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[1] Nevşehir Hacı Bektaş Veli University Faculty of Education, Nevşehir, Türkiye

[2] Afyon Kocatepe University Bolvadin Vocational College, Afyon, Türkiye

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BIBLIOMETRIC ANALYSIS OF ARTICLES ON ERRORS AND MISCONCEPTIONS IN MATHEMATICS EDUCATION

ANÁLISE BIBLIOMÉTRICA DE ARTIGOS SOBRE ERROS E CONCEITOS EQUÍVOCOS NA EDUCAÇÃO MATEMÁTICA

ANÁLİSİS BİBLİOMÉTRİCO DE ARTÍCULOS SOBRE ERRORES Y CONCEPTOS ERRÓNEOS EN LA EDUCACİÓN MATEMÁTİCA

Solmaz Damla GEDİK ALTUN[1]
sdgedik@nevsehir.edu.tr
Murat KESKİN[2]
mkeskin@aku.edu.tr

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ABSTRACT: This study provides an overview of research on errors and misconceptions in mathematics education through bibliometric analysis. It examines quantitative and qualitative characteristics of publications from 2014 to 2024, analyzing articles, authors, citations, countries, and related statistics. Data collection involved three stages: selecting relevant studies, converting them into a bibliometric application format, and performing data cleaning to ensure accuracy. The analysis, based on Web of Science (WoS) articles, includes both performance analysis and scientific mapping. Findings highlight the main trends, developments, and research gaps concerning misconceptions in mathematics teaching. The results reveal dynamics and potential areas for advancement in the field, offering valuable insights for researchers, educators, and policymakers. Ultimately, the study contributes to improving the quality of mathematics education by clarifying the state of research and identifying directions for future investigation.

KEYWORDS: Mathematics Education. Errors. Misconceptions. Dynamics. Potantial Development Areas.

RESUMO: *Este estudo fornece uma visão geral da pesquisa sobre erros e concepções errôneas na educação matemática por meio de análise bibliométrica. Ele examina características quantitativas e qualitativas de publicações de 2014 a 2024, analisando artigos, autores, citações, países e estatísticas relacionadas. A coleta de dados envolveu três etapas: seleção de estudos relevantes, conversão para um formato de aplicação bibliométrica e execução de limpeza de dados para garantir a precisão. A análise, baseada em artigos da Web of Science (WoS), inclui análise de desempenho e mapeamento científico. Os resultados destacam as principais tendências, desenvolvimentos e lacunas de pesquisa relacionadas a concepções errôneas no ensino de matemática. Os resultados revelam dinâmicas e áreas potenciais para avanço na área, oferecendo insights valiosos para pesquisadores, educadores e formuladores de políticas. Em última análise, o estudo contribui para melhorar a qualidade da educação matemática, esclarecendo o estado da pesquisa e identificando direções para investigações futuras.*

PALAVRAS-CHAVE: *Educação Matemática. Erros. Equívocos. Dinâmica. Áreas de Potencial Desenvolvimento.*

RESUMEN: *Este estudio ofrece una visión general de la investigación sobre errores y concepciones erróneas en la educación matemática mediante un análisis bibliométrico. Examina características cuantitativas y cualitativas de publicaciones realizadas entre 2014 y 2024, analizando artículos, autores, citas, países y estadísticas relacionadas. La recolección de datos se desarrolló en tres etapas: selección de estudios relevantes, conversión al formato de aplicación bibliométrica y limpieza de datos para garantizar la precisión. El análisis, basado en artículos de la Web of Science (WoS), incluye tanto el análisis de desempeño como el mapeo científico. Los resultados destacan las principales tendencias, desarrollos y brechas de investigación relacionadas con las concepciones erróneas en la enseñanza de las matemáticas. Asimismo, revelan dinámicas y áreas potenciales de avance en el campo, ofreciendo aportes valiosos para investigadores, educadores y responsables de políticas públicas. En última instancia, el estudio contribuye a mejorar la calidad de la educación matemática al esclarecer el estado actual de la investigación e identificar direcciones para futuras indagaciones.*

