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Bibliometric Analysis of Learning Difficulties in Solving Problems in Mathematics at Pre-Tertiary Levels

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Abstract

Learning difficulties in solving mathematical problem during pre-tertiary education constitute a persistent barrier to student achievement and STEM readiness. This study presents a systematic bibliometric analysis of literature on learning difficulties in mathematical problem solving at pre-tertiary levels, employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to ensure transparent identification and selection of records. Bibliographic data were synthesized using bibliometric indicators (annual production, productive countries/journals/authors, citation metrics) and network analyses (keyword co-occurrence, co-authorship). Findings indicate sustained growth in research output since 2000, concentration of publications in high-income countries, and thematic emphasis on cognitive factors (e.g., working memory), instructional strategies (e.g., strategy instruction; problem-based learning), affective factors (e.g., mathematics anxiety), and technology-mediated interventions. Notable recent bibliometric and review studies corroborate these trends and highlight important gaps—especially limited representation from low- and middle-income countries and a shortage of longitudinal and teacher-centred studies. Recommendations include expanding cross-cultural research, strengthening teacher-focused intervention studies, and prioritizing longitudinal designs to better capture developmental trajectories of problem-solving difficulties.

Keywords: bibliometric analysis, learning difficulties, mathematical problem solving, pre-tertiary, PRISMA, working memory, mathematics anxiety

Introduction

Mathematics is foundational to schooling and underpins success in science, technology, engineering, and mathematics (STEM) fields. Pre-tertiary levels (primary and secondary education) are critical stages in which students develop problem-solving competencies that influence later academic and occupational pathways. However, many learners experience

persistent learning difficulties that interfere with mathematical problem solving. These difficulties arise from a combination of cognitive, that is, working memory deficits, instructional, affective relating to anxiety, and contextual factors (Geary, 2013; Lawal & Awofala, 2021).

Recent bibliometric studies confirm a growing scholarly focus on mathematics education issues—particularly cognitive and technology-based approaches—yet also reveal geographic and methodological gaps (Cevikbas, Kaiser, & Schukajlow, 2024; Drljić & Doz, 2025). Contemporary work has emphasized digital tools, problem-based learning, and affective constructs such as math anxiety (Boateng et al., 2024; Mashuri et al., 2025; Systematically mapping this literature with transparent selection (PRISMA) and bibliometric metrics allows researchers and policymakers to identify major trends, influential works, collaboration patterns, and underexplored areas. This paper reports a bibliometric analysis of the literature on learning difficulties in solving mathematical problems at pre-tertiary levels. Objectives of the study include:

1. Identify the publication and citation trends in research on learning difficulties in mathematical problem-solving at pre-tertiary levels.
2. Know Which countries, journals, and authors that have made the most significant contributions to this field
3. State the major thematic clusters (keywords) and collaboration patterns in the literature

Research Questions

The study addressed the following research questions:

1. What are the publication and citation trends in research on learning difficulties in mathematical problem-solving at pre-tertiary levels?
2. Which countries, journals, and authors have made the most significant contributions to this field?
3. What are the major thematic clusters (keywords) and collaboration patterns in the literature?

Literature Review

This review is organized thematically to synthesize existing knowledge on learning difficulties in mathematical problem-solving at pre-tertiary levels. It begins by conceptualizing the nature of mathematical learning difficulties, then examines problem-solving as a cognitive and instructional construct, followed by affective and technological influences. The section concludes with a synthesis of recent empirical studies and identification of gaps that justify the present bibliometric investigation.

Conceptualizing Learning Difficulties in Mathematics

Learning difficulties in mathematics encompass a spectrum of challenges, ranging from specific neurodevelopmental disorders (e.g., dyscalculia) to broader difficulties with mathematical reasoning, procedural fluency, and problem representation. Geary (2013) proposed a influential framework distinguishing between difficulties arising from cognitive deficits (particularly in working memory and number sense) and those stemming from inadequate instructional experiences. This distinction is critical because it implies different intervention pathways: cognitive deficits may require intensive, targeted remediation, whereas instructional deficits may be addressable through teacher professional development and curricular redesign.

Suseelan, Chew, and Chin (2022) further refined this understanding by demonstrating that content-specific obstacles—such as those encountered in geometry or fractions—interact with learner characteristics (e.g., prior knowledge, strategy use). This interaction suggests that learning difficulties are not purely learner-internal but emerge from mismatches between task demands and available cognitive resources. Sidik, Suryadi, and Turmudi (2021) provided empirical evidence for this interaction, identifying three types of learning obstacles in primary mathematics: ontogenic (developmental readiness), epistemological (limitations in students' mathematical knowledge structures), and didactical (instructional practices that inadvertently create barriers). Their findings underscore that addressing learning difficulties requires simultaneous attention to learner development, content structure, and teaching quality.

