A Bibliometric Analysis of Trends and Keywords in Assessing Students' Preparedness for Mathematics Courses

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ABSTRACT

This study offers a comprehensive bibliometric analysis aimed at uncovering research trends and the evolution of keywords in the field of assessing students' preparedness for Mathematics courses. Data were sourced from the Scopus database, focusing on English-language articles published between 1932 and 2023, excluding current-year publications. A total of 1,703 articles were initially retrieved, with 1,362 meeting the inclusion criteria for further analysis. These articles were systematically examined to identify patterns among leading countries, authors, and journals. The study categorizes the evolution of key topics into four distinct phases: the Initial phase (1933-1983), the Development phase 1 (1984-2003), the Development phase 2 (2004-2013) and the Exploration phase (2014-2023). The findings highlight that the United States leads global contributions, representing 49.34% of the total publications, with Enno Ed Koehn standing out as the most influential author in this domain. The International Journal of Mathematical Education in Science and Technology was identified as the most productive journal, publishing 38 articles with a total of 669 citations. Furthermore, the analysis revealed a remarkable growth in keyword co-occurrences, expanding from 64 keywords to 4,011 over the past 90 years. These findings provide valuable insights for researchers by highlighting existing research gaps in citation metrics, collaboration among leading countries and academic institutions, prominent authors, leading journals, popular subject areas and keywords co-occurrence trends and evolution. This study thus serves as a vital resource for shaping future research strategies and encouraging collaborative efforts within the field.

INTRODUCTION

Evaluating students' preparedness for mathematical courses is a crucial issue in secondary and tertiary education. A student's aptitude for Mathematics is influenced by various factors, including prior knowledge, mental aptitude, and affective traits such as motivation and self-confidence. The pressing need to enhance mathematics education is underscored by ongoing challenges with student readiness, which contribute to high failure and dropout rates in math-related courses, particularly in higher education. Consequently, educators and researchers have sought methods to assess and address gaps in students' mathematical competencies.

Mathematics readiness is closely linked to students' prior secondary school experiences, particularly in foundational subjects like algebra and geometry, which establish the groundwork for more advanced concepts. According to [1], students' study habits, motivation, and ability to apply mathematical theories to real-world situations significantly impact their academic success, underscoring the necessity for targeted strategies to enhance Mathematics education. Moreover, preparedness encompasses more than just knowledge; students

must also exhibit problem-solving skills, logical reasoning, and the ability to apply mathematical principles in unfamiliar contexts.

In recent decades, various methods for assessing students' preparedness for Mathematics courses have been explored, with diagnostic testing becoming a key approach to identify knowledge gaps. Akveld and Kinnear [2] emphasize how universities use these tests to evaluate incoming students' readiness. By applying item response theory, these assessments provide deeper insights into students' abilities, helping educators target specific areas for improvement. These evaluations are vital for tailoring lesson plans to individual needs, ultimately enhancing students' chances of success. Additionally, standardized exams like the SAT and ACT play a crucial role in measuring readiness for college-level Mathematics.

Another important aspect focuses on the emotional factors that influence students' mathematical performance. Cuder et al. [3] highlight that math anxiety and self-efficacy are crucial in shaping middle school students' STEM choices, offering new perspectives for early interventions aimed at promoting more informed decisions. This suggests that evaluations of preparedness for Mathematics courses should consider both cognitive abilities and emotional factors like anxiety and confidence, which affect student success.

Furthermore, contemporary research increasingly emphasizes data-driven and technology-enhanced approaches to evaluating readiness. The rise of online learning platforms facilitates the collection of substantial performance data, which enables effective readiness analysis. This focus aligns with the United Nations' 2030 agenda, highlighting quality education as essential for inclusivity and equity. Abid Haleem et al. [4] assert that digital technologies are crucial in achieving these educational objectives. Their integration, accelerated by the COVID-19 pandemic, has transformed learning environments, enhancing student engagement and fostering greater interest in Mathematics.

While these studies provide valuable insights into assessing students' mathematical preparedness, a broader understanding of the field's research landscape can be attained through bibliometric analysis. By examining publication trends and keyword evolution in this domain, we can identify prevailing research trends, publication volume and growth, key contributors, and the relevance of keywords.

Bibliometric research serves as a vital tool for educators and policymakers, highlighting the volume and impact of research dedicated to evaluating students' preparedness. Through the analysis of publication trends and citation metrics, we can discern how various factors, including cognitive and affective dimensions, have been explored over time.

This study seeks to explore the following critical research questions: (RQ1) What are the emerging trends in assessing students' preparedness in Mathematics courses, and which influential articles, prominent authors, and impactful journals have made substantial contributions to this area of research? (RQ2) What are the key themes within the existing literature on assessing students' mathematical preparedness, and how have these themes developed over time?

METHODOLOGY

This research will extract the bibliographic data from the Scopus database on March 5, 2024, utilizing the query string as presented in Figure 1 as suggested to search the selected topic. The Scopus database was employed in this study since it is one of the largest databases available to scholars for doing literature reviews on a variety of topics [5]. Instead of Scopus, the data may also be obtained using the Web of Science database and Anne-Will Harzing's Publish or Perish software [6], [7]. However, there exists a constraint on the overall quantity of documents that may be retrieved, which is capped at 1000 only at one time [8]. Meanwhile, Scopus is capable of retrieving a greater quantity at one time. The bibliometric analysis conducted in this study will closely follow the methodology outlined by [7], with an additional step, which is citation metrics analysis between initial and refinement results using the Publish or Perish software, as shown in Figure 1 below.