PALABRAS CLAVE: *Educación Matemática. Errores. Concepciones Erróneas. Dinámica. Áreas de Potencial Desarrollo.*

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INTRODUCTION

In the field of mathematics education, one of the most important factors affecting students' learning processes is errors and misconceptions. The distinction between errors and misconceptions is a topic frequently discussed in the literature. Errors usually arise from a lack of knowledge or carelessness, whereas misconceptions refer to deeper and more persistent misunderstandings. For example, Exacta et al. (2024) examined elementary school students' misconceptions about fractions and revealed that most of these misconceptions stemmed from their previous experiences with whole numbers. The errors and misconceptions encountered can lead students to misunderstand and misapply mathematical concepts, which may negatively affect their academic success in the long term. Errors and misconceptions can hinder the development of students' mathematical thinking skills and lead them to develop negative attitudes toward mathematics lessons. Therefore, it is essential for educators and researchers to pay special attention to this issue.

Mathematics educators and researchers exert significant effort to identify, understand, and address these errors and misconceptions. These efforts are undertaken to deepen students' mathematical understanding and to develop more effective teaching strategies. Researchers examine students' thinking processes using various methods and work to determine the sources of misconceptions. These studies employ both qualitative and quantitative research methods and include students from different age groups and educational levels.

Errors and misconceptions arise when students misinterpret or misapply mathematical concepts. These misconceptions can range from simple calculation mistakes to complex conceptual misunderstandings. For example, students might multiply the numerators and denominators separately when multiplying fractions, or treat variables as if they were constant numbers in algebraic expressions.

In mathematics education, errors and misconceptions are important factors that affect how students understand and apply mathematical concepts (Divrik & Coşkun, 2023). Such misconceptions can hinder the development of students' mathematical thinking skills and negatively impact their academic success in the long term. The sources of these misconceptions are varied. Factors such as students' prior knowledge, teaching methods, textbooks, everyday life experiences, and even language use can contribute to the development of misconceptions. For example, the generalization in everyday language that "addition always increases" can make it difficult for students to understand addition with negative numbers (Ngoveni, 2025).

Identifying and addressing errors and misconceptions is critically important for effective mathematics teaching. Teachers can use a variety of methods to understand students' thinking processes (Elmas & Pamuk, 2021). Open-ended questions, problem-solving activities, concept maps, and clinical interviews are some of the techniques used to uncover students' conceptual understanding. In addition, instructional strategies that support conceptual understanding and encourage active student participation should be used. Concrete materials, technology-supported applications, collaborative learning activities, and real-life contexts can help students develop accurate mathematical concepts (Papadouris et al., 2024). Research on errors and misconceptions in mathematics education provides valuable information for curriculum development, textbook preparation, and teacher education. These studies identify specific misconceptions for different age groups and mathematical topics, thus guiding educators.

In the literature, common mathematical misconceptions encountered in mathematics education have been examined in various domains. In the field of algebra, Vaughn et al. (2020) noted that students struggled to understand the concept of variables and interpreted algebraic expressions as concrete objects. In the field of geometry, M. Lee e J. Lee (2019) observed that students had difficulty generalizing the properties of shapes and were overly reliant on prototype examples. Research on the causes of misconceptions highlights the importance of teacher education. Yılmaz and Yetkin-Özdemir (2021) argue that teachers' own misconceptions can be transmitted to students, and thus teacher education should pay special attention to this issue. Various methods have been suggested for identifying errors and misconceptions. Clinical interviews, concept maps, and open-ended questions are among the commonly used methods in the literature. Chen et al. (2022) suggested that technology-supported assessment tools can be effective for analyzing students' thinking processes more deeply. The literature proposes various strategies for addressing misconceptions. Creating cognitive conflict, using concrete materials, and establishing collaborative learning environments are among these strategies. Chinofunga et al. (2023) showed that instructional approaches based on conceptual change theory are particularly effective in addressing deeply rooted misconceptions.

