

Assistive Technologies in Mathematics Education: A Bibliometric Analysis from 2006 to 2026

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ABSTRACT:

This study presents a bibliometric analysis of assistive technologies in mathematics education, mapping the intellectual structure and developmental trajectory of this research area from 2006 to 2026. Following the PRISMA 2020 protocol, 471 records were retrieved from the Scopus database and screened against inclusion criteria addressing publication timeframe, document type, and language, yielding a final dataset of 400 records eligible for analysis. Descriptive and citation metrics were computed in Microsoft Excel, and science mapping analyses, including co-authorship, keyword co-occurrence, thematic mapping, and three-field plot analysis, were performed using VOSviewer 1.6.20. Results indicate a generally upward publication trend, rising from 5 records in 2006 to a peak of 60 in 2025, with the United States contributing the largest share of output (233 records), followed by Canada, India, and the United Kingdom. Michigan State University and Purdue University emerged as the most productive institutions, while Thurlow M. L. and Bouck E.C. were the most prolific authors.

The dataset accumulated 5,077 total citations, led by a highly cited neuroscience-informed article on dyscalculia. Keyword co-occurrence analysis identified accessibility, assistive technology, mathematics, and accommodations as the dominant conceptual core, while artificial intelligence and machine learning emerged as a rapidly consolidating research front after 2023. These findings suggest that although the field remains anchored in longstanding themes of accommodation and accessibility, it is undergoing a technological reorientation toward intelligent and adaptive systems. The study offers researchers, educators, and technology developers an evidence-based overview of collaboration patterns, influential contributors, and emerging priorities in this growing interdisciplinary domain.

Keywords: assistive technology, mathematics education, bibliometric analysis, accessibility, disability, special education

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1. Introduction

Mathematics remains one of the most demanding academic domains for learners with

disabilities, largely because its representational systems, including symbolic notation, spatial layout, and multistep procedures, place heavy demands on visual processing and working

memory that many students with sensory, cognitive, or physical impairments experience differently from their peers (Butterworth et al., 2011). Over the past two decades, the convergence of special education and instructional technology has produced a substantial and steadily growing body of scholarship examining how assistive technology can reduce or remove barriers to mathematical learning.

This literature spans low-tech accommodations such as extended testing time and concrete or virtual manipulatives (Lewandowski et al., 2007; Bouck & Flanagan, 2010), moderate-tech tools such as talking calculators and text-to-speech applications, and increasingly sophisticated high-tech solutions such as tactile graphics generators, screen-reader-compatible mathematics rendering, and computational-thinking curricula for future special educators (Jayant et al., 2007; Soiffer, 2009; Bouck et al., 2021).

The scope of this research area has broadened considerably in recent years. Publications addressing inclusion outcomes for students with intellectual disabilities, testing accommodations, and universal design in postsecondary mathematics have long formed the core of the literature, while the period surrounding the disruption of in-person schooling brought about by the COVID-19 pandemic generated a distinct wave of scholarship on accessible remote mathematics instruction for undergraduates with disabilities.

More recently, the emergence of artificial intelligence and machine learning as tools for accessible content generation has begun to reshape the field's technological vocabulary. Given this accumulation of research across special education journals, computer science and human-computer interaction venues, and general education outlets, the literature on assistive technology in mathematics education has reached a stage of maturity that calls for a systematic, quantitative synthesis of its knowledge base.

1.2 Justification

Despite the volume of research on assistive technology and accessibility in mathematics, no

bibliometric study has yet mapped the intellectual structure, collaboration patterns, and thematic evolution of this specific literature across a twenty-year span.

Narrative and topic-bound reviews, such as those addressing dyscalculia (Butterworth et al., 2011) or universal design in undergraduate mathematics (Nieminen & Pesonen, 2020), offer valuable but circumscribed syntheses that do not capture the field's broader publication patterns. A bibliometric analysis complements this earlier work by applying quantitative and visual methods that reveal collaboration networks, influential authors, high-impact venues, and emerging research fronts that are difficult to detect through manual review alone (Donthu et al., 2021).

Understanding these patterns is of practical value to mathematics educators, instructional technology developers, special education researchers, and academic administrators who are seeking to identify collaboration opportunities, prioritize funding, and locate gaps in current knowledge, including the relatively recent but rapidly expanding interest in artificial intelligence and machine learning applications for mathematics accessibility.

