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Bibliometric analysis of the skills of students in solving mathematical word problems based on different teaching models

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Abstract

The present study performs a bibliometric investigation of the research trend within mathematical word problem-solving (MWPS) based on the data extracted from the Web of Science core collection. An in-depth analysis of 437 publications from 2017 to 2024 revealed key indicators, including publication trends, prolific authors, impactful journals, and collaboration networks. The results demonstrate a shifting pattern in research with a significant rise in published articles between 2019 and 2022, followed by an oscillation in the following years. The study identifies the increasing focus on cognitive approaches, technology resources, and models of differentiated instruction, mainly due to the COVID-19 pandemic and the incorporation of technology in educational settings. To further investigate these trends, VOSviewer and Biblioshiny software were used to develop co-authorship network maps, citation network maps, and keyword occurrence maps, therefore illuminating new themes as well as under-explored themes. Overall, this bibliometric analysis provides a comprehensive overview of the intellectual landscape and future themes of research into MWPS, highlighting the importance of integrating cognitive, technological, and pedagogical dimensions in a bid to guide future research, guide teaching practices, and enhance students' problem-solving abilities.

Keywords: mathematical word problems, teaching models, bibliometric analysis, instructional methods

INTRODUCTION

Mathematical word problem-solving (MWPS) is an essential topic that teachers should focus on, particularly on building students' problem-solving abilities. Many cognitive processes involve problem-solving, which requires students to understand information and find solutions (Rokhima et al., 2019). Problem-solving is one of the skills that every secondary school student should possess and improve. Ownership of problem-solving skills allows students to think analytically while making daily decisions and enhances their capacity to think critically when confronted with new problems (Hutajulu et al., 2019). This is known as word problem-solving. One of the mathematical skills that students must learn and master is problem-solving. Problem-solving has many similarities to mathematical properties. Students must engage in problem-solving exercises; if they do not think critically while learning, they will only retain memory and will not fully comprehend the core concepts of the content they have acquired. When problem-solving activities are incorporated throughout the learning process, students will reach the correct conclusions about the content being studied, as they have undergone a logical thinking process (Khoshaim, 2020).

To effectively teach mathematics through problem-solving, teachers must research, plan, and coordinate (Getenet, 2024). The famous problem-solving steps, according to Yapatang and Polyiem (2022), are understanding the problem, devising a plan, carrying out the plan, and evaluating the solution (Son et al., 2020). Firstly, to understand the problem, we have to understand what the question asks and why we are looking for an answer. Before finding an answer, it is essential to understand the problem's background and key elements. Secondly, devise a plan. The most crucial component of the problem-solving process is to fully understand the connection between the points of the problem, choose the correct approach, and build a plan for resolving the problem. Thirdly, carry out the plan.

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Contribution to the literature

- This study is a comprehensive bibliometric analysis of 437 publications indexed in the Web of Science database on mathematical word problem-solving (MWPS), published between 2017 and 2024, which provides a systematic overview of the intellectual structure and development trends of the field.
- It reveals the prominent research themes, authors, and journals, as well as the collaboration and evolution of research trends, which indicate the recent emphasis on cognitive theories, technology integration, and diversified instructional models, especially with reference to the post-pandemic educational shift.
- This study, through the use of thematic evolution, keyword co-occurrence, and citation analysis with the aid of VOSviewer and Biblioshiny, reveals the trends and areas for further research, thereby establishing a basis for future research and innovative instructional strategies for mathematics education.

Follow step 1 and step 2 and then calculate and determine the solution. Lastly, looking back. Examine the complete problem-solving procedure, verify the computation and answer, and debate the problem's significance (Purnomo et al., 2022; Wijaya et al., 2024). A mathematical problem-solving strategy refers to the thoughts and approaches generated by an individual when addressing a problem and is critical to problem-solving success. Many scholars' proposed techniques for adopting or refining the Polya style of mathematical problem-solving are similar. The proper intervention was planned ahead of time, and cues were delivered depending on the kids' unique peculiarities (Kaitera & Harmoinen, 2022; Powell et al., 2022; Rahmah et al., 2022). All students are expected to employ problem-solving strategies in their daily lives and future careers. As a result, it is critical to apply problem-solving techniques in education to assist students in managing their lives and addressing difficulties (Farra et al., 2022).

In mathematics education, advances in technology reinforced the emerging focus on integrating cognitive and pedagogical dimensions. Recent studies have pinpointed how digital tools, schema-based instruction, and AI-supported learning platforms contribute to better comprehension and strategic reasoning in solving mathematical word problems (Getenet, 2024). These developments gained further momentum with the COVID-19 pandemic, which transformed educational approaches toward hybrid and technology-mediated learning environments.