The Importance of the Study

The bibliometric analysis of errors and misconceptions in mathematics education occupies a significant place in educational research. Such a study provides valuable insights for understanding the general state, trends, and development of research conducted in the field of mathematics teaching and learning. Bibliometric analysis involves the quantitative examination of academic publications in a specific area. This method can reveal the evolution of research on errors and misconceptions in mathematics education over time, the most highly cited works, prominent researchers and institutions, collaboration networks, and research themes (Aria & Cuccurullo, 2017).

A bibliometric analysis of errors and misconceptions in mathematics education can play an important role in shaping future research and practice strategies by providing a

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comprehensive overview of the current state of the field. This type of study can make valuable contributions to efforts to enhance the quality of mathematics education and serve as a guide for educational researchers and educators.

The Aim of the Study

The aim of the study titled bibliometric analysis of errors and misconceptions in mathematics education is to systematically review the existing literature on errors and misconceptions encountered in the process of mathematics teaching and learning, and to reveal research trends in this area.

This study aims to present a general overview of research conducted on errors and misconceptions in the field of mathematics education. Using the bibliometric analysis method, the quantitative and qualitative characteristics of scientific publications on this topic are examined, thereby identifying developments, trends, and gaps in the field.

By providing a comprehensive overview of the current state of research, the study can contribute to the planning of future research, the effective use of resources, and the shaping of educational policies. Furthermore, such an analysis can enable the systematic evaluation of the body of knowledge on errors and misconceptions in mathematics education, thus helping to determine strategies for improving teaching methods and enhancing student achievement.

METHOD

The steadily expanding body of literature has led to increasing challenges in conducting comprehensive literature reviews in the field. While literature reviews reveal various scientific approaches by synthesizing accumulated knowledge, bibliometric analysis has also taken its place among these methods. By providing the ability to analyze large data sets, it serves as a statistical analysis structured within the "research theme–scientist–publication" triangle, indicating the orientation of research in the field. Among quantitative analysis methods, it is considered objective and reliable. It is a trustworthy and user-friendly method for managing large numbers of publications included in a study, and it is highly effective in illustrating publications, citations, authors, and the relationships among them. It reveals the general landscape of the research area, offers a holistic and expanding perspective, and is adopted as an important tool for measuring and evaluating academic research findings. Two main approaches are mentioned for such studies: conducting searches based on keywords or key phrases and then examining the publications in detail, or analyzing all publications in a specific journal or within a group of journals, or particular publications therein. In this study, the first approach was employed, conducting a bibliometric analysis of articles related to

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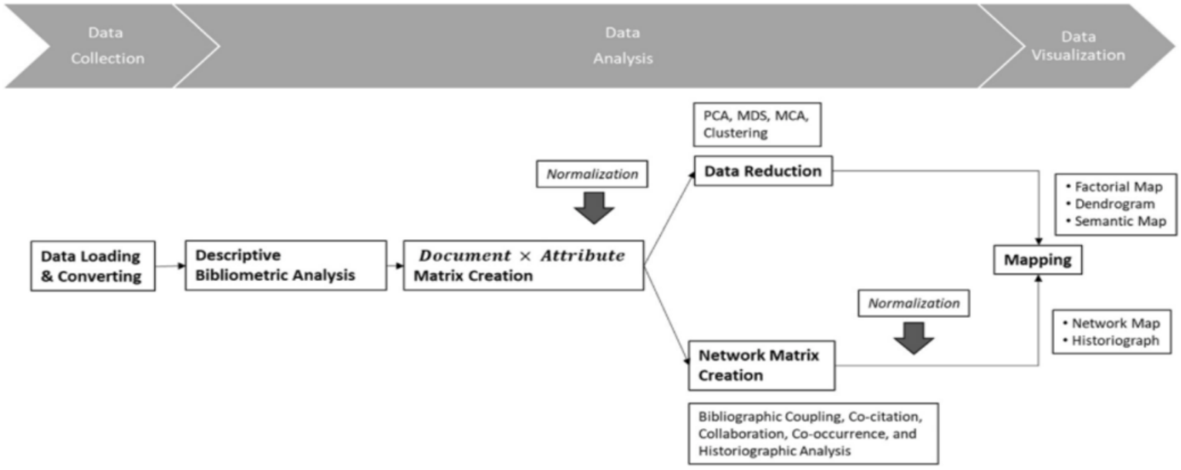
misconceptions (MC) in the field of mathematics education. The scientific workflow used for this analysis consists of data collection, data analysis, and data visualization. This workflow is illustrated in Figure 1.