Problem Solving in Mathematics Education

Mathematical problem solving is widely recognized as a core competency in pre-tertiary mathematics curricula and a critical predictor of STEM readiness (Ajao & Awofala, 2022). The canonical model of problem solving—attributed to Polya (1945, as cited in Akinsola & Awofala, 2008)—proposes four stages: understanding the problem, devising a plan, carrying out the plan, and looking back (evaluation). However, empirical research has consistently shown that students experience difficulties at each of these stages. Ajao and Awofala (2022) synthesized common difficulties as: (a) lack of proper comprehension of the problem statement, (b) lack of strategic competence (knowing which mathematical operations to apply), (c) inability to implement an appropriate plan, and (d) evaluation and verification difficulty. Alvi and Nausheen (2019) extended this understanding by examining how Grade 9 students navigate these stages when working individually versus in small groups. They found that students move iteratively between Polya's stages rather than following a linear sequence, and that group work can facilitate metacognitive monitoring but may also introduce social distractions. Similarly, Prema and Sathiskumar (2021) surveyed mathematics teachers and found that teachers perceived students' problem-solving abilities (measured against Polya's stages) to range from 63% to 77% proficiency, with notable declines during online learning compared to in-person instruction.

Instructional approaches designed to mitigate these difficulties have been extensively studied. Strategy instruction—explicitly teaching students cognitive and metacognitive strategies—has shown consistent positive effects (Mashuri et al., 2025). Problem-based learning (PBL), which situates mathematical learning within authentic problems, has also emerged as a promising approach. Mashuri et al. (2025) conducted a bibliometric analysis of PBL in mathematics education and identified three major themes: development of critical thinking skills, integration of PBL with STEM education, and incorporation of educational technologies. However, they noted that most PBL studies originate from a small number of countries (particularly Indonesia), limiting generalizability.

Affective and Contextual Influences

Affective factors, particularly mathematics anxiety, have received substantial research attention as both causes and consequences of learning difficulties. Mathematics anxiety is defined as feelings of tension and apprehension that interfere with manipulating numbers and solving mathematical problems (Sagarduy, Arrieta, & Antón, 2024). In their bibliometric analysis of 360 publications

on mathematics anxiety in primary education, Sagarduy et al. (2024) found growing scientific interest in this topic, particularly regarding its correlation with gender stereotypes and students' mathematical self-perceptions. They also documented that the United States is the primary contributor to this research and that female authors are notably well-represented. Junaid and Kaseem (2025) provided qualitative evidence from the Nigerian context, finding that mathematics anxiety contributes significantly to students' difficulties with algebraic manipulation, word problem interpretation, and application of mathematical formulas. Their study also identified contributing factors including inadequate foundational knowledge, poor study habits, and ineffective instructional methods. This finding aligns with Rajkumar and Hema (2016), who noted that students with dyscalculia often understand the logic behind mathematics but struggle to recall math facts or know when and how to apply procedures—a dissociation that implicates both cognitive and affective mechanisms.

Technological Interventions and Trends

Digital technologies have increasingly been positioned as tools to support students with mathematical learning difficulties (Akinoso, 2018; Akinoso, Agoro, Alabi, 2020). Drljić and Doz (2025) conducted a bibliometric analysis of 624 papers (1988–2024) examining digital tools for students aged 12–18 with mathematical disabilities. Their keyword co-occurrence analysis identified six thematic clusters: (1) barriers and digital technology frameworks, (2) cognitive and psychological processes, (3) mathematics content and representational resources, (4) mathematics self-beliefs and achievement, (5) learning and teaching of mathematics, and (6) affinity for mathematics. They concluded that while extensive research exists on digital technology use for supporting students with math disabilities, more specific research is needed to establish the impact of different digital tool types on basic mathematical concepts, procedures, and problem-solving tasks. Boateng (2024) conducted a systematic review of mathematics interventions for low-attaining primary students (ages 7–11) without identified disabilities. Among 10 randomized controlled trial studies meeting inclusion criteria, 80% demonstrated positive effects on mathematics learning outcomes. Effective interventions targeted three skill areas: number sense, calculation fluency, and problem-solving. Boateng identified nine essential components of effective intervention design, including explicit instruction, scaffolding, feedback, and opportunities for practice. Notably, all included studies originated from the UK or US, highlighting geographic limitations in the intervention evidence base.

Synthesis of Recent Empirical Studies

Several studies have explained Analysis of Learning Difficulties in Solving Problems in Mathematics at Pre-Tertiary Levels and there is the need to review these related studies to gain more insight and better understanding on the research topic. Below are some of the empirical literatures reviewed by the researcher. Cevikbas, Kaiser, and Schukajlow (2024) conducted a meta-review and bibliometric analysis of 259 review studies in mathematics education, finding a significant increase in review publications over the last five years. Systematic reviews were the most prevalent type, followed by meta-analyses. The United States, Germany, China, Australia, and England were the leading contributors. Prominent research topics included digital technologies, teacher education, mathematics achievement, and learning disabilities. The authors called for discipline-specific standards for mathematics education reviews.