DATA COLLECTION

STEP 1: MAIN TOPIC SEARCH
- TITLE-ABS-KEY (student* AND prepared* AND for AND math*) Scopus
- Results: 1703 documents

STEP 2: REFINEMENT DOCUMENTS
- Exclude current year publication (2024)
- Type of documents: articles only.
- Language: English only.
- TITLE-ABS-KEY (student* AND prepared* AND for AND math*) AND PUBYEAR > 1932 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))
- Results: 1362 documents

DATA ANALYSIS

STEP 3: BIBLIOMETRIC ANALYSIS
- Citation metrics
- Research trends
  - a) Leading country and academic institutions
  - b) Prominent author with the most cited articles
  - c) Productive journals
  - d) Most popular subject areas
- Keywords co-occurrence trends and evolution

Publish or Perish
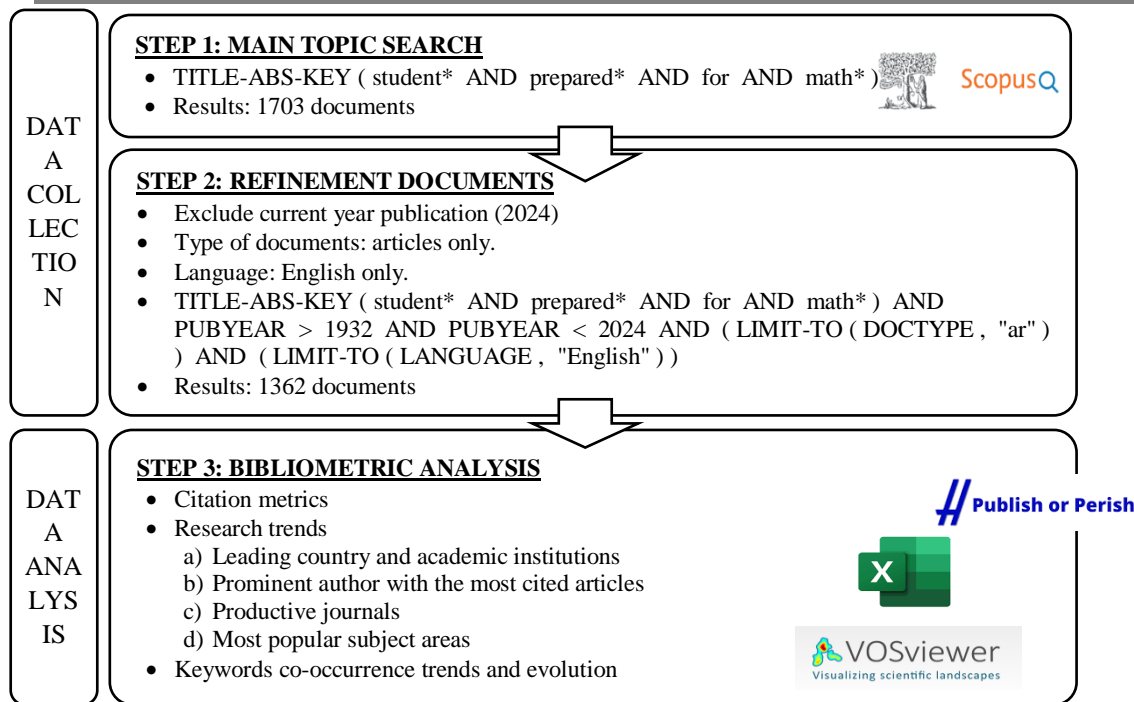
VOSviewer
Visualizing scientific landscapes

Figure 1. Bibliometric analysis flowchart

This bibliometric analysis will have two main phases: data collection and data analysis. In the first phase, there were two steps, which are the main topic search and refinement documents steps. The data will be obtained from the Scopus database using the topic search query, as in Figure 1. They will next go through filter processes that include numerous criteria that must be met, such as the type of documents published, the year of publication, and the language used. The remaining documents will then go through the second phase, which is data analysis. In this phase, the remaining data will be analyzed to identify the citation metrics between initial and refinement results, the research trends in major nations, the notable authors and impactful journals that have actively published articles on students' preparedness for Mathematics courses and the prevalent keywords that have been used in the prior studies. This study also addressed the keyword evolution based on chronological groups (Initial Phase: 1933-1983; Development Phase 1: 1984-2003; Development Phase 2: 2004-2013; and Exploration Phase: 2014-2023) to identify research gaps from the bibliometric data, enabling future scholars to understand the evolution of students' preparedness for Mathematics courses research and suggest new theme or methods.

As a result of the first step, the Scopus database revealed 1,703 documents related to the keywords students' preparedness for Mathematics courses between the years 1933 and 2024. However, according to requirements for refinement data, which are document type (article) in English and published up until the year 2023 as proposed by [7], [8], [9], there were only 1362 documents in the final data that satisfy the requirements. The refinement data will then be exported into CSV and RIS format, allowing an extensive bibliometric analysis to reveal significant research trends and patterns in the field of student preparation for Mathematics courses.

In order to analyze and visualize the findings of this study, several analytical techniques using a few software will be employed. The analysis will start using Publish or Perish software to perform the citation metrics analysis for initial and refinement results. Then, the analysis will proceed to identify the leading countries and academic institutions, prominent authors with the most cited articles, productive journals, and the most popular subject areas using Microsoft Excel. Meanwhile, VOSviewer software will interpret the trends of collaborations among countries and the keywords used by presenting the results through network visualizations that highlight the relationships between documents, authors, and countries. The link strength given in the network visualization represents the strength of the correlation between two nodes [9], [10]. As noted by [11], VOSviewer will create a network visualization based on two counting methods: full counting and fractional counting. This study will employ full counting for all analyses using VOSviewer, as it provides an integer number to represent the connection strength between nodes, which is determined by the co-authored documents [10].

RESULTS AND DISCUSSION

The results of this bibliometric analysis of the term "students' preparedness for Mathematics courses" from the Scopus database will be discussed in three main sub-sections: Citation metrics analysis, Research trends, and Keyword co-occurrence trends and evolution.