Figure 1
Science Mapping Workflow



Note. Bibliometrix (2025).

Bibliometric analysis consists of two parts: performance analysis and scientific mapping. Performance analysis includes the growth and distribution of publications, author-related timelines, conceptual orientations, citation counts and distributions, as well as various impact factors, while scientific mapping refers to word dendrograms, co-occurrence networks, thematic mappings, and collaboration and co-citation networks. In other words, performance analysis is descriptive and highlights the distinguishing features of the research, examining the contributions of research components, whereas scientific mapping concerns intellectual interactions and structural connections.

Data Source

In the study, bibliometric analysis procedures were applied to articles published from 2014 up to the present 2024. Relevant articles, authors, citations, and the countries of the authors, along with related statistical data, were utilized. The process of gathering articles consisted of three sub-stages: In the first stage, data relevant to the aim of the study were obtained. In the second stage, these data were uploaded after being converted into the appropriate bibliometric application format. Finally, to ensure data quality, all data were individually examined and cleaned. The articles were scanned from the Clarivate Web of Science (WOS-https://www.webofscience.com/wos/) database (hereafter referred to simply as WoS) without making any distinction between indexes. In this

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way, by determining the knowledge base and intellectual structure, conceptual structure and relations, and the social structure of the scientific community on the topic of misconceptions in mathematics education within a certain time period, a scientific map of the subject area was created and a performance analysis was conducted—in other words, an X-ray was taken.

Articles, considered reliable scientific sources, were selected as the document type, and the field of educational research was chosen in an effort to include as many articles related to mathematics education as possible. Although some articles unrelated to mathematics education were still encountered, unless there was evidence showing this, all articles were first examined via their abstracts, and if no evidence was found in the abstract, the entire article was examined individually in order to identify all articles related to mathematics education, even if they belonged to different fields. No filtering was performed based on language of publication. After filtering, 424 articles were obtained, but following the examinations, this number decreased to 235 (n = 235).

A two-dimensional search was conducted in the topic field to identify the articles. This field searches through studies' titles, abstracts, and keywords and their derivatives (keyword plus) [WoS]. For identifying research on misconceptions in mathematics education, mathematical concepts were used as the first group of keywords in the topic search, while keywords related to misconceptions constituted the second group (Search Term: ((TS=("Mathematics" OR "mathematical*" OR "Geometry" OR "cluster" OR "numbers" OR "algebra" OR "Calculus" OR "Quantitative Reasoning" OR "Trigonometry" OR "functions" OR "derivative" OR "integral" OR "Statistics and Probability" OR "equations" OR "inequality" OR "triangle" OR "quadrangle" OR "rectangle" OR "square" OR "polygon" OR "solid geometry" OR "analytic geometry" OR "circle" OR "circumference" OR "closed disc" OR "circular region" OR "closed circular region" OR "transformations" OR "differential equations" OR "polynomial" OR "arithmetic")) AND TS=("misconception*" OR "concept* error*" OR "misunderstandings")) NOT TS=("quantum numbers") and Article (Document Types) and Education Educational Research (Web of ScienceCategories) and 2024 or 2023 or 2022 or 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 (Publication Years).