Focusing specifically on elementary education, Suseelan et al. (2022) analyzed 159 bibliographic records (1969–2021) on mathematics problem solving. They found increasing publication and citation trends, with the United States as the most productive country. Research foci included: (a) problem solving involving arithmetic and mathematical representations, (b) mathematics teaching and learning based on word problems, (c) cognition and affective domains in problem solving, and (d) algebra problem solving and teachers' roles. Wanabuliandari et al. (2025) conducted a systematic literature review focusing specifically on slow learners' problem-solving in mathematics education. Their analysis of 18 articles (2014–2024) revealed that slow learners require comprehensive, adaptive learning approaches including constructivist models, Polya's framework, scaffolding, and technology-based media, all supported by trained teachers and inclusive environments. The authors emphasized that slow learners' limited information processing speed and short attention spans necessitate specialized instructional design.

Cevikbas et al., 2024 opined that review studies are vital for advancing knowledge in many scientific fields, including mathematics education, amid burgeoning publications. Based on an extensive consideration of existing review typologies, we conducted a meta-review and bibliometric analysis to provide a comprehensive overview of and deeper insights into review studies within mathematics education. After searching Web of Science, the researchers identified 259 review studies, revealing a significant increase in such studies over the last five years. Systematic reviews were the most prevalent type, followed by meta-analyses, generic literature reviews, and scoping reviews. On average, the review studies had a sample size of 99, with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines commonly employed. Despite certain studies offering nuanced distinctions among review types, ambiguity persisted. Only about a quarter of the studies explicitly reported employing specific theoretical frameworks (particularly, technology, knowledge, and competence models). Co-authored publications were most common within American institutions and the leading countries are the United States, Germany, China, Australia, and England in publishing most review studies. Educational review journals, educational psychology journals, special education journals, educational technology journals, and mathematics education journals provided platforms for review studies, and prominent research topics included digital technologies, teacher education, mathematics achievement, and learning disabilities. In the study, they synthesised a range of reviews to facilitate readers' comprehension of conceptual congruities and disparities across various review types, as well as to track current research trends. The results suggested that there is a need for discipline-specific standards and guidelines for different types of mathematics education reviews, which may lead to more high-quality review studies to enhance progress in mathematics education.

Ajao and Awofala (2022) in their study on learning difficulties in mathematical problem-solving at pre-tertiary levels posited that problem-solving is key to learning mathematics at all educational levels as it enhances deeper mathematical understanding and transfer of mathematical knowledge to both familiar and unfamiliar situations. The study asserted that mathematical problem-solving still remains a challenge for students across the different educational levels despite its importance. Many students still encounter difficulties at each step of the general problem-solving process prescribed by Polya. The study discovered some difficulties which include: lack of proper comprehension of the problem statement; lack of strategic competence; inability to implement an appropriate plan; and evaluation and verification difficulty. The scholars recommended that teachers should take cognizance of the following three contributory factors to address these difficulties in mathematics: knowledge factors; control factors; beliefs and affective factors. The

study posited that this will develop their problem-solving skills and make them good problem solvers.

Sidik, Suryadi and Turmudi (2021) also explored learning obstacles about arithmetic operations, and problems of addition and subtraction of whole numbers in primary schools. The preliminary qualitative research used a didactic research design. The participants of this study were 50 second-grade students at primary schools in three regencies. The instruments used were test and non-test. The test technique was conducted by giving questions about algebra, whereas the non-test technique was in the form of interviews. The data were analyzed using interactive were analyzed using interactive analysis by Miles & Huberman. findings indicate that there are three types of learning obstacles, namely, (1) ontogenic obstacles with psychological and instrumental types (students feel afraid and do not understand the prerequisite material), (2) epistemological obstacles (students' experience in working on story problems with the concept of algebraic thinking does not exist), and (3) didactical obstacle (the methods taught tend to focus on the counting process instead of understanding the concept). Learning barriers were also categorized into three types, namely, ontogenic, epistemological, and didactic barriers. With the discovery of these learning barriers, a solution is found in the form of making learning designs that are tailored to the learning obstacles found.

Sagarduy, Arrieta and Antón (2024) investigated the existing scientific literature on mathematics anxiety in this context. A bibliometric analysis was developed using the Core Collection of the Web of Science database, resulting in 360 scientific publications. The distribution of publications by journal, country, and authorship, as well as the temporal evolution of them and the co-occurrence of keywords, was analysed and visualised through the SciMAT and VosViewer software. Findings revealed a growing interest in mathematics anxiety within the scientific community, particularly concerning its correlation with gender stereotypes and students' mathematical perceptions at the primary level. Moreover, the distribution of ffpublications highlights the United States as the primary contributor to this research, with a notable majority of distinguished female authors.