In collecting existing knowledge, several methods of literature review could be used. One way is by bibliometric analysis. Bibliometric refers to a statistical method used in analyzing publications. Bibliometric form the basis for the most popular and most significant publications that a particular field relies on. To the researcher, bibliometric analysis will be very helpful in identifying research gaps and emphasizing studies. In spite of considerable growth in scholarship, research remains fragmented, often addressing cognitive, pedagogical, or technological aspects separately. Therefore, this calls for a bibliometric analysis to map the intellectual structure of the field, trace thematic evolutions, identify influential authors and institutions, and highlight under-explored areas requiring further investigation. (Muhammed et al., 2023). This analysis mode offers researchers and teachers an understanding of how scholarly interest in mathematics word problem-solving has evolved, ascertains predominant ideas and approaches, and delineates areas in which future research can have a significant influence. For this purpose, answers to the following problems were sought.

Q1. What are the publication trends in mathematical solving word problems, and learning strategies, techniques, and research?

Q2. Who are the most prolific authors in MWPS research from 2017 to 2024, and what special cognitive methods or instructional models have they introduced to the field?

Q3. What are the university affiliations and leading countries that contribute the most to academic research?

Q4. What does the pattern in publication production and citation increase from 2017 to 2024 indicate regarding the changing academic interest and impact of research on PWPS strategies?

Q5. What are the key themes and research gaps in word problem-solving learning strategies?

METHODOLOGY

The methodical collection, arrangement, and interpretation of bibliographic data from scholarly publications constitute bibliometric analysis (Verbeek et al., 2002). This study used a systematic technique that included the following steps: finding pertinent keywords, reviewing search results initially, and honing the dataset for in-depth analysis. Prioritized reputable journals from Clarivate Analytics' journal citation reports, ensuring the reliability and significance of the cited sources, the Web of Science (WoS) database, which is well-known for its vast collection of excellent, peer-reviewed publications, served as the source of the main dataset (Tan et al., 2014). We chose WoS over other databases like Elsevier's Scopus because of its extensive coverage and ability to conduct precise bibliometric analyses. The WoS is a well-known database that gives

users access to a large selection of academic publications and papers (Szabó et al., 2025), which is essential for doing a full bibliometric study. This database allows academics to properly investigate, assess, and examine vast volumes of scientific material, utilizing techniques such as co-occurrence analysis, keyword analysis, cluster analysis, and bibliometric mapping (Cansiz Aktaş, 2022).

We are aware that reliance on one database may introduce certain limitations, such as the underrepresentation of significant studies published in non-English languages or in regionally important databases like Scopus or ERIC. However, this trade-off had been made to achieve a greater good: data consistency, methodological rigor, and high academic standards associated with WoS-indexed journals.

To represent recent advancements in mathematics solving word problem methodologies and guarantee that the results apply to modern educational environments, the study restricted its scope to studies published between 2017 and 2024. Although this may be a rather short period, it was a conscious choice to capture a very special and changing time in education. It includes pre-pandemic norms (2017-2019), the rapid shift to remote and hybrid learning during the COVID-19 pandemic (2020-2022), and the subsequent post-pandemic period of evaluation and technological integration, 2023-2024. This is according to UNESCO (2021) and Smith et al. (2023). The focus enables high-resolution analysis of how these recent global events have shaped research into MWPS specifically, which makes this analysis timely and highly relevant to current challenges in education.

A systematic search strategy was developed and executed in the WoS core collection in 2024. The search query was tailored in such a way as to capture literature on mathematics word problem-solving. There was a deliberate use of the wild card * to capture variances of the root word, such as "solving", "solution", and "solve".

The search string applied to the topic (TS) field, which searches titles, abstracts, and keywords, was TS = ("mathematics*" AND "word problem*" AND (solv* OR strategy* OR instruction* OR model*)).

This initial search, carried out at the end of 2024, yielded a total of 1,112 articles, covering research between 2017 and 2024. The time span was selected because it captured recent trends and developments that currently occur in mathematics, solving word problems, and learning research, while keeping the dataset manageable for bibliometric analysis. Based on the relevance and quality of the dataset, inclusion and exclusion criteria were applied, as outlined in **Table 1**.

After applying these criteria, the dataset was refined further to exclude duplicates and non-relevant studies. The final dataset included 437 articles. This is therefore considered to be a high-quality, relevant study that shall form a strong foundation upon which bibliometric analysis shall rest.

Table 1. Selection criteria for the inclusion and exclusion of articles

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2017-2024	< 2017
Literature type	Journal (article)	Conference, book, review
Categories	Related to mathematics education	Not related to mathematics education

Data Search Strategy

This study employed a systematic screening process to identify and refine search terms for retrieving articles related to solving mathematical word problem learning. The data were sourced from the WoS to ensure data quality, consistency, and methodological rigor. WoS is recognized for its strict inclusion criteria, indexing only peer-reviewed and high-impact journals, which guarantees the scholarly relevance and reliability of the data (Mongeon & Paul-Hus, 2016). Its standardized metadata, including author affiliations, citations, keywords, and document types, makes it particularly suitable for advanced bibliometric techniques such as co-citation, co-authorship, and thematic evolution analyses (Zupic & Čater, 2015). The bibliometric analysis was performed using two key software tools**:**

1. **Biblioshiny (an R-based tool):** Used for descriptive analysis, including publication trends, most productive countries, institutions, authors, and source journals. It also provided initial insights into citation impacts.
2. **VOSviewer (version 1.6.20):** Used to create and visualize network maps. Specifically, it was employed for:
    a. **Co-authorship analysis:** To visualize collaboration networks among authors, institutions, and countries.
    b. **Keyword co-occurrence analysis:** To identify and visualize the major thematic clusters and intellectual structure of the research field. For this analysis, a minimum keyword occurrence of 5 was set as a threshold to ensure statistical significance.