Objectives

This study aims to:

1. describe the growth trajectory of publications on assistive technology in mathematics education between 2006 and 2026;
2. identify the leading countries, institutions, journals, and authors contributing to the field;
3. determine the most cited works and the most influential authors and journals;
4. map co-authorship, co-citation, and bibliographic coupling networks to reveal collaboration patterns and the intellectual structure of the field; and
5. examine keyword co-occurrence, thematic mapping, and trend topics to characterize the conceptual evolution of research in this domain.

2. Methodology

2.1 Data Sources

Bibliographic data were retrieved from the Scopus database. Scopus was selected because of its broad multidisciplinary coverage, which is well suited to a topic that spans special education, computer science, rehabilitation, and mathematics education, and because of the completeness of its citation and affiliation metadata, which supports rigorous quantitative synthesis (Donthu et al., 2021).

2.2 Search Strategy

The search was executed using the following Scopus query, applied to article titles, abstracts, and author keywords:

TITLE-ABS-KEY((mathematics OR math) AND ("assistive technology" OR accessibility OR adaptive OR accommodation*) AND (disabilit* OR "special education"))

This query combines three conceptual blocks joined by the Boolean operator AND: a mathematics-related term, an assistive-technology or accessibility-related term, and a disability or special-education term. Wildcard truncation was applied to accommodation and disability to capture morphological variants such as accommodations and disabilities. The initial search returned 471 records.

2.3 Inclusion and Exclusion Criteria

Screening followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure a transparent and reproducible selection process (Page et al., 2021).

Records were included if they concerned mathematics-related assistive technology or accessibility research, addressed a disability-focused or special-education population, fell within the publication window of 2006 to 2026, were classified under an eligible document type (article, conference paper, book chapter, review, or book), and were written in English.

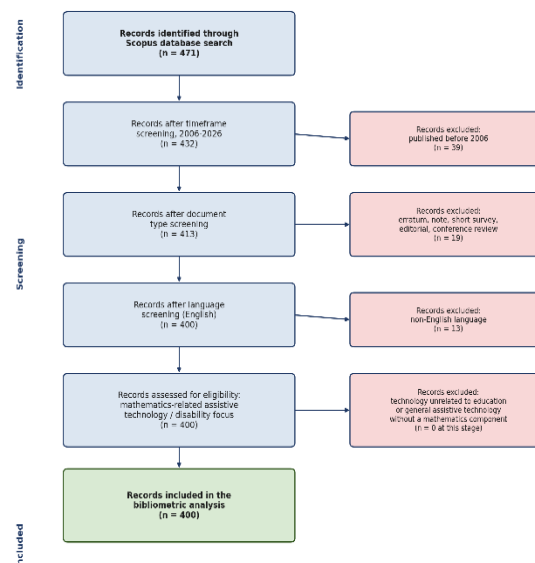


Figure 1: PRISMA 2020 flow diagram of the identification, screening, and inclusion process

Applying the timeframe criterion reduced the pool from 471 to 432 records, excluding 39 records published before 2006. Restricting document type to article, conference paper, book chapter, review, and book reduced the pool to 413 records, excluding 19 records classified as erratum, note, short survey, editorial, or conference review. Restricting language to English further reduced the pool to 400 records, excluding 13 non-English records. Records were also excluded at the eligibility stage if they addressed assistive technology in domains unrelated to education or if they discussed general assistive technology without a specific mathematics component. The final dataset comprised 400 records eligible for bibliometric analysis.

2.4 Data Cleaning and Pre-processing

Prior to analysis, the exported Scopus CSV file was cleaned to improve the accuracy of subsequent metrics. Author names were checked for spelling and initialization inconsistencies across records, and affiliation strings were parsed to standardize country and institution names. Duplicate records were checked using title and DOI matching, and no duplicates were found within the final dataset. Author keywords and index keywords were normalized to lowercase and trimmed of extraneous whitespace to

support accurate keyword co-occurrence counts. Missing citation counts were treated as zero rather than excluded, consistent with standard bibliometric practice (Donthu et al., 2021).