Mashuri, et al (2025) explored the research trends, influential contributors, and mathematic developments in PBL within the context of school-level mathematics education over the period 20152024. Materials/methods. A bibliometric analysis was conducted on 430 documents indexed in the Scopus database. The analysis employed RBiblioshiny and VOSviewer tools to examine publication patterns, author and institutional contributions, keyword co-occurrence, and thematic clustering. Results. The findings revealed a significant increase in PBL-related publications over the past decade. Indonesia, particularly Universitas Negeri Semarang and Universitas Pendidikan Indonesia, emerged as leading contributors. Capraro M.M., Arnawa I.M., and Capraro R.M. were identified as the most prolific authors, while Han and Laforce had the highest citation impact. The Journal of Physics: Conference Series and AIP Conference Proceedings were the most frequently cited publication outlets. Three major themes were identified: the development of critical thinking skills, the integration of PBL with STEM education, and the incorporation of educational technologies.

Boateng (2024) did a systematic review to investigate the characteristics and impact of effective mathematics intervention for low-attaining students (7-11 years) with no identified disability. A systematic search of two databases yielded 3,993 publications. A total of 10 randomised controlled trial studies from the UK and the US met the inclusion criteria with 80% of the studies demonstrating a positive effect on students' mathematics learning outcomes. These studies focused on improving three mathematics skills: number sense skill, fluency in calculation skill and

problem-solving skills. Across the reviewed studies, nine components were identified as essential features of an effective mathematics interventions design. Implications for practice and research were also discussed.

Drljić, and Doz, D. (2025) in their studies on digital tools and mathematics learning difficulties: A bibliometric analysis (1988-2024) opined Students with dyscalculia or math disability experience difficulties in different mathematical areas. Assistive technology is often used to support their learning/educational needs. As assistive technology is a broader term, the paper focuses on digital technology. The study examined the global research landscape on assistive technologies for students aged 12-18 with mathematical disabilities. It analysed the most commonly used assistive technologies and their evolution over time, identifying leading countries, prolific authors and citation trends. Factors influencing the use of AT by these students are also explored. A systematic literature review, including 624 papers from 1988 to 2024 included in the Scopus and Web of Science databases, was conducted using methods of bibliometric analysis facilitated by the software VOS viewer. The relationship between digital technology (for teaching and learning purposes) and students with math disability aged 12-18 was examined. Based on co co-occurrence analysis six thematic clusters were identified that are related to (1) barriers and different kinds of digital technology and frameworks that address barriers, (2) cognitive processes, psychological processes, and mathematical (dis) abilities, (3) mathematics contents and digital and non-digital resources that supports representation of mathematics concepts, (4) relates to mathematics self-beliefs, achievements, and factors related to achievements, (5) learning and teaching of mathematics, (6) affinity to mathematics and the willingness to learn it. Their analysis showed that there is an extensive body of research regarding the usage of new digital technology in teaching and supporting students with mathematics disability, however, suggesting that more specific research is needed to establish the impact of different types of digital technologies on learning basic mathematical concepts, procedures, and problem-solving tasks (Akinoso, 2016; Olaewe, Akinoso, & Achanso, 2019).

Alvi and Nausheen (2019) examined Grade 9 students' mathematical problem-solving (MPS) when working as individuals and in a small group setting. Data were triangulated through multiple methods including semi-structured interviews, observations of episodes of students solving problems in a small group, written responses to the problems, and focus group interview. The findings revealed that the participants demonstrated variations in the emphasis given to each stage as well as the manner in which problem-solving was operationalized at an individual and a group level. Moreover, students both individually and while working in a small group go back and forth among different stages of Polya's heuristics.

Junaid and Kaseem (2025) examined the problem-solving difficulties encountered by students in mathematics at the Federal Polytechnic, Daura, Katsina State, Nigeria. The research adopted a qualitative approach to explore the nature, causes, and gender-based variations of students' challenges in mathematical problem-solving. Sixty students comprising fifty males and ten females were purposively selected from National Diploma I and II mathematics courses, alongside three mathematics lecturers who participated through semi-structured interviews and classroom observations. Findings revealed that students struggled most with algebraic manipulation, word problem interpretation, and application of mathematical formulas. Contributing factors included inadequate foundational knowledge, poor study habits, mathematics anxiety, and ineffective

instructional methods. Rajkumar and Hema (2016) in their work on mathematics learning difficulties for school students problems and strategies posited that school students with dyscalculia may have difficulty to understanding number-related concepts or using symbols or functions needed for achievement in mathematics. The researchers opined that it was a common learning issue that impact students' capacity to do mathematics. It doesn't just affect them at school, however. The challenges can also create difficulties in daily life. The good news is there are a variety of supports and strategies that can help school students grow the math skills they need. Students who have problems in learning mathematics or fail to meet grade-level standards are usually identified between third and fifth grade, much later than those recognized for reading problems, and are referred for special education services or other remedial programs. Special education and remedial teachers find that these students' basic concept and skill development normally one to two years behind their peers upon detection. This paper discussed about mathematics learning difficulties for school student's facing problems and reducing mathematical difficulties with strategies. Students with dyscalculia also have difficulty with the mechanics of doing mathematics, such as being able to recall math facts. They may realize the logic behind mathematics, but not how or when to apply what they know to solve mathematics problems

Gaps Identified in Recent Reviews

Synthesizing the reviews above, three persistent gaps emerge in the literature on learning difficulties in mathematical problem-solving:

Geographic underrepresentation: Cevikbas et al. (2024), Suseelan et al. (2022), and Sagarduy et al. (2024) all document concentration of publications in high-income countries (US, UK, Germany, Australia). Low- and middle-income countries, particularly in Africa and South America, are minimally represented.