A. Citation Metrics Analysis

This section will present and discuss the key findings from the citation metrics analysis using Publish or Perish software between initial and refinement documents. According to the results in Table 1 below, Publish or Perish software reveals significant differences between initial and refined searches of literature on students' preparedness for Mathematics courses. The initial search yielded 1,703 papers with 19,771 citations, resulting in an average of 11.61 citations per paper and an h-index of 61. In contrast, the refined search, which included filters for publication year (restricted up until the year 2023), document type (article only) and language (English only), identified 1,362 papers with 13,989 citations, yielding a lower average of 10.27 citations per paper and an h-index of 51. This refinement search increased the average number of authors per paper (2.88), indicating greater collaboration.

In contrast, metrics such as cites per author and g-index showed reductions, reflecting a decline in the overall impact of the filtered dataset. Overall, the refinement process, while limiting the dataset, provided a more focused analysis of relevant literature, revealing important insights into research trends and collaborative dynamics within the field. Therefore, the refined data (1362 articles) will be used for the rest of the analysis in this study.

Table 1: Citation metrics comparison based on initial and refinement search

Metric Data	Initial Search	Refinement Search
Source	Scopus	Scopus
Query	TITLE-ABS-KEY (student* AND prepared* for AND math*)	TITLE-ABS-KEY (student* AND prepared* AND for AND math*) AND PUBYEAR > 1932 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))
Query date	05/03/2024	05/03/2024
Year	1933 – 2024	1933 – 2023
Papers	1703	1362
Citations	19,771	13,989
Cites/year	217.26	153.73
Cites/paper	11.61	10.27
Cites/author	10,135.62	6463.61
Papers/author	867.76	668.74
Author/paper	2.75	2.88
h-index	61	51
g-index	110	91
hi-norm	40	32
hi-annual	0.44	0.35
hA-index	16	13

B. Research Trends

This research trends and impacts of students' preparedness for Mathematics courses research will be discussed in terms of publication trends based on leading countries and academic institutions and prominent authors with the most publications.

Leading Countries and Academic Institutions

According to data obtained from the Scopus database on March 5, 2024, the distribution of published articles concerning students' preparedness for Mathematics courses, spanning from 1933 to 2023, has seen a significant increase in research publications in recent decades. From 1933 to the late 1990s, publications were limited, with most years having no publication or only a few articles published. However, from the 2000s onwards, there has been a steady increase, particularly after 2009. This upward trend became more noticeable from 2014 onwards, with a peak in 2019 at 111 publications. Meanwhile, in the last three years (2021-2023), the publications remained consistently high, with 99 to 100 publications annually, indicating that this topic continues to attract significant scholarly attention.

In order to gain a clearer understanding of publication trends in terms of international collaboration, a co-authorship analysis using VOSviewer was conducted, and the result of the network visualization is illustrated in Figure 2 below. This network visualization was only set to consider articles that had a maximum of 25 countries per document. Among these selected articles, only the countries with a minimum of 5 articles will proceed to be analyzed and portrayed in the network. As a result, 43 out of 140 countries met the setting. However, among these 43 countries, only 36 are connected, which represents that they collaborated.
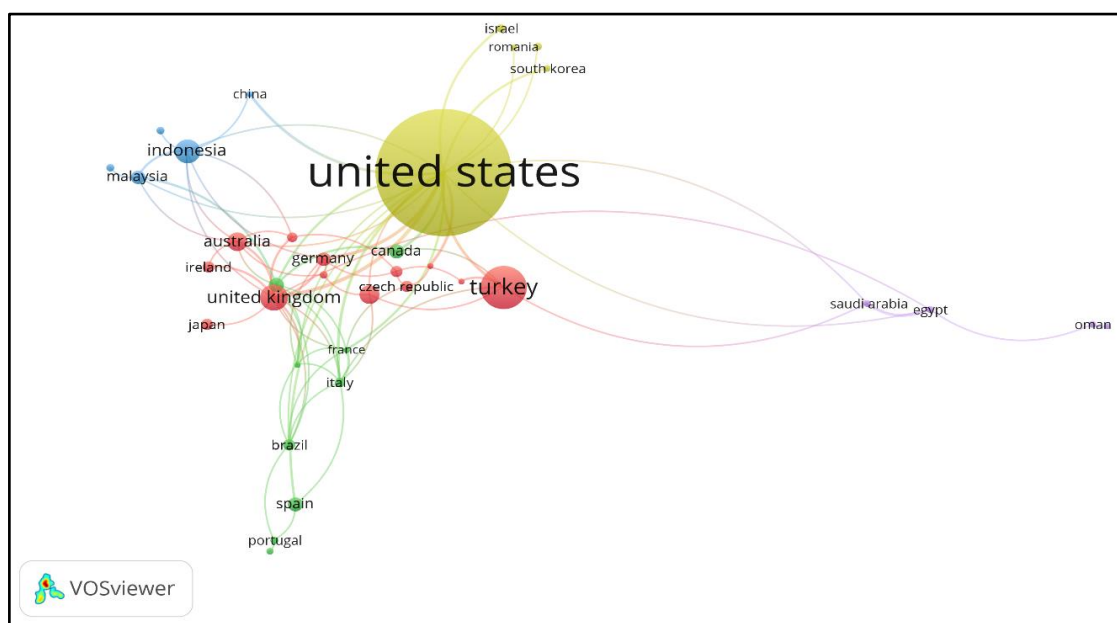

Figure 2. Network visualization of the country's collaborations related to students' preparedness for Mathematics courses from 1933 to 2023 (Online map can be accessed online through https://tinyurl.com/29rl37bq)