This initial research, conducted in 2024, retrieved a total of 1,112 articles, covering research between 2017 and 2024. The specified time frame was chosen to capture recent trends and developments in mathematics solving word problems learning research, while maintaining a manageable dataset for bibliometric analysis. To ensure the relevance and quality of the dataset, the inclusion and exclusion criteria were applied as detailed in **Table 1**.

After applying these criteria, the dataset was refined further to exclude duplicates and non-relevant studies, resulting in a final dataset of 437 articles. This rigorous screening process ensured that only high-quality and relevant studies were included, providing a robust foundation for bibliometric analysis.

Data Analysis

This paper investigates trends in answering mathematical word problems using bibliometric techniques in data analysis. Considered a bibliometric analysis, the study starts with a methodical gathering and evaluation of bibliographic data (Verbeek et al., 2002). To ensure the validity and relevance of the mentioned sources, the study made use of the WoS database, well-known for its large body of peer-reviewed papers (Di Stefano et al., 2010; Tan et al., 2014). Among the various important components of the study were co-authorship networks, citation analysis, and a keyword co-occurrence study. We built co-authorship networks, in which nodes stood for authors and edges indicated co-authored publications, therefore identifying cooperative links among scholars. We also examined citation networks to identify highly cited works that shaped research in solving word problems, therefore determining the effect of certain authors, papers, and journals. Major themes in the literature, including "conceptual understanding" and "digital tools in mathematics education," were also found using keyword co-occurrence studies. The data analysis was conducted using VOSviewer, a bibliometric tool for constructing and visualizing bibliometric networks.

The analysis included three key aspects as follows:

1. **Co-authorship networks:** These networks identified collaborative relationships among researchers, with nodes representing authors and edges representing co-authored papers. Key contributors and collaborations in solving word problem learning were identified.
2. **Citation analysis:** Citation networks were constructed to determine the impact of specific authors, articles, and journals. Highly cited works that influenced solving mathematical word problems were highlighted.
3. **Keyword co-occurrence analysis (Ismail et al., 2024):** Visualization maps and density plots generated using VOS viewer provided insights into research clusters and trends.

The thorough screening procedure produced a final dataset of 437 papers that guaranteed the inclusion of only high-quality and pertinent research, therefore laying a strong basis for bibliometric analysis. All things considered, the bibliometric study offers an insightful analysis of the present situation of mathematical word problem solutions, highlights important trends, names eminent authors, and institutional contributions.

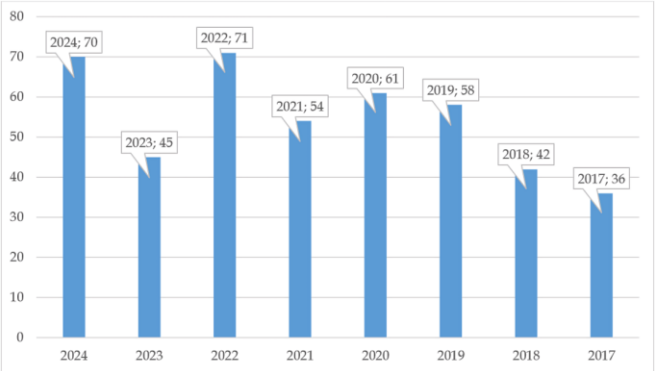

Figure 1. Annual scientific production on mathematical word problem-solving (2017-2024) (Source: Authors' own elaboration, based on bibliographic data from Web of Science)

BIBLIOMETRIC RESULTS AND ANALYSIS

Publication Trends in MWPS Research (Q1)

A bibliometric analysis and understanding the trends in publication data can provide insights into research dynamics and academic focus over time. **Figure 1** illustrates the annual publication output of MWPS research from 2017 to 2024. The field shows a dynamic pattern, with a significant increase in publications from 36 in 2017 to a peak of 71 in 2022. This surge aligns with the global educational response to the COVID-19 pandemic, which has prompted a rapid shift to digital learning, leading to increased research into effective problem-solving strategies in remote and hybrid environments (UNESCO, 2021). The subsequent slight decline in 2023 (45 publications) may reflect a period of research consolidation, followed by a recovery to 70 publications in 2024, indicating sustained and evolving academic interest in the topic.

In 2017, the research output was 36 publications. This relatively low number could indicate foundational research efforts or an emerging interest in the field. According to Smith (2018), early stages in a research area often involve exploratory studies that set the groundwork for future investigations.