2.5 Data Analysis

Descriptive and citation metrics, including annual publication counts, author productivity, and journal and country distributions, were computed and tabulated in Microsoft Excel. Science mapping analyses, including co-authorship networks, keyword co-occurrence maps, co-citation analysis, bibliographic coupling, and thematic and trend mapping, were performed using VOSviewer version 1.6.20, a widely used software tool for constructing and visualizing bibliometric networks (van Eck & Waltman, 2010). Full counting was applied for co-authorship and keyword co-occurrence analyses, with a minimum threshold set on the number of documents per author and the number of occurrences per keyword to reduce visual noise from marginal nodes. The thematic mapping and three-field plot procedures follow the analytical logic popularized by the bibliometrix framework, which formalizes strategic-diagram construction on the basis of the centrality and density of keyword clusters (Aria & Cuccurullo, 2017).

3. Results

3.1 Descriptive Statistics

3.1.1 Publication growth over time

Between 2006 and 2026, the 400 records in the final dataset show a generally upward trajectory in scholarly output, punctuated by fluctuations typical of an emerging interdisciplinary field. Annual output rose from 5 publications in 2006 to a peak of 60 publications in 2025, the highest single-year total in the dataset, before easing to 22 records in the partial year of 2026. A first period of sustained growth appears between 2011 and 2014, when output rose from 16 to 23 publications a year, likely reflecting the expansion of mobile and tablet-based assistive technologies during that period. A second period of growth appears between 2019 and 2021, when output rose from 21 to 28 publications, coinciding with

the disruption of in-person schooling during the COVID-19 pandemic and the associated demand for accessible remote mathematics instruction (Gin et al., 2021). The sharp rise recorded in 2025 corresponds with an increase in publications addressing artificial intelligence and machine learning applications for accessible mathematics instruction, terms that were almost entirely absent from the literature before 2023.

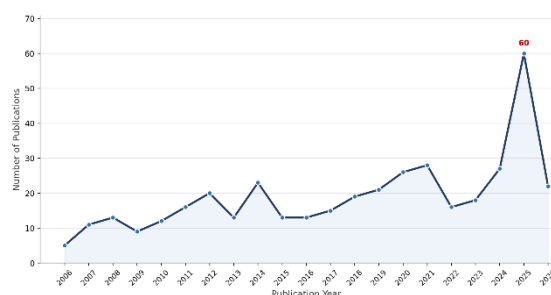


Figure 2: Annual scientific production, 2006-2026

3.1.2 Distribution by document type, country, institution, and journal

Of the 400 records, journal articles constitute the largest share (227 records, 56.8%), followed by conference papers (111 records, 27.8%), book chapters (39 records, 9.8%), reviews (14 records, 3.5%), and books (9 records, 2.3%). This distribution indicates that the field is anchored primarily in peer-reviewed journal literature while retaining a substantial conference-proceedings component, largely contributed by the computer-accessibility and engineering-education communities.

Author affiliations indicate that the United States dominates this research area, appearing in the affiliations of 233 of the 400 records. Canada (20 records), India (15), the United Kingdom (11), Italy (10), Spain (8), Saudi Arabia (7), Australia (7), and Greece (7) follow at a considerable distance, indicating that although the field draws contributions from more than 40 countries, its center of gravity remains concentrated in North America.

At the institutional level, Michigan State University (11 records) is the most productive single institution, followed by Purdue University (9), the University of Minnesota (8), the University of Louisville (7), the University of

Virginia (6), and George Mason University (6). This pattern reflects the strength of established special education and educational psychology programs in producing this literature.

At the journal level, publications are dispersed across special education, computer-accessibility, and general education venues. Lecture Notes in Computer Science (19 records, largely proceedings from the ACM ASSETS and ICCHP conference series) and the ASEE Annual Conference and Exposition proceedings (12 records).

Reflect a substantial computer-science and engineering-education contribution to this literature, while Education Sciences (9 records), the Journal of Learning Disabilities (7), and the Journal of Special Education Technology (7) represent the core special-education and educational-technology outlets.

3.1.3 Top contributing authors

Author-level productivity analysis identifies Bouck E.C. as the most prolific contributor, with 10 publications, spanning topics from virtual manipulatives (Bouck & Flanagan, 2010; Bouck et al., 2020) to computational-thinking instruction for preservice special education teachers (Bouck et al., 2021). Wei X. and Soiffer N. follow with 6 publications each. Soiffer's contributions concentrate on accessible mathematics rendering and speech-based delivery of mathematical content for screen-reader users (Soiffer, 2007, 2009). Witmer S.E. and Elliott S.N. each contributed 5 publications, largely addressing testing accommodations for students with disabilities.