These 36 countries in Figure 2 have been clustered using the Louvain algorithm, which focuses on identifying strong community structures within the network [7], [12]. As a result, 36 countries detected by VOSviewer were clustered into five clusters with 80 links, and the total link strength was 115. The five clusters are: Cluster 1 (Red) had 13 items, Cluster 2 (Green) had nine items, Cluster 3 (Blue) had five items, Cluster 4 (Yellow) had five items, and Cluster 5 (Purple) had four items. The details for each cluster are listed in Table 2 below. The size of nodes represents the number of documents that have been published in each country. The more papers are published, the larger the nodes are. Meanwhile, the lines show the strength of connection between the two countries. The shorter the distance between nodes (country), the stronger the connection [7]. Therefore, based on Figure 2, the largest node was the United States from Cluster 4, with a total of 661 documents that received

the highest citations (8,803 citations) among other countries, had collaborated with 22 countries and had a total link strength of 44. It was followed by Turkey from Cluster 1, which had 122 papers and received 735 total citations. Turkey collaborated with six countries, which produced a total link strength of nine. Meanwhile, Malaysia, which ranks 12th with 20 articles that received 141 citations, had collaborated with five countries (United States, Australia, India, Indonesia and Norway). Therefore, the research on students' preparedness for Mathematics courses in Malaysia provided more opportunities to collaborate with other countries.

Besides the leading countries, this study also discussed the leading academic institutions. The top 10 leading academic institutions that actively published articles related to students' preparedness for Mathematics course research are listed in Table 3 below. These data highlight several key contributors, mainly from the United States and Turkey. Purdue University from the United States leads in total publications with 23 papers, contributing 1.69% to the total, but has a relatively moderate average citation per paper at 4.26. In terms of impact, the University of Virginia stands out, with an average of 31.07 citations per paper, followed closely by Vanderbilt University (30 citations per paper), which both indicate strong influence despite fewer publications. The Ohio State University also demonstrates a strong impact with 16.00 citations per paper from only 14 documents. Meanwhile, Turkish institutions, particularly Karadeniz Technical University and Hacettepe University, contribute significantly, with notable citation averages of 10.86 and 6.33, respectively. In conclusion of these results, the United States institutions seem to dominate both in terms of publication volume and citation impact, with several universities contributing both quality and quantity to the research area.

Table 2: Distribution of research related to students' preparedness for Mathematics courses by region

Cluster	Countries (Number of documents; Number of collaborations)
Cluster 1 (Red): 13 countries	Turkey (122; 6), United Kingdom (56; 13), Australia (34; 8), South Africa (33; 4), Germany (20; 6), Czech Republic (16; 3), Ireland (15; 2), Japan (15; 1), Poland (15; 4), Hungary (12; 4), Sweden (8: 3), Chile (6; 2), Kazakhstan (6; 2)
Cluster 2 (Green): 9 countries	India (23; 9), Canada (22; 3), Spain (22; 3), Brazil (15; 7), Italy (12; 9), Portugal (8; 3), Slovakia (7; 1), France (5; 7), Switzerland (5; 7)
Cluster 3 (Blue): 5 countries	Malaysia (20; 5), Indonesia (49; 8), New Zealand (8; 1), Norway (9; 1), China (6; 2),
Cluster 4 (Yellow): 5 countries	United States (661; 22), Israel (10; 1), Netherlands (8; 1), South Korea (7; 1), Romania (5; 1)
Cluster 5 (Purple): 4 countries	Egypt (7; 4), Saudi Arabia (7; 3), Oman (7; 2), Jordan (5; 1)

Table 3: Top 10 leading academic institutions related to students' preparedness for Mathematics courses research

No	Academic Institutions	Country	Total Documents	Total Citations	Contribution rate (%)	Average Citation per paper
1	Purdue University	United States	23	98	1.69	4.26
2	University of Michigan	United States	17	163	1.25	9.59
3	The Ohio State University	United States	14	224	1.03	16.00
4	University of Virginia	United States	14	435	1.03	31.07
5	Karadeniz Technical University	Turkey	14	152	1.03	10.86

6	Texas A&M University	United States	13	197	0.95	15.15
7	Hacettepe University	Turkey	12	76	0.88	6.33
8	Vanderbilt University	United States	10	300	0.73	30.00
9	NC State University	United States	10	53	0.73	5.30
10	The University of Texas	United States	10	150	0.73	15.00

Prominent Authors with The Most Publications

Analyzing the prominent authors with the highest publication is essential in bibliometric analysis, as it helps identify key contributors who have significantly shaped the research trends within a specific topic. This is important in recognizing the pioneer leaders, understanding the distribution of intellectual contributions across institutions and countries, and revealing potential collaborations. There were 1,333 authors within these 1,362 articles detected by VOSviewer and Publish or Perish software, with an average of two to four authors per paper (2.75). The list of prominent authors with the most publications related to students' preparedness for Mathematics courses is presented in Table 4. As in Table 4, Enno Ed Koehn from Lamar University, United States, leads the list with seven articles since 1997, boasting an h-index of 14 and contributing 0.51% to this field with 76 citations. It was followed by Adnan Baki from Trabzon University, Turkey. He has published five articles related to students' preparedness for Mathematics courses since 2000, contributing 0.37% to the field, and has received 118 citations with an h-index of 13. Besides these two most prominent authors, Michal Sebastian Maćkowski and Priotr Franciszek Brzoza from the Silesian University of Technology, Poland, have made significant contributions in a short time. They started publishing the related articles in 2018 and retrieved 69 and 49 citations, respectively. Furthermore, the other productive authors in this research theme, such as Fiona Faulkner from Technological University Dublin, Ireland and Bülent Güven from Trabzon University, Turkey, also had their contributions in helping to advance scholarly discoveries in their respective regions.