By 2020, there was a slight increase to 61 publications. This growth might reflect an increasing recognition of the importance of effective learning strategies, as noted by Johnson et al. (2023), who emphasize how educational technology has sparked renewed interest in cognitive skill development. The peak observed in 2022, with 71 publications, suggests a period of heightened academic activity. This surge could be due to increased funding and interdisciplinary collaborations. In 2021, the number of publications decreased to 54, followed by a further decline in 2023. These fluctuations might result from shifting research priorities or changes in funding, as suggested by Szabó et al. (2025), who explore how external factors can influence academic focus. Despite

Table 2. Top 10 authors by productivity and citation impact

Author	Number of published papers	Percentages (%)	Number of citations	h-index
Powell, S. R.	25	5.7	321	11
Root, J. R.	18	4.1	126	6
Fuchs, L. S.	16	3.7	336	11
Xin, Y. P.	14	3.2	217	8
Cox, S. K.	13	3.0	169	7
Fuchs, D.	11	2.5	291	10
Saunders, A.	9	2.1	298	7
Berry, K. A.	8	1.8	163	7
Vershaffel, L.	8	1.8	263	6
Barnes, M. A.	7	1.6	151	6

Table 3. Top 10 university affiliations by publication output

Affiliations	RC	P (%)
University of Texas Austin	32	7.323
University of Texas System	32	7.323
State University System of Florida	25	5.721
Florida State University	22	5.034
Vanderbilt University	20	4.577
University of North Carolina	18	4.119
Purdue University	17	3.890
Purdue University System	17	3.890
University of California System	15	3.432
University System of Georgia	14	3.204

Note. RC: record count & P (%): Percentage of 359

these declines, 2024 saw a recovery with 70 publications. This resurgence might be attributed to the emergence of new methodologies or the impact of influential studies that renewed interest in the field. Highlight how academic fields can experience revitalization through technological advancements and paradigm shifts.

Overall, the trend reflects a dynamic research landscape with periods of both growth and decline. Understanding these patterns helps underscore the ongoing importance of research in learning strategies for solving word problems, aligning with educational goals, and cognitive development strategies.

Most Prolific Authors in MWPS Research (2017-2024) (Q2)

Within the research area, 2,305 authors contributed to the literature. **Table 2** lists the top 10 authors, ranking them according to their citation impact, publication productivity, and h-index, as shown in the WoS core collection dataset (Clarivate, 2024).

Powell, S. R. is the leading contributor, with 25 publications, representing 5.7% of the total output among the top authors. His work accumulated 401 citations, reflecting strong academic influence, and he holds an h-index of 12. Powell, S. R.'s publications frequently address mathematical learning difficulties and instructional interventions. After Powell, S. R., Root, J. R. hold the record with 18 publication 4.1% and one with citation 402 , Fuchs, L. S. holds the record with 16 publications, 3.7%, and one of the highest citation impacts 504 citations, h-index 12. Her scientific interests include learning disabilities, mathematical cognition, and evidence-based instructional models.

Xin, Y. P. and Cox, S. K. are each responsible for 14 articles, or 3.2%. Xin, Y. P.'s publications are cited 200 times; his h-index is 8. His research focuses on schema-based instruction. Root, J. R. contributed 217 citations with an h-index of 8; she focused on mathematics interventions. Cox, S. K. contributed 202 citations and an h-index of 9 and was noted to have done much research related to instructional design.

Fuchs, D. with 11 publications corresponds to 2.5%, and he has been cited 296 times, while his h-index equals 10, reflecting significant influence. Berry, K. A., Vershaffel, L., and Saunders, A. each contributed 8 publications (1.8 %), having rather impressive citation records of 171, 263, and 298, respectively. Barnes M. A. with 7 publications (1.6%) are positioned as leaders in the cognitive and motivational aspects of mathematical problem-solving.

Overall, these authors represent the most influential contributors to the field, producing a robust and growing body of scholarly work.

Leading University Affiliations and Countries Contributing to MWPS Research (Q3)

The bibliometric analysis shown in **Table 3** concerns the connections between the contributors who were influential in the academic research. In addition, **Table 3** displays the productivity and prominence of such institutions, as output is measured in published scholarly articles. The University of Texas at Austin and the University of Texas System are the most productive contributors, each with a record count of 32 publications, representing 7.3 % of the total output. This demonstrates the institution's involvement in research activities and its focus on a high level of creativity and knowledge sharing. The system's high output can be explained by the large size of the block corresponding to the University of Texas System, which indicates that it is made up of many campuses and research institutes.