3.2 Citation Analysis

3.2.1 Most cited articles

Across the 400 records, cumulative citations total 5,077, yielding a mean of approximately 12.7 citations per document. The single most cited work is Butterworth et al. (2011), a Science article on dyscalculia that has accumulated 573 citations, an outlier that reflects both the prestige of its publication venue and the foundational nature of its neuroscience-informed account of mathematical learning difficulty.

Other highly cited works include Gray et al. (2012) on computerized working memory training for adolescents with learning disabilities and comorbid ADHD (195 citations), Dessemontet et al. (2012) on inclusion and academic achievement among children with intellectual disabilities (174 citations), and Jayant et al. (2007) on automated tactile graphics translation (80 citations), an early and influential contribution to accessible mathematics diagram generation.

3.2.2 Highly cited authors and journals

When citation counts are examined at the document-type level, review articles carry the highest average impact, at 53.6 citations per document, followed by journal articles, at 15.9 citations per document. Conference papers and book chapters, despite their numerical contribution to the dataset, average markedly fewer citations, at 4.9 and 2.8 respectively, a pattern consistent with the generally shorter citation half-life of proceedings literature relative to journal articles (Donthu et al., 2021).

At the journal level, Science accounts for the single highest citation total (573, from one article), while CBE Life Sciences Education, with three publications and 195 total citations, records the highest average citation rate among journals contributing more than one document (65 citations per document).

Among special-education-specific outlets, Exceptional Children (4 records, 114 total citations, 28.5 average) and the Journal of Learning Disabilities (7 records, 127 total citations, 18.1 average) stand out as high-impact venues within the field's disciplinary core.

3.3 Science Mapping

The following subsections present the science mapping component of the analysis. Each map was generated in VOSviewer 1.6.20 following the parameters described in Section 2.5. Figures are indicated at the corresponding location and will be inserted following the completion of the network extraction and layout procedures.

3.3.1 Co-authorship networks

Co-authorship analysis was configured using full counting, with the minimum number of documents per author set to two, to reduce visual noise from single-contribution nodes. The resulting author network is intended to reveal the extent to which the field's most productive authors, including Bouck, Wei, and Soiffer, form interconnected research clusters or operate as largely independent contributors.

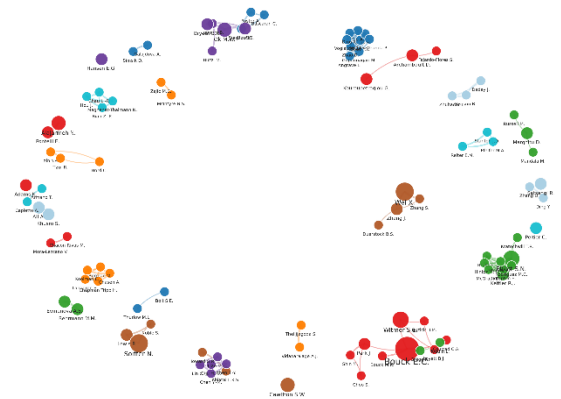


Figure 3: Co-authorship network of authors

At the institutional and country level, co-authorship maps are intended to show the extent to which international collaboration has developed alongside the dominant United States-based cluster identified in the descriptive analysis, and the degree to which research groups in Canada, the United Kingdom, and continental Europe operate as independent or interconnected nodes.

3.3.2 Co-occurrence of keywords

Keyword co-occurrence analysis of author keywords, using a minimum occurrence threshold of three, situates accessibility (46 occurrences), assistive technology (41), mathematics (34), STEM (25), accommodations (23), learning disabilities (22), students with disabilities (22), and special education (21) as the most frequently used terms in the dataset, forming the conceptual core of the field. Emerging terms such as artificial intelligence and machine learning, each appearing in 8 records, cluster almost exclusively within publications from 2023 onward, signaling an incipient but rapidly consolidating research front at the

intersection of artificial intelligence and mathematics accessibility.