Table 4: The most prominent authors that actively published research related to students' preparedness for Mathematics courses

No	Author Name	Scopus ID	H-index	Year of 1st article	Total articles	Total citations	Contribution Rate (%)	Current Affiliation	Country
1	Koehn, Enno Ed	7005236068	14	1997	7	76	0.51	Lamar University	United States
2	Baki, Adnan	3617381920 0	13	2000	5	118	0.37	Trabzon University	Turkey
3	Maćkowski, Michal Sebastian	6602140149	8	2018	5	69	0.37	Silesian University of Technology	Poland
4	Brzoza, Piotr Franciszek.	1452177000 0	5	2018	4	49	0.29	Silesian University of Technology	Poland
5	Faulkner, Fiona	3586781090 0	10	2014	4	67	0.29	Technological University	Ireland

								Dublin	
6	Froyd, Jeffrey E.	7004489173	24	2011	4	17	0.29	College of Engineering, Columbus	United States
7	Güven, Bülent	23967729200	11	2012	4	75	0.29	Trabzon University	Turkey
8	Hirsch, Linda S.	7007119251	12	2005	4	58	0.29	New Jersey Institute of Technology	United States
9	Kimmel, Howard S.	7006377116	16	2006	4	58	0.29	Newark College of Engineering	United States
10	Langie, Greet	22962002600	12	2017	4	13	0.29	KU Leuven	Belgium

Productive Journals and Popular Subject Areas

The identification of the most productive journals that publish articles on students' preparedness for Mathematics courses is a critical aspect of bibliometric analysis. This analysis not only provides insights into where the influential studies are being published but also helps researchers identify credible platforms for their work and track evolving research trends in the selected topic. The list of the top 10 most productive journals that actively published related articles is listed in Table 5 below. The leading journal in this area of topic is the International Journal of Mathematical Education in Science and Technology, which has published 38 articles (2.79% of the total refinement publications) and has accumulated 669 citations. This journal received a CiteScore 2023 of 3.3, and the highly cited article titled "Student Learning and Perceptions in a Flipped Linear Algebra Course" by [13]. This article has been cited 280 times, which shows its significant impact. Meanwhile, the School Science and Mathematics journal follows with 14 articles (1.03%) and 136 citations, while PRIMUS has published 13 articles (0.95%), with both journals playing vital roles in advancing interdisciplinary discussions in education.

Understanding the influence of these journals helps researchers and institutions determine the most appropriate platforms for publishing high-impact research. It also aids in recognizing emerging trends and influential studies, as demonstrated by highly cited articles such as "Remediation beyond developmental education: The use of learning assistance centers to increase academic preparedness in community colleges" by [14] in the Community College Journal of Research and Practice and "Context of STEM integration in schools: views from in-service Science Teachers" by [15] in the Eurasia Journal of Mathematics, Science and Technology Education. Therefore, based on these findings, it can be concluded that recognizing the most productive journals is essential for researchers seeking to make meaningful contributions and stay informed about the latest developments in Mathematics education, ensuring that their work aligns with current trends and has the potential for a wide-reaching impact.

Table 5: The most productive journals that actively published articles related to students' preparedness for Mathematics courses

No	Source Title	Total Publications (%)	Total Citations	CiteScore 2023	Highly Cited Article (Title)	Times Cited	Publisher
1	International Journal of	38 (2.79)	669	3.3	Student learning and perceptions in a flipped	280	Taylor and Francis

	Mathematical Education in Science and Technology				linear algebra course [13]		
2	School Science and Mathematics	14 (1.03)	136	2.3	Integrating Science, Mathematics, and Technology in Middle School Technology-Rich Environments: A Study of Implementation and Change [16]	36	John Wiley and Sons Inc
3	PRIMUS	13 (0.95)	34	1.6	Core Mathematics at the united states military academy: leading into the 21st century [17]	8	Taylor and Francis
4	Community College Journal of Research and Practice	11 (0.81)	117	2.2	Remediation beyond developmental education: The use of learning assistance centers to increase academic preparedness in community colleges [14]	37	Taylor and Francis
5	Education Sciences	11 (0.81)	91	4.8	How creativity in STEAM modules intervenes with self-efficacy and motivation [18]	37	MDPI
6	Eurasia Journal of Mathematics, Science and Technology Education	9 (0.66)	176	4.3	Context of STEM integration in schools: Views from in-service science teachers [15]	61	Modestum LTD
7	Teaching Mathematics and its Applications	8 (0.59)	33	2.4	Mathematics in the disciplines at the transition to university [19]	9	Oxford University Press
8	CBE Life Sciences Education	7 (0.51)	214	6.5	Promoting undergraduate interest, preparedness, and professional pursuit in the sciences: An outcomes evaluation of the SURE program at Emory University [20]	79	American Society for Cell Biology
9	Journal of Physical Education and Sport	7 (0.51)	45	2.8	Impact of the combined use of health-improving fitness methods ("Pilates" and "Bodyflex") on the level of functional and psychophysiological	19	Editura Universitati i din Pitesti

				capabilities of students [21]		
10	Journal of Chemical Education	7 (0.51)	54	5.6	ConfChem Conference on Flipped Classroom: Flipping at an Open-Enrollment College [22]	20	American Chemical Society

Other than the analysis of the most productive journals, the analysis of popular subject areas for selected topics also will be discussed in this study. Analyzing the popular subject areas covered for selected topics provides valuable insights into the evolution and focus of scholarly work across different periods. The top subject areas covered by articles related to students' preparedness for mathematical courses are shown in Figure 3 below. According to Figure 3, the distribution of publications by subject area from the 1930s to the 2020s reveals the research trends and the beginning of interest trends. Social Sciences has consistently dominated the landscape, with 37.73% of all publications in the 2010s and 36.66% in the 2020s, demonstrating its central role in understanding students' preparedness for Mathematics courses. Other than Social Sciences, Engineering has also seen significant representation, peaking at 28.61% in the 2000s, reflecting its growing intersection with educational research.