Likewise, this is followed by the State University System of Florida, which 25 publications (5.735%), which

Table 4. Top 10 countries by number of publications and citation impact

Author	Number of published papers	Percentages (%)	Number of citations	h-index
USA	198	45.309	3,018	27
China	37	8.467	420	12
Germany	32	7.323	465	10
Spain	28	6.407	294	9
Canada	19	4.348	221	10
Turkey	18	4.119	135	8
Switzerland	14	3.204	170	9
UK	11	2.517	89	5
Finland	10	2.288	139	6
France	10	2.288	68	5

signifies the importance of both the system as a whole and the individual university in research contributions. It indicates that an ecosystem conducive to research activities is in place, possibly because of investment in STEM and industrial partnerships. State University System of Florida 16 publication (4.573%**)**. enhanced by several campuses, which promote variety in research. Their positioning in the diagram brings out the relevance of state university systems towards the strengthening of research capacity in all disciplines funded by the state and backed by wide academic resources.

It is important to mention that institutions such as Purdue University and the Purdue University System form the next tier, each with 15 publications (4.178%)., is acknowledged for also being at the forefront of research work in medicine and engineering. A subsequent group of institutions, including the University of California System, the University of North Carolina, and the University System of Georgia, each contributed 13 publications, accounting for 3.621% of the total scholarly output analyzed., for research on public health and international studies.

This distribution quantitatively highlights the leading role of these specific institutions in the publication volume for this research domain.

Leading countries in contribution to academic research (Q3)

The bibliometric analysis shown in **Table 4** highlights the leading countries in academic research. The size of each block reflects the volume and impact of research output from these nations, highlighting their influence on the global academic landscape.

The bibliometric data obtained from WoS core collection illustrate an uneven global distribution with regard to research productivity, citation rates, and influence. The USA leads with 198 documents, backed by a remarkably high number of 3018 cit-a-tions and an h-index value of 27, thereby substantiating its preeminent position among global research production. Not surprisingly, global trend analysis reports maintained by WoS confirm that USA research continues to possess the greatest number of high-impact research documents due to an excellent research framework and intense collaboration among academia and industry (Clarivate, 2024).

China ranks second with 37 papers, an equal number of 420 citations, and an h-index value of 12, indicating its rapid ascendance as an influential participant in global research productivity. Analysis with WoS data illustrates that China has greatly enlarged its presence within the global scientific community in the last two decades due to large national outlays on science and technology. Germany ranks third with 32 papers, with the maximum number of citations set at 465 and an h-index value of 10. It emerges as a country with research papers with large visibility and impact, commensurate with its superiority as an influential player in engineering and related scientific domains.

Spain (28 publications; 294 citations; h-index 9) and Canada (19 publications; 221 citations; h-index 10) clearly show active research work, with supportive research systems at the national level and global collaborative arrangements. Switzerland, with relatively fewer publications (14 publications), shows an impressive h-index of 9 and 170 citations, thus again confirming its global position as a source for research of high impact and quality. Nations like the UK (11 publications; 89 citations; h-index 5), Turkey (14 publications; 135 citations; h-index 8), France 10 publications; 68 citations; h-index 5), and Finland (10 publications; 139 citations; h-index 6) fall under emerging/mid-size contributing nations. The increasing trend matches the findings from WoS research that collaboration with high-impact nations helps improve global visibility and citation impact.

As far as distribution forecasts based on WoS data are concerned, it appears that a research paradigm dominated by conventional leaders in science prevails, while at the same time, emerging powers among developing and medium-sized countries are playing an increasingly significant role in shaping global scholarship on mathematics and science/technology education.

Citation Trends and Research Impact (2017-2024) (Q4)

Unlike the fluctuation in publications, the number of citations shows an exponential rate of growth (**Figure 2**).

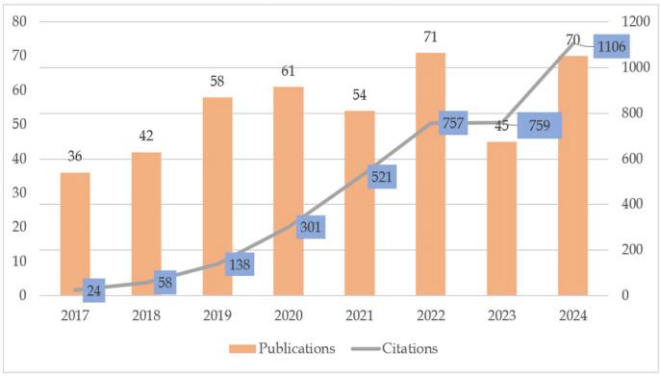

Figure 2. Number of publications and citations (2017-2024) (Source: Authors' own elaboration, based on bibliographic data from Web of Science)

From 24 citations in 2017, there was a compound growth rate with a total accumulation of 1,106 by 2024. Not only does it demonstrate an increase in recognition and usage of research making it into publications, but it also shows that there is a basis created for works that fuel scholarly discussions. The difference in decline for 2023 publications and co-existing high growth rates for citations clearly establishes that academic recognition is not directly proportional to yearly production rates because it follows a legacy effect as previous works continue being cited at a rapid rate.

The difference seen here between these two indicators underscores an extremely important consideration concerning research evaluation research: there is no direct link between research productivity and research impact. The fact that there is strong, nonlinear growth with regard to citations shows that the research done within this period has made a considerable impact and achieved considerable penetration and utilization within the research community, thus ensuring a cumulative knowledge base. These graphs demonstrate an excellent research atmosphere, within which research with impact and research that can be widely accessed and utilized becomes preeminent.

