

Yu, Y., Jin, Z., & Qiu, J. (2021). Global Isotopic Hydrograph Separation Research History and Trends: A Text Mining and Bibliometric Analysis Study. *Water*, *13*(18), 2529. https://doi.org/10.3390/w13182529

Yuan, Z., Deng, X., Ding, T., Liu, J., & Tan, Q. (2023). Factors influencing secondary school teachers’ usage behavior of dynamic mathematics software: A partial least squares structural equation modeling (PLS-SEM) method. *Electronic Research Archive*, *31*(9), 5649–5684. https://doi.org/10.3934/era.2023287

Zahner, W., Tenney, K., Pelaez, K., & Choppin, J. (2025). What is Ambitious (Mathematics) Teaching? Clarifying a Key Concept in Education Research and Practice. *Journal of Education*. https://doi.org/10.1177/00220574251393976

Zou, D., Huang, X., Kohnke, L., Chen, X., Cheng, G., & Xie, H. (2022). A bibliometric analysis of the trends and research topics of empirical research on TPACK. *Education and Information Technologies*, *27*(8), 10585–10609. https://doi.org/10.1007/s10639-022-10991-z