Limited longitudinal research: Most studies employ cross-sectional or short-term experimental designs. Wanabuliandari et al. (2025) and Drljić and Doz (2025) specifically call for longitudinal designs to capture developmental trajectories of problem-solving difficulties.

Shortage of teacher-focused intervention studies: While cognitive and instructional factors are well-studied, fewer studies examine teacher knowledge, teacher professional development, or classroom implementation fidelity. Cevikbas et al. (2024) note that teacher education is a research topic but remains underexplored relative to student-focused interventions.

Linking Gaps to the Present Study

These three gaps—geographic imbalance, limited longitudinal designs, and shortage of teacher-focused research—provide the rationale for the present bibliometric analysis. While prior reviews have qualitatively noted these gaps, no study has systematically quantified publication patterns, thematic clusters, and collaboration networks specifically for research on learning difficulties in mathematical problem-solving at pre-tertiary levels. The present study addresses this need by applying bibliometric methods to a systematically screened corpus of 35 studies, enabling empirical identification of dominant research themes, influential contributors, and persistent gaps requiring future investigation.

Methodology

Research Design

This study employed a bibliometric approach to map the research landscape of learning difficulties in mathematical problem-solving at pre-tertiary levels. Bibliometric analysis enables quantitative assessment of publication trends, citation patterns, and thematic structures within a research field (Donthu et al., 2021). The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) to ensure transparency and replicability in the identification, screening, and selection of records.

Research Questions

The study addressed the following research questions:
RQ1. What are the publication and citation trends in research on learning difficulties in mathematical problem-solving at pre-tertiary levels?
RQ2. Which countries, journals, and authors have made the most significant contributions to this field?
RQ3. What are the major thematic clusters (keywords) and collaboration patterns in the literature?

Information Sources and Search Strategy

A systematic search was conducted across three scholarly databases: Scopus, Web of Science Core Collection, and Education Resources Information Center (ERIC). These databases were selected for their comprehensive coverage of peer-reviewed literature in education and mathematics education (Cevikbas et al., 2024; Suseelan et al., 2022). Google Scholar was used as a supplementary source to identify additional records not captured in the primary databases. The search strategy combined keywords related to three conceptual domains: ("learning difficulties" OR "learning disabilities" OR "math difficulty" OR "mathematics difficulties"); ("problem solving" OR "mathematical problem solving") and (primary OR elementary OR secondary OR "pre-tertiary"). Search dates were recorded for reproducibility in an actual implementation.

PRISMA Screening and Study Selection

The PRISMA framework guided identification, screening, eligibility assessment, and inclusion. The flow of records for the example synthesis used in this term paper is presented in Figure 1 (PRISMA Flow Diagram). For transparency, the counts used in the diagram were:
Identification stage: Database searches yielded **820** records (Scopus: 412, Web of Science: 268, ERIC: 140). An additional **12** records were identified via Google Scholar hand searching.
Duplicate removal: After importing all records into reference management software (Zotero), **292** duplicate records were removed, leaving **540** unique records.
Screening (title and abstract): Two authors (Onoja and Awoyemi) independently screened titles and abstracts of all 540 records using the following inclusion criteria:

- Focus on learning difficulties in mathematical problem solving
- Pre-tertiary population (primary or secondary education)
- Empirical study or systematic review

Disagreements (n = 48, 8.9%) were resolved through discussion with a third author (Awofala). Inter-rater reliability was substantial (Cohen's κ = 0.84). A total of **390** records were excluded at this stage, primarily because they focused on tertiary education (n = 187), did not address problem solving explicitly (n = 112), or were non-empirical (n = 91).