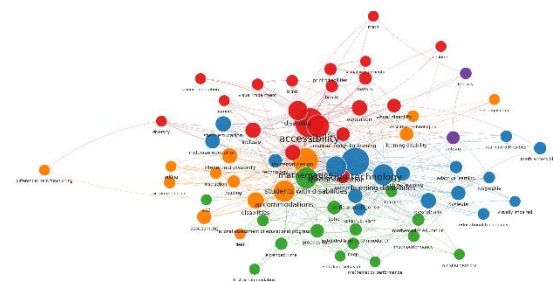


Figure 4: Keyword co-occurrence network (author keywords)

3.3.3 Co-citation analysis

At the author level, 117 authors met the minimum threshold of two documents and formed 140 co-authorship linkages. The network is dominated by small, densely connected clusters rather than a single unified core, indicating that collaboration in this field tends to occur within relatively closed research teams. Thurlow M.L. anchors the largest and most cohesive cluster, with sustained co-authorship ties reflecting a long-running research program optimizing special education through educational accountability, instructional decision-making, dropout prevention, and the valid integration and testing accommodation of students with disabilities. Burgstahler S. and Bouck E.C. form two further prominent clusters each, the former focuses on the application of Universal Design (UD) framework to technology, physical spaces, and student services, alongside the successful transition of youth with disabilities to postsecondary education and careers.

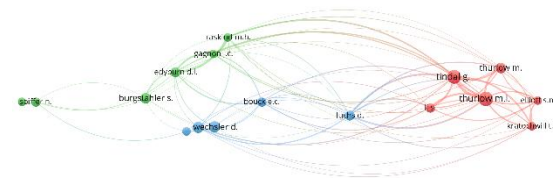


Figure 5: Document co-citation network

3.3.4 Bibliographic coupling

The bibliographic coupling analysis revealed a highly interconnected knowledge structure dominated by Butterworth (2011), which emerged as the most influential document in the network, as indicated by its large node size

and central position. This finding suggests that Butterworth (2011) shares a substantial reference base with many studies in the dataset and serves as a key intellectual foundation for the field. Several smaller clusters were identified around Jayant (2007), Chu (2009), Smith (2014), Senjam (2020), and Rabhi (2018), indicating the presence of related but distinct research streams.

The network also shows the emergence of more recent publications, including Elavsky (2024), Zhai (2024), Wanabuliandari (2025), and O'Brien (2025), which are connected to the core literature but occupy more peripheral positions. This pattern suggests that while the field remains strongly anchored to foundational studies, it is gradually expanding through new thematic directions and contemporary contributions.

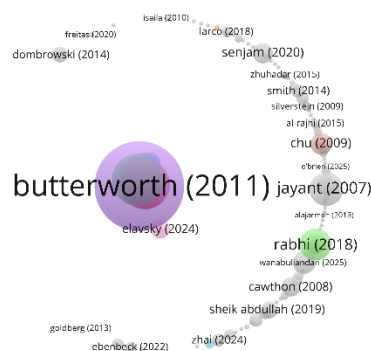


Figure 6: Bibliographic coupling network of documents

3.3.5 Thematic mapping

Thematic mapping situates the keyword clusters identified in Section 3.3.2 along the dimensions of centrality, or degree of interaction with other themes, and density, or degree of internal development. Five keyword clusters emerged from the co-occurrence network. A cluster built around assistive technology, special education, learning disabilities, and dyscalculia forms the field's largest and most internally developed theme, indicating a well-established motor theme. A second large cluster built around accessibility, STEM, disability, and universal design shows comparably high centrality, reflecting its strong interconnection with the field's other conceptual clusters. A third cluster centered on mathematics, accommodations, and intellectual disability, and a fourth built around students with disabilities,

extended time, and process data, occupy more moderate positions, consistent with established but comparatively narrower basic themes. A small residual cluster limited to autism and literacy occupies the low-centrality, low-density quadrant typically associated with peripheral or still-emerging themes.

3.3.6 Trend topics and thematic evolution

Trend topic analysis, based on the weighted median publication year of each keyword occurring at least three times, indicates a clear temporal ordering in the field's vocabulary. Older terms such as print disabilities, mathml, and technology carry median years in the early 2010s or before, while accessibility, assistive technology, and mathematics cluster around a median of 2018 to 2019. The most recent terms, including artificial intelligence, machine learning, adaptive learning, process data, and extended time accommodation, carry median years of 2025, confirming that these concepts have entered the literature only very recently and are still gaining ground.