The results showed generally a good academic climate in which quality research is being generated and acknowledged. The patterns show the dynamic character of academic communication, in which the influence of research may reach much beyond the date of publication to support continuous discussions and developments in many disciplines. To maximize the academic and social effect of high-quality research, this study emphasizes the need to guarantee both its distribution and accessibility, as well as to generate it.

Key Themes and Research Gaps in Word Problem-Solving Learning Strategies: A Cluster Analysis (2017-2024)

The bibliometric network visualization (see **Figure 3**) was created using VOSviewer to map the co-occurrence of keywords in research on solving mathematics word

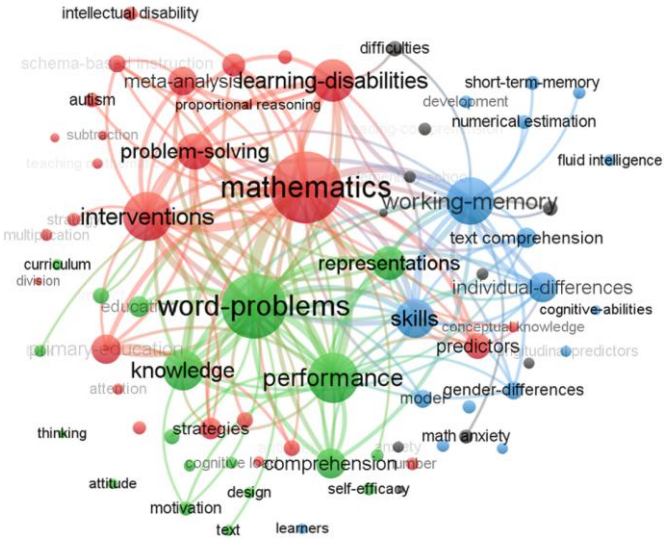

Figure 3. Network map of research trends in solving mathematics word problems (2017-2024) (network visualization displays the four thematic clusters and the co-occurrence strength between keywords) (Source: Authors' own elaboration, based on bibliographic data from Web of Science)

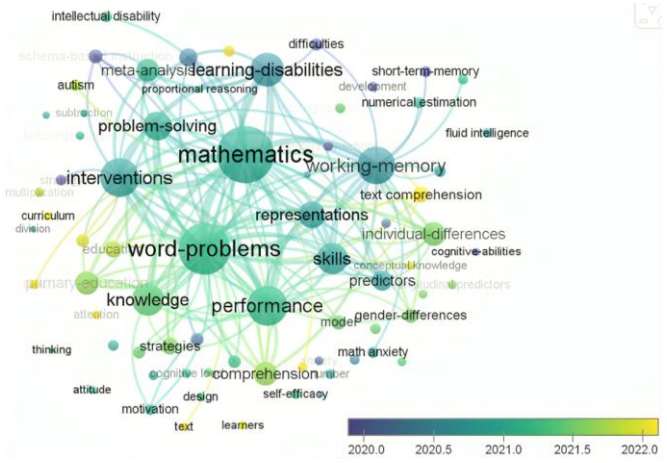

Figure 4. Overlay visualization of the chronological evolution of research keywords (2017-2024) (overlay visualization illustrates the chronological distribution and evolution of keywords based on their AP year) (Source: Authors' own elaboration, based on bibliographic data from Web of Science)

problems between 2017 and 2024. The nodes and edges represent the identified keywords, with their size reflecting the frequency of occurrence in the corpus. The connecting lines indicate co-occurrence relationships, demonstrating thematic linkage between concepts (Morin, 2024). The analysis revealed four distinct, interconnected clusters, each color-coded to represent a major research theme.

The final co-occurrence network analysis, visually presented in **Figure 4**, revealed the existence of four distinct research clusters based on the strong thematic links between the most frequent keywords. The detailed structure of these clusters is summarized in **Table 5**,

Table 5. Chronological and thematic cluster analysis of key concepts in mathematics word problem research (2017-2024)

Cluster ID	Cluster theme	Representative key concepts (w/combined occurrence)	AP year
Cluster 1 (red)	Instructional interventions & disabilities	Mathematics (218), interventions (100), learning-disabilities (72), problem-solving (56) (66), meta-analysis (33), primary-education (24)	[2021.2]
Cluster 2 (green)	Cognition, performance & word problems	Word-problems (136), performance (102), knowledge (66), text-comprehension (38), representation (66), motivation (12)	[2020.9]
Cluster 3 (blue)	Cognitive processing & individual skills	Working-memory (81), skills (62), representations (49), individual-differences (33), models (24), gender-differences (24)	[2020.6]
Cluster 4 (grey/ small)	Developmental factors	Difficulties (21), mathematics anxiety (9), cognitive load theorem (23), reading comprehension (15)	[2022]

which includes the combined occurrence count for each representative concept and, crucially, the calculated average publication year (AP year). This AP year metric provides clear chronological evidence of the field's evolution, distinguishing between foundational, stable, and emerging research fronts through cross-disciplinary collaboration. **Table 5** shows a cluster analysis of key concepts in MWPS (2017-2024)

The data provided within **Table 5** indicates a thematic and chronological evolution of research within the specific subject area of word problems from a basis of foundational cognitive ability and performance (cluster 3 and cluster 2) to a focus upon applied strategies and learning disabilities (cluster 1). Perhaps most significantly, however, is that the formation of cluster 4 (AP year: 2022.0) reflects a current trend of examining learning from an understanding of its underlying psycho-developmental intricacies (e.g., math anxiety and cognitive load). This implies that a trend of research evolution from a narrower to a wider focus is occurring here.