Meanwhile, Computer Science and Mathematics have gained prominence since the 1990s, reflecting the increasing influence of technological and quantitative approaches on education. On the other hand, areas like Arts and Humanities, Business, Management, and Accounting, and Medicine have had smaller contributions overall, but their importance has grown at different times. This analysis is valuable as it helps future researchers see where to focus their work and explore new areas that may need more attention.
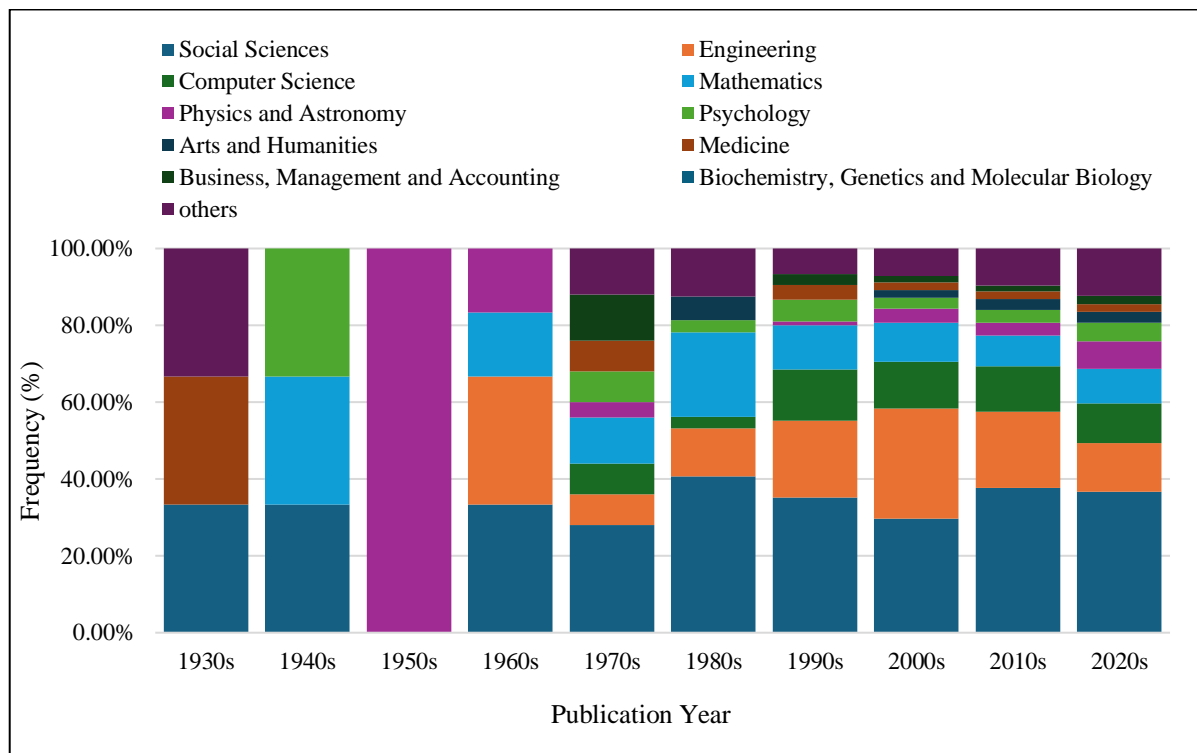

Figure 3. Publication for the most popular subject area for each decade

C. Keywords Co-occurrence Trends and Evolution

In this sub-section, VOSviewer will be utilized to conduct two distinct types of analyses: Overall keyword co-occurrences and keyword evolution across four chronological groups. The refined dataset, which was retrieved from the Scopus database, comprises 1,362 English articles that were published up to the year 2023. This

dataset will be systematically divided into four timeframes: 1933-1983, 1984-2003, 2004-2013, and 2014-2023, allowing the evolution of keywords used can be analyzed and discussed.

The keyword co-occurrence analysis using VOSviewer reveals significant insights into key themes in the research landscape. In the analysis, VOSviewer will be set to include ALL keywords, either identified by the author or extracted from the database. However, only documents that have a keyword with a minimum of 5 occurrences will be selected for further analysis. As a result, out of 6169 keywords detected, only 332 keywords met the threshold and clustered into five clusters with 5153 occurrences and 7368 links, as visualized in Figure 4. The keyword "students" emerged as the most frequent, with 460 occurrences and a total link strength of 3027, indicating its central role in the literature. This keyword was paired with 316 other keywords. "Engineering education" followed with 283 occurrences. This keyword was paired with 7368 other keywords and had a total link strength of 1874. This data highlights its prominence in educational research. Meanwhile, the keyword "teaching" appeared 207 times with a link strength of 1515 and was paired with 284 other keywords.
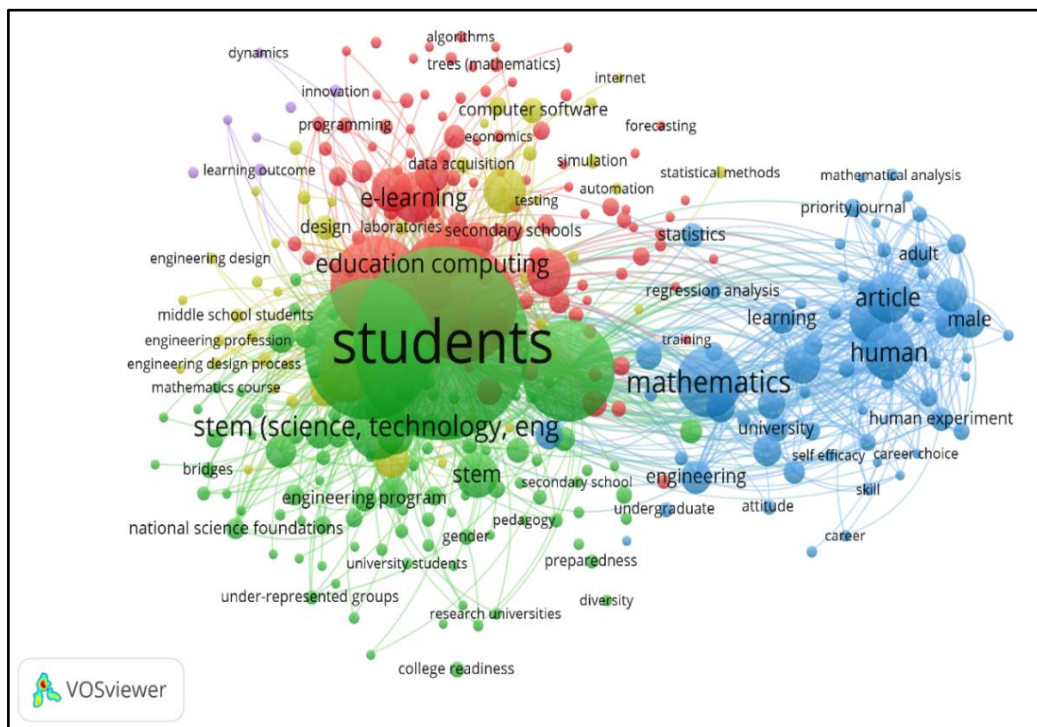