A complementary thematic evolution map, comparing the 2006-2015 and 2016-2026 sub-periods, shows that the accommodation-centered clusters of the earlier period, built around assistive technology and special education, and around accommodations and students with disabilities, persist into the later period but expand substantially in size and connect increasingly to STEM- and disability-focused vocabulary. This pattern indicates continuity rather than replacement: the field's foundational themes have not been displaced by newer technological concerns but have instead absorbed and been reorganized around them.

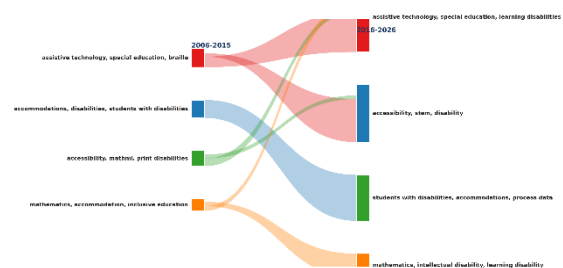


Figure 7: Thematic evolution map across sub-periods

3.3.7 Three-field plot analysis

A three-field plot linking the most productive authors, their most frequent keywords, and the journals in which they publish was constructed to visualize these three dimensions jointly. Bouck E.C. and Wei X. connect most strongly to accessibility- and accommodation-related keywords, which in turn flow predominantly toward special-education and educational-technology outlets such as the *Journal of Learning Disabilities* and the *Journal of Special Education Technology*, while Soiffer N.'s keyword profile flows more heavily toward computer-science and accessibility-conference venues such as *Lecture Notes in Computer Science* and the *ACM International Conference Proceeding Series*, reflecting the field's dual disciplinary character as both an educational and a computing research area.

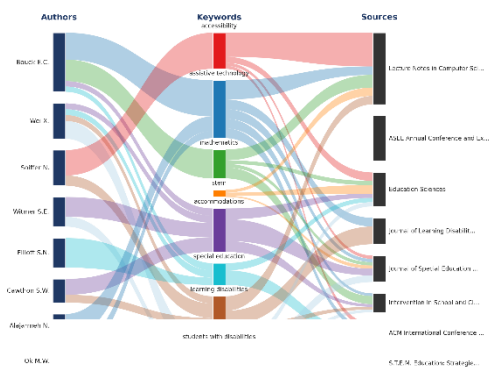


Figure 8: Three-field plot of authors, keywords, and sources

4. Discussion

The results of this bibliometric analysis offer a quantitative portrait of how assistive technology research in mathematics education has developed over the past two decades, and several patterns merit closer interpretation.

The steady growth in publication output, culminating in a peak of 60 records in 2025, suggests that this field has moved from a peripheral concern within special education toward a more established research area in its own right. The two visible inflection points, one around 2011 to 2014 and another around 2019 to 2021, align plausibly with the diffusion of mobile and tablet-based technologies and with the

accessibility demands created by the abrupt shift to remote instruction during the COVID-19 pandemic (Gin et al., 2021). The most recent surge, driven by keywords such as artificial intelligence and machine learning, indicates that the field is now undergoing a technological reorientation rather than merely continuing its earlier growth trajectory, a pattern consistent with how emerging technologies tend to generate rapid publication bursts once early feasibility work demonstrates their applicability to accessibility problems.

The concentration of output in the United States, together with the prominence of institutions such as Michigan State University and Purdue University, points to a research infrastructure that remains geographically uneven. This is not unusual in special education research more broadly, but it does raise a substantive question about whether solutions developed and validated primarily within a single national policy and schooling context, such as those addressing accommodations under U.S. special education law, generalize easily to other educational systems. The relatively modest presence of collaboration across country clusters, as shown in the co-authorship mapping, reinforces this concern and suggests that international cross-pollination remains an area for growth.

At the author level, the productivity of scholars such as Bouck, whose work spans virtual manipulatives and computational thinking instruction for preservice teachers (Bouck & Flanagan, 2010; Bouck et al., 2020), and Soiffer, whose contributions to accessible mathematics rendering for screen-reader users represent some of the field's earliest technical solutions (Soiffer, 2009), illustrates how a small number of sustained research programs have shaped the field's technical vocabulary over time. This pattern is consistent with the general finding in bibliometric scholarship that productivity in emerging interdisciplinary fields tends to cluster around a limited set of anchor researchers before broadening (Donthu et al., 2021).