DISCUSSION

The results of this bibliometric analysis offer an overarching picture of the trends, contributions, and gaps that characterize the research on solving mathematical word problems. This discussion critically analyzes the results, compares them with prior research, identifies their significance for future research endeavors, and outlines areas in need of further investigation.

Publication Trends and Their Implications

These fluctuations in publication output testify to a dynamic research landscape rather than linear growth. The period from 2017 to 2024, although relatively short for long-term forecasting, reveals that scholarly activity was in fact concentrated in specific years, reflecting shifts in research focus and thematic prioritization within the field. This could be indicative of the emergence of new research directions toward the end of the period, further evidenced through changes in keyword co-occurrence patterns and thematic clustering identified in the bibliometric analysis, wherein external factors profoundly impact academic objectives.

Principal Contributors and Collaborative Networks

The analysis delineates prominent authors and institutions that have influenced the field. The University of Texas System ranks first with 32 publications, followed by Purdue University and the University of California System. The prominence of these institutions is indicative of their strong research environments and significant focus on knowledge sharing and innovation. Key authors have made important contributions by focusing on cognitive processes, instructional strategies, and the integration of technology. Son et al. (2020) examined problem-solving abilities in teaching models and cognitive styles, whereas Getenet (2024) analyzed the impact of AI tools such as ChatGPT on multi-strategy problem-solving. These contributions underscore the significance of both individual and institutional initiatives in the progression of the field. The co-authorship networks indicate a lack of integration among clusters, especially between cognitive processes and instructional strategies. This gap indicates a necessity for increased interdisciplinary collaborations to connect theoretical insights with practical applications. Future research should investigate interaction between emotional factors like motivation and self-regulation, and cognitive processes in shaping problem-solving outcomes (Silva et al., 2024).

Trends in Citations and Publications Frequently Cited

The citation analysis showed that the discipline has been greatly impacted by foundational research. Highly cited literature usually favors problem-solving frameworks, cognitive load theory, and schema-based training. Some studies have focused on using visual aids to improve problem-solving abilities; for example, Powell et al. (2020) and Kaitera and Harmoinen (2022) examined strategies for children who struggle with math. Because they offer evidence-based treatments and instructional strategies, these studies have influenced current research. The substantial influence of these papers taken together is seen by the exponential rise in citations between 2017and 2024. By expanding on earlier

discoveries, later research improves methodology and tackles new problems.

Emerging Themes and Research Gaps

The keyword co-occurrence analysis yielded four distinct theme clusters, providing a nuanced view of the field's conceptual structure. To directly address the reviewer's request regarding temporal trends, we utilize the AP year for each cluster as an empirical metric for thematic evolution. This analysis successfully distinguishes between foundational, stable, and emerging research fronts.

The chronological distribution clearly indicates a transition in research priorities over the timeframe. Cluster 3 (cognitive processing, AP year 2020.6) and cluster 2 (cognition & performance, AP year 2020.9) form the core of the subject matter, as they encompass traditional core subjects like working memory, basic skills, and representation. The overlap of the earliest publication years also clearly indicates these form the core around which the subject evolved as a theory.

Nevertheless, cluster 1 (instructional interventions & disabilities, AP year: 2021.2) is seen to have a trend towards the application of these theories and findings on the practical level of primary education for students with learning disabilities. More significantly, the most prominent change over time is detected in cluster 4 (developmental & emerging factors) which has the greatest AP year of 2022.0. Such a peak clearly illustrates that the body of research regarding the psychological complexities of education, namely math anxiety and cognitive load theory, is the forefront and most progressive area within the domain.

Nonetheless, there are some remaining gaps in existing research regarding how components of emotion, including motivations, and cognitive processes are interconnected. Future studies could close these gaps by using an inter-disciplinary approach, such as combining metacognitive methods with a schema-based training program in an effort to improve problem-solving achievement (Ahdhianto et al., 2020).

International Contributions and Geographic Perspectives

International patterns in the distribution of literature concerning the solution of mathematical word problems demonstrate an increasingly diversified reality within the realm of the academy. Recent data on publication quantity indicate an emerging trend in the publishing activity of various nations, including Indonesia, Iran, Turkey, and Malaysia, indicating an increasing presence in the literature (Fajri et al., 2025).