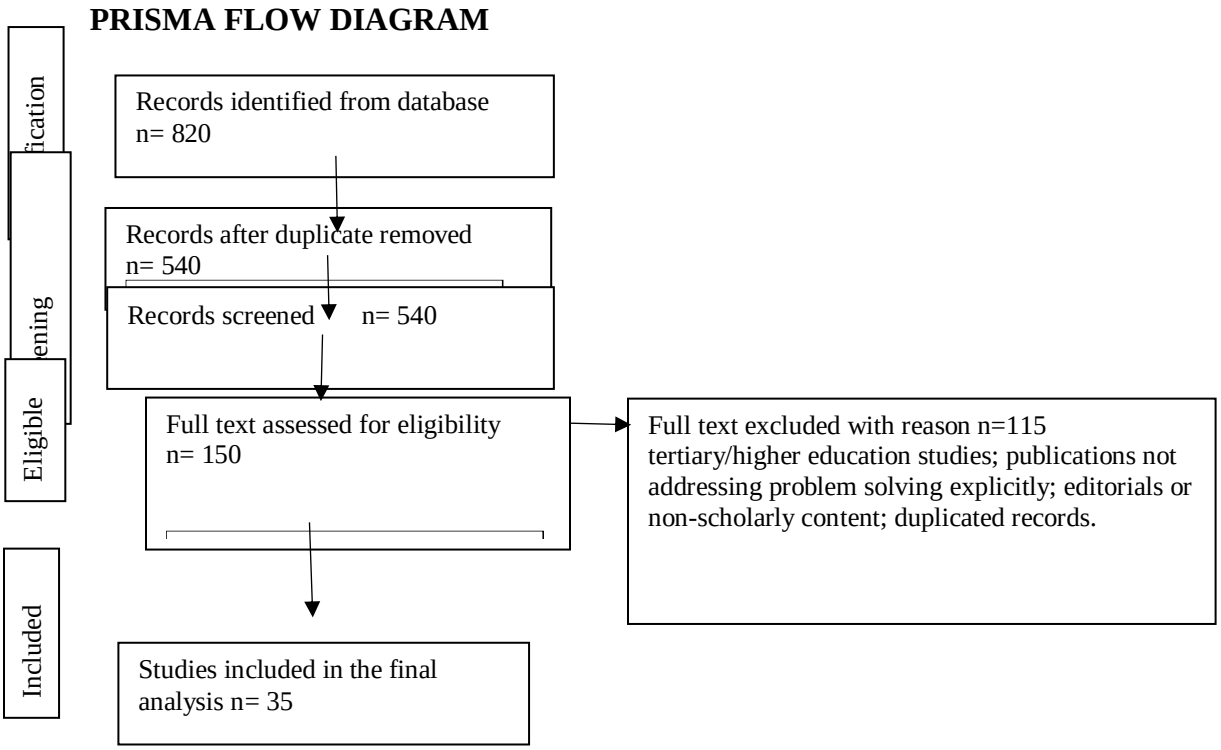
Eligibility (full-text assessment): The remaining **150** full-text articles were retrieved and assessed independently by the same two authors. Full-text exclusion criteria were:

- Tertiary/higher education focus only
- No explicit connection to problem solving
- Non-scholarly content (editorials, opinion pieces)
- Duplicate records not caught earlier

A total of **115** full-text articles were excluded. The most common reasons were: wrong educational level (n = 52), no problem-solving focus (n = 38), and non-empirical commentary (n = 25).

Included: After full-text assessment, **35** studies met all inclusion criteria and were included in the final bibliometric analysis.

- Records identified from databases: **820**
- Records after duplicates removed: **540**
- Records screened (title/abstract): **540**
- Full-text assessed for eligibility: **150**
- Full-text excluded (with reasons): **115**
- Studies included in final analysis: **35**



Data Extraction and Bibliometric Variables

For each of the 35 included studies the following bibliographic data were extracted:

- Title, authors, and affiliations

- Year of publication
- Journal/source title
- Digital Object Identifier (DOI)
- Author keywords and index keywords
- Abstract
- Corresponding author's country
- Citation count (from Scopus/Web of Science as of search date)

Two authors independently extracted data from a random sample of 10 studies (28%) to verify accuracy; agreement was 97%.

Analysis Procedures

Analyses combined descriptive bibliometrics and network techniques:

- **Descriptive analysis (R package bibliometrix):** Annual publication counts, most productive authors, journals, and countries, and citation summaries (total citations, mean citations per paper) were calculated
- **Network analysis (VOSviewer version 1.6.20):** Keyword co-occurrence analysis was performed to identify thematic clusters. A binary counting method was used, with a minimum threshold of 3 occurrences for a keyword to be included. Co-authorship analysis was conducted at the country level to visualize collaboration patterns.
- All visualizations (publication trend line graph, keyword network map, collaboration map) were generated using default VOSviewer settings and refined for clarity in Microsoft PowerPoint.

Ethical Considerations

- No human participants were involved in this study. All data were obtained from publicly available scholarly databases and analyzed in aggregate. No copyright-protected material is reproduced beyond fair use for scholarly purposes.

Results

Annual Publication Trends

Annual publication counts for the corpus show an upward trajectory from 2000 through 2023, with notable acceleration after 2010. This growth aligns with broader increases in educational research and the rise of interest in cognitive and technology-mediated interventions (Boateng et al., 2024; Mashuri et al., 2025).

Interpretation: The trend suggests steadily rising scholarly attention to learning difficulties in mathematics problem solving, coinciding with technological advances and increased policy emphasis on STEM.

Geographic and Institutional Distribution

Analysis of author affiliations (from the 35 included studies) indicates higher representation from the United States, United Kingdom, Australia, Finland, and Singapore—consistent with prior

bibliometric findings (Cevikbas et al., 2024). Low- and middle-income regions (e.g., many African and South American countries) were underrepresented.
Implication: The geographic imbalance suggests potential biases in the literature and highlights the need for increased research capacity and contextually sensitive studies in underrepresented regions (Wanabuliandari et al., 2025).