Also, since it was the last days of December 2024, studies between the years 2014 and 2024 were considered, excluding possible concepts related to the field of science. For example, in the case of the topic "numbers", the keyword "numbers" was used, but the science-related term group "quantum numbers" was excluded. In this way, efforts were made to reach articles specific to the goal; additionally, all articles were initially examined through their abstracts and then, if necessary, through the full text, until evidence confirmed their specificity to the topic area, giving the final shape to the data set.

Limitations of the Study

The limitations of the study include selecting only WoS as the data source, choosing articles published between 2014 and the most recent month of 2024, selecting articles as the publication type, not making any selection regarding publication language due to the number of articles, and filtering articles according to mathematics education.

Data Analysis

For data analysis, both the VOS Viewer (1.6.20) application, which is considered reliable, and the Biblioshiny web application under RStudio (version 2024.12.0 Build 467, last accessed 02.01.2025, hereafter referred to simply as Biblioshiny) were used. Additionally, Microsoft Excel software was utilized to create the graphics. After the installation of RStudio was completed, the application required the installation of R (version R-4.4.2). After installing R, the Bibliometrix package was installed, and Biblioshiny was accessed via the web browser by typing bibliometrix biblioshiny in the console window under RStudio and pressing the Enter key. In other words, RStudio, together with R applications and the Bibliometrix package, were used to access Biblioshiny.

While the main aim of the study is the performance analysis and scientific mapping of KY, the following analyses were conducted for performance analysis: field-specific descriptive analysis (main information), annual scientific production, average citations per year, three--field plot, most relevant sources, identification of core sources by Bradford's law, sources' local impact by H-index, most relevant authors, authors' production over time, authors' local impact by H-index, corresponding authors' country, countries' scientific production, and most globally cited documents. For scientific mapping analysis, analyses were conducted on word cloud & trend topics, thematic map, factor analysis, co-citation of authors (cited authors), co--citation of references (cited references), co-authorship and collaboration network according to author and institution criteria, international collaboration network, and the co-occurrence network of authors' keywords, as well as the trends of these keywords over time. The specific program and plugin used for each analysis are indicated in the findings section of the relevant analysis. Biblioshiny and VOSviewer were used for these analyses.

Validity and Reliability

Considering validity and reliability, which are fundamental criteria for any study, it is expected that the data source should be reliable. For this reason, a trustworthy and comprehensive database such as WoS, which contains publications with high impact factors in the top-level indexes like SSCI, ESCI, and SCI-Expanded, was chosen as the data source.

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Validity in a research study concerns the accurate determination of scope for revealing the scientific impact of analyses, identifying the trends that emerge in the study, and appropriately addressing and evaluating the research variables as they should be. Clear criteria were set for the selection of the articles to be analyzed and for identifying articles to be excluded, and these criteria were explicitly stated. To ensure this, the article selection criteria underwent several stages, with particular care taken to select the articles most relevant to the aim of the research. Additionally, to enhance validity, detailed information was provided regarding the web address from which the database was accessed and the access date.

Furthermore, the limitations of the study were specified. The search filters used for accessing the articles, the method of reviewing articles after filtering, the method of data analysis, and the reasons for using specific data analysis tools all represent the study's external validity.

For a quantitative analysis to be reliable, it needs to yield consistent results when similar data and methods are used; therefore, detailed information about the data and methodology is provided in this study. By its nature, bibliometric analysis offers a systematic, transparent, and reproducible research process, contributing to the quality of the study. The findings of the research were presented as obtained, without interpretation. The findings and results were discussed in a manner consistent with the literature review. Additionally, information about the software used for data analysis was provided. Details are also included about which software was used for each analysis and which values were taken as the basis. Since the data used in this research belong to documents from WoS, ethical approval was not required, and at all stages of the research, YÖK's scientific research and ethical guidelines were followed.