Figure 4: Network visualization of all keywords co-occurrences from 1933 to 2023 (Online map can be accessed online through https://tinyurl.com/25kgr3nm)

The research gaps from this network map can be identified by analyzing the links between nodes. If two keywords lack a connection, it shows potential gaps in the literature, presenting opportunities for future research related to students' preparedness for mathematical courses. Identifying these gaps can help guide the new research theme by overlooking the topics and expanding the scope of existing research.

In addition to analyzing the overall keywords in research related to students' preparedness for mathematical courses, this paper will also explore the evolution of these keywords across four distinct phases: the initial phase (1933-1983), the development phase 1 (1984-2003), the development phase 2 (2004-2013), and the exploration phase (2014-2023). For each phase, a full counting analysis that only focuses on keywords with at least five occurrences, if possible, will be used as a setting for network visualization in VOSviewer. In the initial phase, the minimum occurrences for each keyword need to be changed to a minimum of 2 occurrences since the keywords during this period were limited. There were only 64 keywords detected throughout these 50 years, with 9 out of them having a minimum of 2 occurrences. However, only 5 of them are connected and clustered in 1 cluster with 10 links and a total link strength of 20, as illustrated in Figure 5a. The keywords are "aesthetic appeal", "aesthetic properties", "apparel design", "statistical analysis", and "mathematical analysis", with each keyword having 2 occurrences, 4 links and a total link strength of 8.

In the next phase, which is Development Phase 1 (1984-2003), 19 out of 656 keywords met the threshold of a minimum of 5 occurrences of a keyword. These keywords were clustered into 2 clusters, connected to other 105 keywords and created a total link strength of 398, as illustrated in Figure 5a. The most popular keyword during this period was "engineering education", which appeared 46 times and was connected to 16 other keywords, resulting in a total link strength of 135. This result highlights the growing focus on engineering education as a central theme during this period. It is followed by "students" with 33 occurrences, connected to 16 keywords and contributing to a total link strength of 122. This data reflects the importance of student involvement in educational discussions. Other notable keywords included "teaching", which appeared 24 times with 14 links and a total link strength of 71, emphasizing the role of pedagogy. Meanwhile, "curricula" was mentioned 21 times with 15 links, generating a total link strength of 82, showing the ongoing interest in curriculum development. The keyword "mathematical models" has 16 occurrences with 15 connections and a total link strength of 47, suggesting its relevance in developing more structured approaches to education during this era. These findings show a shift towards improving the educational framework, especially in technical and mathematical disciplines.

The network map during Development Phase 2 (2004-2013) reflects a notable increase in keyword density compared to the previous phase, which indicates a broader and more interconnected research landscape. Over the 10 years, 2348 keywords were detected, with 82 of them meeting the threshold of at least 5 times mentioned, which will then proceed to further analysis. These 82 keywords were clustered into 2 clusters with 1044 links, resulting in a total link strength of 3377. This growth highlights the expansion of the research related to students' preparedness for mathematical courses during this period. Keywords from the earlier era, such as "engineering education", "students", "teaching", "curricula", and "mathematical models", continue to gain prominence. "Engineering education" appeared 98 times, with 67 links and a total link strength of 515. "Students" also show a significant rise with 169 occurrences, 81 links, and a total link strength of 826. "Teaching" maintained its importance by appearing 98 times, with 78 links and a total link strength of 528. "Curricula" followed with 80 occurrences, 67 links and a total link strength of 440, while "mathematical models" appeared 32 times with 27 links and a total link strength of 89. As a result, the network map for this phase is denser than in the previous era. This denser map not only shows a growing interest in these educational themes but also shows a higher degree of interconnectedness among the research topics, signalling the deepening complexity and maturity of the field during this period.

As shown in Figure 5, the network maps became progressively denser over time, with the Exploration Phase (2014-2023) being the most densely populated. During this period, 4011 unique keywords were detected, and 179 of them were mentioned at least 5 times. These 179 keywords were clustered into 5 distinct clusters with 3058 connections, generating a total link strength of 8168. The keyword "students", which appeared since Development Phase 1 (1984-2003), continued to dominate as a central theme. "Students" appeared 256 times and was connected to 166 other terms, including "education", "STEM", "e-learning", "professional development", and "performance", with a total link strength of 1426.

Meanwhile, "engineering education" remained the second most popular mentioned keyword, having first appeared in the Development Phase 1. During the Exploration Phase, it was mentioned 138 times, with 123 links and a total link strength of 797. This keyword was linked to several terms such as "students" (link strength 121), "Mathematics" (link strength 6), "education" (link strength 25), and "teaching" (link strength 62). These connections suggest an ongoing interest in understanding the relationship between engineering education and other critical aspects of the educational landscape, including student performance and teaching strategies.