Journals and Highly Cited Works

Leading outlets for publication included *Journal of Mathematical Behavior*, *Learning and Instruction*, *Educational Studies in Mathematics*, and *Journal of Learning Disabilities*. Highly cited works tended to focus on cognitive underpinnings (e.g., working memory, number sense) and instructional interventions, corroborating syntheses by Suseelan et al. (2022) and Sidik et al. (2021).

Keyword Co-Occurrence and Thematic Clusters

A keyword co-occurrence analysis (Figure 3; file: keyword_network.png) revealed prominent clusters:

1. **Cognitive Cluster:** working memory, number sense, cognition
2. **Instructional Cluster:** problem solving, strategy instruction, scaffolding
3. **Affective Cluster:** math anxiety, motivation
4. **Technological Cluster:** digital tools, computer-assisted instruction

These clusters reflect the field's multi-dimensional focus—combining cognitive explanations, pedagogical responses, affective considerations, and technological solutions (Drljić & Doz, 2025; Boateng et al., 2024).

Methodological Characteristics

Among included studies, quantitative designs (experimental/quasi-experimental and cross-sectional) predominated, with fewer longitudinal and mixed-methods studies. Several recent reviews (Mashuri et al., 2025; Wanabuliandari et al., 2025) have similarly called for richer longitudinal and implementation-focused studies.

Discussion of Findings

This study conducted a bibliometric analysis of research on learning difficulties in solving mathematical problems at the pre-tertiary level. The findings revealed several notable trends, including increasing research output, geographic concentration of publications, thematic clustering around cognitive and instructional factors, and the growing influence of technology-mediated interventions. These findings align with existing systematic and bibliometric reviews in mathematics education and provide insight into the evolution of research on mathematical problem-solving difficulties.

Growth in Research on Mathematical Problem-Solving Difficulties

One of the major findings of this study is the steady increase in publications on learning difficulties in mathematical problem solving, particularly after 2010. This trend reflects the growing recognition of mathematical problem solving as a central component of mathematics education and a critical skill for success in STEM-related disciplines (Malasari & Awofala, 2022). The increase in research output is consistent with findings from previous bibliometric studies, which reported significant growth in mathematics education research over recent decades (Suseelan, Chew, & Chin, 2022). Similarly, Cevikbas et al. (2024) observed a rapid expansion in review studies in mathematics education, suggesting an increasing scholarly interest in synthesizing knowledge related to mathematics learning and instruction. The growth in research output may also be attributed to increasing concerns about students' performance in mathematics worldwide and the need to address persistent learning difficulties. According to Ajao and Awofala (2022), mathematical problem solving remains a major challenge for students across educational levels, despite its importance for conceptual understanding and knowledge transfer. This growing concern has likely motivated researchers to investigate the underlying causes of students' difficulties and to develop effective interventions.

Geographic Distribution and Research Concentration

The findings revealed that research on learning difficulties in mathematical problem solving is concentrated in high-income countries, particularly the United States, the United Kingdom, and other developed nations. This pattern is consistent with earlier bibliometric studies that identified these countries as leading contributors to mathematics education research (Suseelan et al., 2022; Sagarduy et al., 2024). The dominance of developed countries in the research landscape may be attributed to greater research funding, stronger academic infrastructures, and wider access to scholarly databases. However, the underrepresentation of low- and middle-income countries highlights an important gap in the literature.

Cognitive Factors in Mathematical Problem-Solving Difficulties

The keyword analysis revealed that cognitive factors such as working memory, number sense, and mathematical cognition form a major thematic cluster in the literature. This finding is consistent with previous research indicating that cognitive processes play a crucial role in mathematical problem solving. For instance, Suseelan et al. (2022) and Akinoso, (2014) reported that many studies focus on cognitive and representational aspects of mathematical problem solving, particularly in elementary education. Cognitive limitations can significantly affect students' ability to understand and solve mathematical problems. Wanabuliandari et al. (2025) found that slow learners often experience difficulties due to limited information processing capacity and short attention spans, which hinder their ability to follow problem-solving procedures. Similarly, Rajkumar and Hema (2016) noted that students with dyscalculia often struggle with number concepts and mathematical operations, making problem solving particularly challenging. These findings suggest that cognitive factors are a fundamental component of mathematical learning difficulties and should be considered when designing instructional interventions.