FINDINGS

This section of the study presents the findings of the bibliometric analyses of articles in WoS related to misconceptions encountered in mathematics education. The findings are presented in two sections: 1. Performance Analysis and 2. Scientific Mapping.

This section covers the performance analysis of the articles. This analysis examines the contribution of the "research theme-researcher-publication" triangle to the article and serves as a distinguishing feature of the articles while providing a descriptive approach. The analyses were reported in the order they appear in Biblioshiny. The aim here is to make it easier for researchers who wish to conduct similar analyses to follow this study without difficulty.

Descriptive Analysis of the Literature   Main Information

According to the descriptive analysis of the field, the basic characteristics of the reviewed articles are presented in Table 1 (Biblioshiny – Overview > Main Information). The data collection comprised 235 articles related to misconceptions in mathematics education, published in all languages and found in all indexes in the WoS database between 2014 and 2024. During the analysis, although 235 articles appeared in WoS for the specified years, one of these articles was perceived as being published in 2025 in Biblioshiny. Upon examining the journal in which the article was published, it was understood that it was actually published in 2024 (Published: 11 May 2024, https://link.springer.com/article/10.1007/s10763-024-10464-4) but the citation information shows the year as 2025 (Volume 23, pp. 143–168, (2025), https://link.springer.com/article/10.1007/s10763-024-10464-4). When the article's details in WoS were examined, it was seen that the early access date was 2024. As a result of these circumstances, the researchers approved the inclusion of the article in the data source and considered the publication year accordingly. Additionally, the publication year was corrected to 2024 in the Biblioshiny data file and the analyses continued.

Table 1
Descriptive characteristics of the articles

Feature	Value
Basic Information About Data	
Article Area	Misconceptions in Matematics Education
Makale Type	Article
Database	WoS
Article Language	All Languages
Index	All indexed scanned in WOS
Publication Year	2014:2024
Number of Sources	103
Number of Articles	235
Annual İncrease Rate Y (%)	10,72
Average age of article	5,27
Average Number of Citations per Article	7,102
Reference Sources	9235
İnformation About Article Content	
Additionak Keywords (ID)	366
Author Keywords (DE)	842
İnformation About Authors	
Number of Authors	580

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Feature	Value
Single-Author Articles	39
Rate of Co- Authors per Article	2,71
International Co-Authorship Rate (%)	16,6

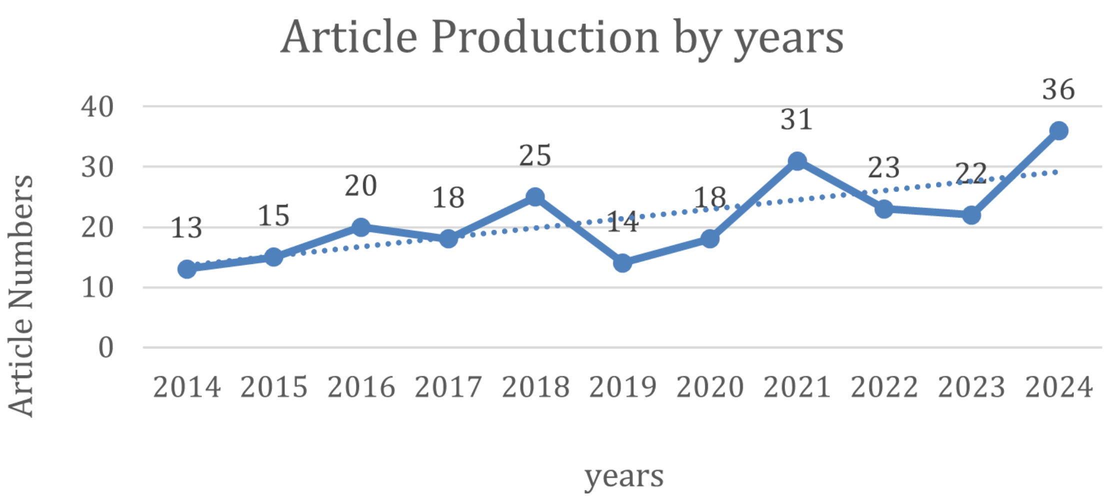
Note. Prepared by the authors (2025).