In conclusion, the analysis of keyword co-occurrences and keyword evolution for each phase provides essential insights into the evolving landscape of students' preparedness for mathematical courses. By exploring the changing prevalence and interconnections of key terms across distinct chronological phases, the popular themes and emerging trends in this critical area of education can be identified. The significant increase in keyword occurrences highlights the growing complexity and importance of understanding students' preparedness in Mathematics.

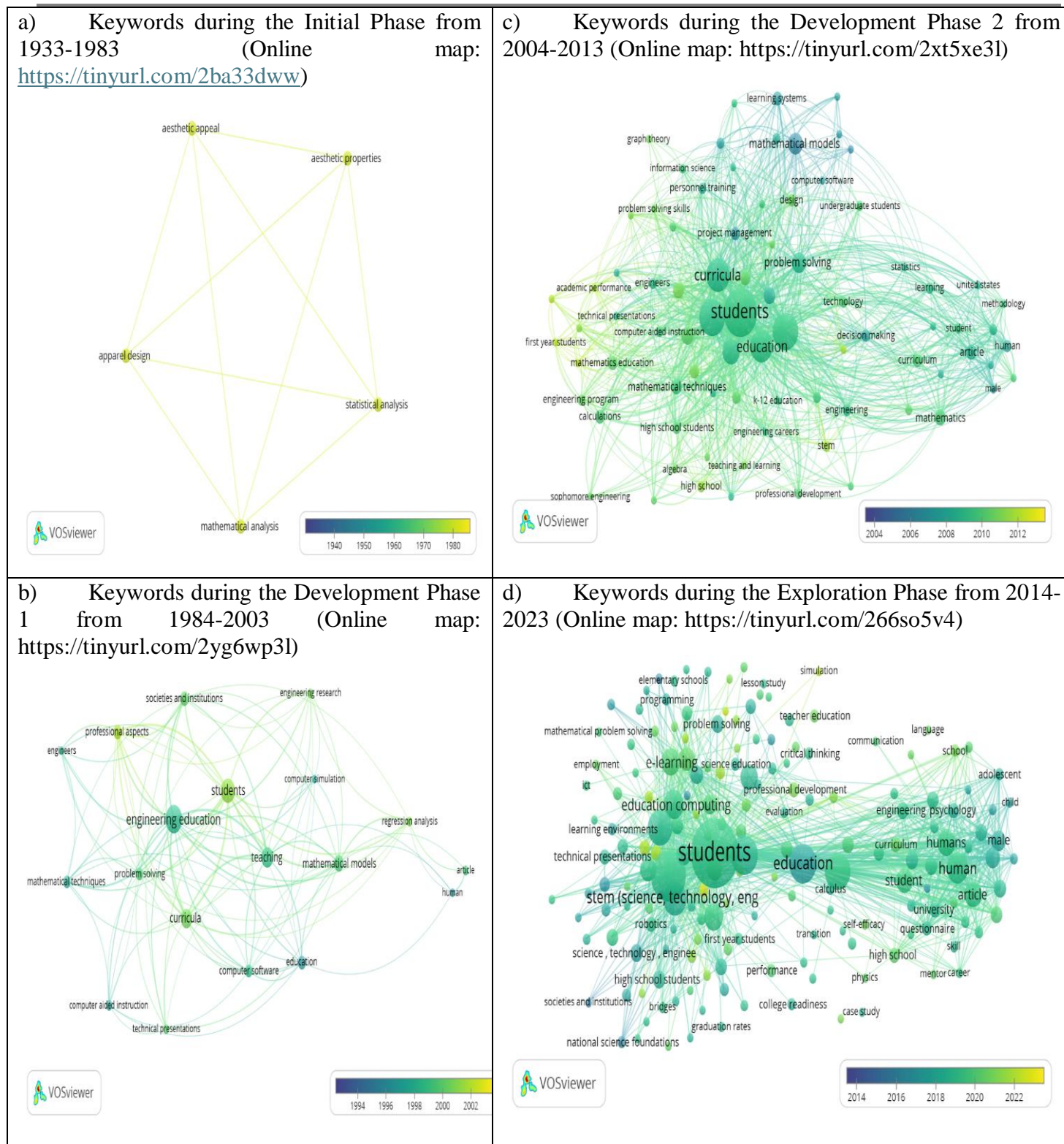| a) Keywords during the Initial Phase from 1933-1983 (Online map: https://tinyurl.com/2ba33dww)	c) Keywords during the Development Phase 2 from 2004-2013 (Online map: https://tinyurl.com/2xt5xe3l)
b) Keywords during the Development Phase 1 from 1984-2003 (Online map: https://tinyurl.com/2yg6wp3l)	d) Keywords during the Exploration Phase from 2014-2023 (Online map: https://tinyurl.com/266so5v4)

Figure 5. Keyword evolution for Initial Phase (1933-1983), Development Phase 1 (1984-2003), Development Phase 2 (2004-2013) and Exploration Phase (2014-2023)

CONCLUSION

This bibliometric review offers important insights into current research trends and highlights areas requiring further exploration in the study of students' preparedness for Mathematics courses. By analyzing 1,362 articles from the Scopus database spanning the years 1933 to 2023, this study reveals significant growth in this field, with substantial contributions from a wide range of authors, academic institutions, countries, and journals. It also tracks the development of keywords, shedding light on emerging areas of interest. The analysis, conducted

using Publish or Perish, Microsoft Excel, and VOSviewer, covers research from 43 countries, 614 journals, 108 academic institutions, 1,333 authors, and 4,011 keywords.

The findings of this paper will aid future researchers in planning international collaborations and fostering the exchange of ideas and knowledge with fellow scholars. Furthermore, the analysis of keyword trends may help identify new research gaps, providing opportunities for future investigations into students' preparedness for Mathematics courses. As the field continues to evolve, it is essential for ongoing research to remain innovative, address real-world challenges, and develop new models to meet the dynamic needs of the educational landscape and workforce demands.

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