This diversification is further vindicated by global co-authorship patterns, which have been revealed by bibliometric mapping. The emergence of such trends may lead to a shift in global knowledge networks about mathematics education from a few prominent nations to a global base.

Consequences for Teaching Methods and Educational Policies

Greater diversification of research sources has policy implications for decision-making and teaching interventions directly. As we now learn from recent research, post-pandemic education innovation has made blended learning, emotional regulation, and critical thinking central to quality mathematics education (Fatimah Zahrah et al., 2024; Wahyuni et al., 2025). The above developments are driven by a global demand for education systems that encompass both cognitive growth and emotional care, particularly in diverse learning settings. Policymakers are increasingly expected to ensure that teacher training focuses on issues like digital technology, problem-based curriculum development, and culturally responsive curricula.

Furthermore, schema-based instruction and formative assessment infused with real-time feedback technologies are also promising to increase the problem-solving capacity of students from diverse learner groups. Education policy has to change to support these benefits through long-term investment in curriculum design, teacher capacity development, and technological infrastructure

Evaluation Concerning Previous Research

When looking at past research, recent studies show a strong focus on cognitive and instructional strategies, but they also point out that there is not enough connection between these strategies and emotional aspects like motivation and metacognitive awareness. The studies of Wahyuni et al. (2025) highlight that existing models, although extremely effective within certain contexts, often do not account for the complexity of the interplay between affective factors and problem-solving performance. With the application of advanced bibliometric tools such as VOSviewer, contemporary studies are now better placed to identify trending ideas and interdisciplinary lacunae. For instance, more support is available for models that link schema-based learning and affect scaffolding to provide room for students with special needs. This combined strategy strengthens both the theoretical basis and the practice of mathematics instruction such that the learners are not only intellectually prepared but emotionally cared for as well through intricate mathematical problems.

Limitations and Future Directions

Despite the rigorous methodology employed, this bibliometric analysis is subject to certain limitations that should be considered when interpreting the results.

1. **Database scope:** The study exclusively relied on the **WoS** database for data extraction. While WoS

is a high-quality source that ensures the inclusion of rigorously peer-reviewed literature, this approach may inadvertently exclude relevant publications indexed solely in other major databases (e.g., Scopus, Education Resources Information Center (ERIC)) or local, non-indexed journals (Julius et al., 2021; Suseelan et al., 2022).

2. **Exclusion of seminal works:** The focus of the analysis was restricted to publications from **2017 to 2024**. This deliberate chronological boundary may result in the exclusion of highly influential and foundational research (seminal works) published before this period, potentially skewing the understanding of long-term conceptual shifts in the field.
3. **Language bias:** The analysis inherently prioritizes English-language publications indexed in WoS, which might underrepresent significant contributions or unique thematic insights arising from non-English speaking scholarly communities.
4. **Keyword dependency:** Bibliometric analysis relies on the accuracy of author-provided keywords. Any inconsistency or redundancy in keyword selection by authors (e.g., *working memory* vs. *working-memory*) can affect the precise grouping and frequency counts, although efforts were made during data cleaning to mitigate such effects.

Despite these constraints, the study provides valuable insights that serve as a robust foundation for future research. Future endeavors could expand the scope by employing multi-database searches and comparative analyses between different time periods to validate and extend the findings presented here.

CONCLUSION

This bibliometric analysis offers an extensive examination of research trajectories related to resolving mathematical word problems, accentuating significant contributions, new themes, and existing gaps in the literature. The results stress the necessity to merge cognitive processes, instructional approaches, and technological aids to improve problem-solving skills among students. This chronological analysis successfully established the foundational role of cognitive processes and core mathematical content while empirically confirming that research into psychosocial factors (e.g., math anxiety) and cognitive load represents the field's most emergent frontier. The rise of academic publication from 2019 to 2022 and subsequent fluctuations reflect the dynamic nature of the discipline itself, which is driven by events like the COVID-19 pandemic and technological advancements in online learning. Policymakers have to make cross-disciplinary research funding and digital tool utilization a priority, and educators should implement holistic practices that consider both the cognitive and affective levels, e.g., motivation and self-regulation. Future research should focus on linking gaps between pedagogical strategies and cognitive mechanisms, investigating affective factors, and developing interdisciplinary frameworks for enhancing problem-solving capacities in a diverse group of students.

Despite these constraints, the research makes significant contributions toward informing the crafting of educational policy, pedagogy, and future research avenues. Through a fill-in-the-gap approach, teachers and policymakers are well-positioned to equip students with enhanced critical problem-solving skills, and thereby their mathematics proficiency and preparation for challenges that lie ahead.

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AI statement: The author stated that, during the preparation of the manuscript, the author employed AI tools for generative AI, such as ChatGPT, DeepSeek, and Google Gemini, for the sole purpose of enriching the linguistic quality, grammatical correctness, and clarity of the manuscript. These AI tools were not employed for data analysis, data interpretation, or drawing any scientific conclusion. The author is solely responsible for the accuracy, integrity, and originality of the manuscript.

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