The citation analysis reveals a further nuance: review articles and a small number of high-visibility works, most notably the neuroscience-informed account of dyscalculia by Butterworth et al. (2011), account for a disproportionate share of total citation impact. This is consistent with a broader pattern in the literature whereby synthesis pieces and works published in high-prestige, general-science outlets accumulate citations at a rate that specialized applied work, such as conference proceedings on assistive tools, rarely matches (Donthu et al., 2021). This does not necessarily mean that applied, tool-focused contributions are less important to practice; it more likely reflects differences in audience size and citation practices across disciplinary communities.

The keyword co-occurrence and thematic mapping results indicate that the conceptual core of the field, built around accessibility, accommodations, and assistive technology, has remained relatively stable, while newer clusters organized around artificial intelligence and adaptive learning are only beginning to consolidate. Read alongside the thematic evolution map, this suggests the field is in a transitional phase: established accommodation-oriented research continues to anchor the literature, even as a distinct and still-developing research front addresses how intelligent systems might reshape accessible mathematics instruction going forward (Nieminen & Pesonen, 2020).

Two limitations may temper these interpretations. First, the analysis draws on a single database, and although Scopus offers strong multidisciplinary coverage, some relevant work indexed only in other databases may be absent (van Eck & Waltman, 2010). Second, co-citation and bibliographic coupling analyses could not be performed because the exported records did not include full cited-reference lists, which limits the extent to which the field's deeper intellectual lineage could be mapped using the science mapping procedures associated with tools such as VOSviewer (van Eck & Waltman, 2010) and bibliometrix (Aria & Cuccurullo, 2017).

5. Conclusion

This bibliometric analysis traced the development of assistive technology research in mathematics education from 2006 to 2026 using a Scopus-derived dataset of 400 records. The findings show a field that has grown steadily, and in recent years sharply, moving from a small and scattered literature to a more established area with recognizable core themes, productive research groups, and a defined citation structure. Accessibility, accommodations, and assistive technology remain the field's conceptual anchors, while artificial intelligence and machine learning represent an emerging front that is beginning to reshape its technological vocabulary. Research output remains heavily concentrated in the United States and in a small number of institutions and authors, and international collaboration, while present, is not yet extensive. Citation impact is likewise uneven, with a handful of highly cited works, particularly those published in high-visibility, general-science venues, accounting for a disproportionate share of the field's overall influence. Taken together, these patterns suggest a field that is maturing in scope and output but that still has room to diversify in terms of geographic reach, collaborative depth, and the range of venues through which its most significant findings reach a broader audience.

Based on these findings, several recommendations can be offered. First, researchers and funding bodies in countries outside the current productivity core, particularly in regions with limited representation in this dataset, could be encouraged to invest in and publish assistive technology research specific to mathematics education, since current findings may not generalize well across different educational systems and policy contexts. Second, greater cross-institutional and cross-country collaboration could be pursued deliberately, as the co-authorship analysis indicates that many research groups currently operate in relative isolation from one another. Third, given the rapid and recent emergence of artificial intelligence and machine learning as keywords in this literature, scholars are encouraged to pursue rigorous, replicable studies in this area now, while the

research front is still forming, so that its evidence base develops with the same methodological care applied to more established assistive technology approaches. Fourth, researchers producing applied and tool-focused work, which this analysis shows tends to receive fewer citations than broader synthesis or general-science publications, could consider pairing technical contributions with review or synthesis pieces that can reach a wider readership and better

demonstrate their practical significance. Finally, future bibliometric work on this topic would benefit from a multi-database approach that includes full cited-reference data, which would allow co-citation and bibliographic coupling analyses to be performed and would offer a more complete picture of the field's intellectual foundations than was possible using the Scopus export alone.

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8. Author Declaration

The author declares that this manuscript is an original work. All sources of information have been appropriately acknowledged and cited in accordance with accepted scholarly and ethical standards. The author also declares that there are no financial, professional, personal, or institutional conflicts of interest that could have influenced the conduct of the study, the interpretation of the findings, or the preparation of this manuscript.