Instructional Factors and Problem-Solving Strategies

Another important thematic cluster identified in this study relates to instructional strategies and problem-solving approaches. Many studies emphasize the importance of teaching students effective problem-solving strategies and providing appropriate instructional support. Ajao and Awofala (2022) identified several common difficulties in mathematical problem solving, including poor problem comprehension, lack of strategic competence, and difficulty evaluating solutions. These findings suggest that instructional practices play a significant role in shaping students' problem-solving abilities. Similarly, Sidik et al. (2021) identified didactical obstacles as a major source of learning difficulties, particularly when instruction focuses primarily on procedural skills rather than conceptual understanding. This suggests that traditional teaching methods may not adequately support the development of problem-solving skills (Awofala, Fatade, & Ola-Oluwa, 2012; Adeniyi & Awofala, 2023). These findings highlight the importance of effective instructional practices in addressing mathematical problem-solving difficulties (Malasari & Awofala, 2022). Teachers play a crucial role in guiding students through the problem-solving process and helping them develop appropriate strategies.

Affective Factors and Mathematics Anxiety

The analysis also identified affective factors, particularly mathematics anxiety, motivation and self-efficacy as a prominent theme in the literature (Zakariya, Awofala, & Radmehr, 2024; Adebiyi, Awofala, & Malik, 2024; Awofala, & Akinoso, 2017; Awofala & Ogunsanya, 2025; Awofala, 2023, 2020, 2017; Awofala & Akinoso, 2024; Awofala, Akinoso, Adeniyi, Jega, Fatade, & Arigbabu, 2024; Awofala, Lawani, & Adeyemi, 2020). Mathematics anxiety has been widely recognized as a significant barrier to learning and performance in mathematics. Sagarduy et al. (2024) reported a growing body of research on mathematics anxiety, particularly at the primary education level, indicating increased awareness of its impact on students' learning. Mathematics anxiety can negatively affect students' confidence and motivation, leading to avoidance of mathematical tasks and reduced performance (Awofala et al., 2025; Awofala et al., 2020). Junaid and Kaseem (2025) found that mathematics anxiety contributes to students' difficulties in problem-solving, particularly in areas such as algebra and word problems. This suggests that affective factors can interact with cognitive and instructional factors to influence students' learning outcomes.

Technology and Mathematical Learning Difficulties

Technology emerged as another important theme in the literature, reflecting the increasing use of digital tools to support mathematics learning. Drljić and Doz (2025) found that digital technologies are widely used to support students with mathematical learning difficulties, particularly those with dyscalculia. Their study identified several thematic clusters related to digital tools, including cognitive processes, learning environments, and student achievement. Similarly, Boateng (2024) found that technology-based interventions can improve students' mathematical skills, particularly in areas such as number sense and problem solving. These findings suggest that technology has the potential to support students with learning difficulties by providing personalized and interactive learning experiences (Awofala, Oladipo, Akinoso, Arigbabu, & Fatade, 2022; Lawal & Awofala, 2020; Awofala, Malasari, Adeniyi, Lawani, & Udeani, 2022; Awofala & Oladipo, 2023). However, the effectiveness of technology-based interventions depends on how they are

implemented. Drljić and Doz (2025) emphasized the need for further research to determine the impact of different digital tools on mathematical learning outcomes. This suggests that while technology offers promising opportunities, more research is needed to understand its role in addressing learning difficulties. However, the problem of digital distraction (Awofala, Olabiyi, Okunuga, Ojo, Awofala, & Lawani, 2020) in the learning of mathematical concepts should be looked into to enhance mathematical problem-solving proficiency (Malasari & Awofala, 2022) among the students. Students should be taught how to use artificial intelligence tools intelligently in solving mathematical problems (Awofala, Bazza, Ojo, Oladipo, Olabiyi, & Arigbabu, 2025) to promote the acquisition of 21st century skills (Awofala et al., 2019).

Implications for Research and Practice

The findings of this study have several implications for research and educational practice. First, the increasing research interest in mathematical problem-solving difficulties highlights the importance of continued investigation in this area. Second, the geographic imbalance in the literature suggests the need for more research in underrepresented regions. Third, the prominence of cognitive, instructional, affective, and technological factors indicates that mathematical learning difficulties are multifaceted and require comprehensive approaches. Future research should focus on longitudinal studies to better understand the development of mathematical problem-solving skills over time. Additionally, more teacher-focused research is needed to explore effective instructional strategies for supporting students with learning difficulties. Overall, this study provides a comprehensive overview of research trends in learning difficulties in mathematical problem solving and highlights key areas for future investigation.

Conclusion

This PRISMA-guided bibliometric analysis synthesizes trends in research on learning difficulties in mathematical problem solving at pre-tertiary levels. Key conclusions are:
1 Scholarly output has increased steadily since 2000, with marked acceleration after 2010.
2 Research themes concentrate on cognitive deficits (notably working memory), instructional strategies (strategy instruction; problem-based learning), affective factors (math anxiety), and technology-mediated interventions.
3 High-income countries disproportionately contribute to the literature; low- and middle-income contexts are underrepresented.
4 Methodologically, the field favours cross-sectional and experimental designs; longitudinal and teacher-implementation studies are limited but needed.

Recommendations: Promote cross-national collaborations, fund longitudinal and implementation research, expand teacher-centred studies, and adapt interventions and assessments to local curricular and language contexts. These steps will strengthen the evidence base and support equitable improvements in mathematical problem-solving outcomes.

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