The total number of sources in which the articles were published has been determined as 103 (n=103). While the annual growth rate of publications was calculated as 10.72%, the average age of the documents is 5.27, the average number of citations per article is 7.102, and the number of publications cited as references in the articles is 9,235.

Annual Scientific Production

The yearly production of studies related to KM is presented in Figure 2. Accordingly, it is seen that the highest number of articles were written in 2024.

Figure 2
Article production graph by years



Note. Prepared by the authors (2025).

When examining Figure 2, a fluctuating pattern can be observed in the number of articles. While the number of articles increased in 2024, 2015, and 2016, there were also increases in 2018, 2020, 2021, and 2024, but decreases occurred in 2017, 2019, 2022, and 2023. An upward trend can be seen in publication numbers across the specified years.

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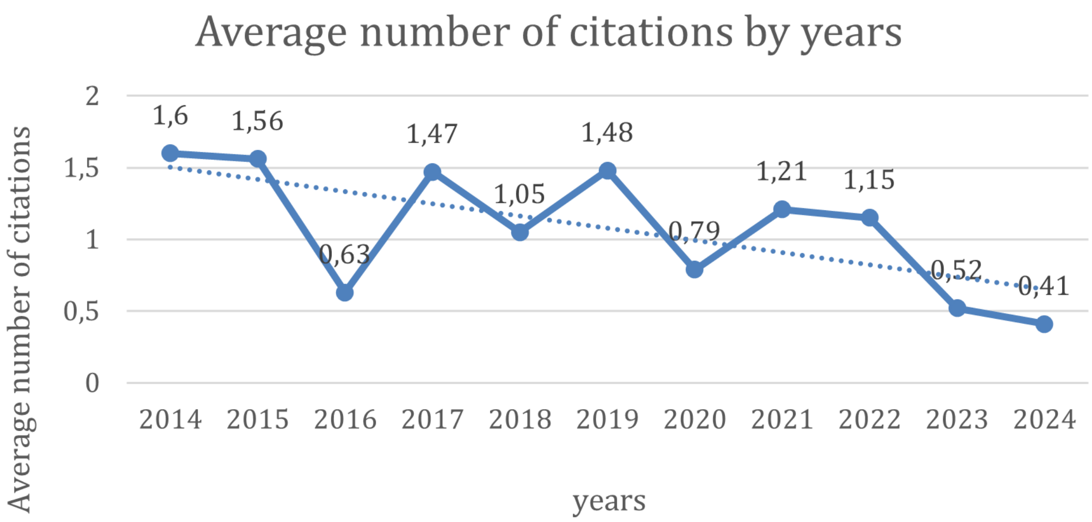
Average Citations per Year

When the average number of citations per year for the articles is examined, the trend appears to be the opposite of the number of articles produced each year. As clearly shown in Figure 3, there is a downward trend in average citation numbers. A fluctuating pattern is also present in this graph.

Figure 3
Average number of citations per year



Note. Prepared by the authors (2025).

The inverse trend between the number of articles produced and the average number of citations indicates that, while a decrease in the average number of citations during years with increased article production may be considered normal, the slope of this decline appears to be steeper.

Most Relevant Sources

The top 10 most relevant sources related to the topic of the study are shown in Figure 4. The source titled "International Journal of Mathematical Education in Science and Technology" is the one that has published the most articles on KM (n=26). In the chart containing the top 10 most relevant sources, the last one, "Journal fur Mathematik-Didaktik," is represented with 5 publications. Although the number of articles per source falls below five for the remaining sources, considering there are 103 sources and 235 articles, the average number of articles per source can be calculated as approximately 2.282.

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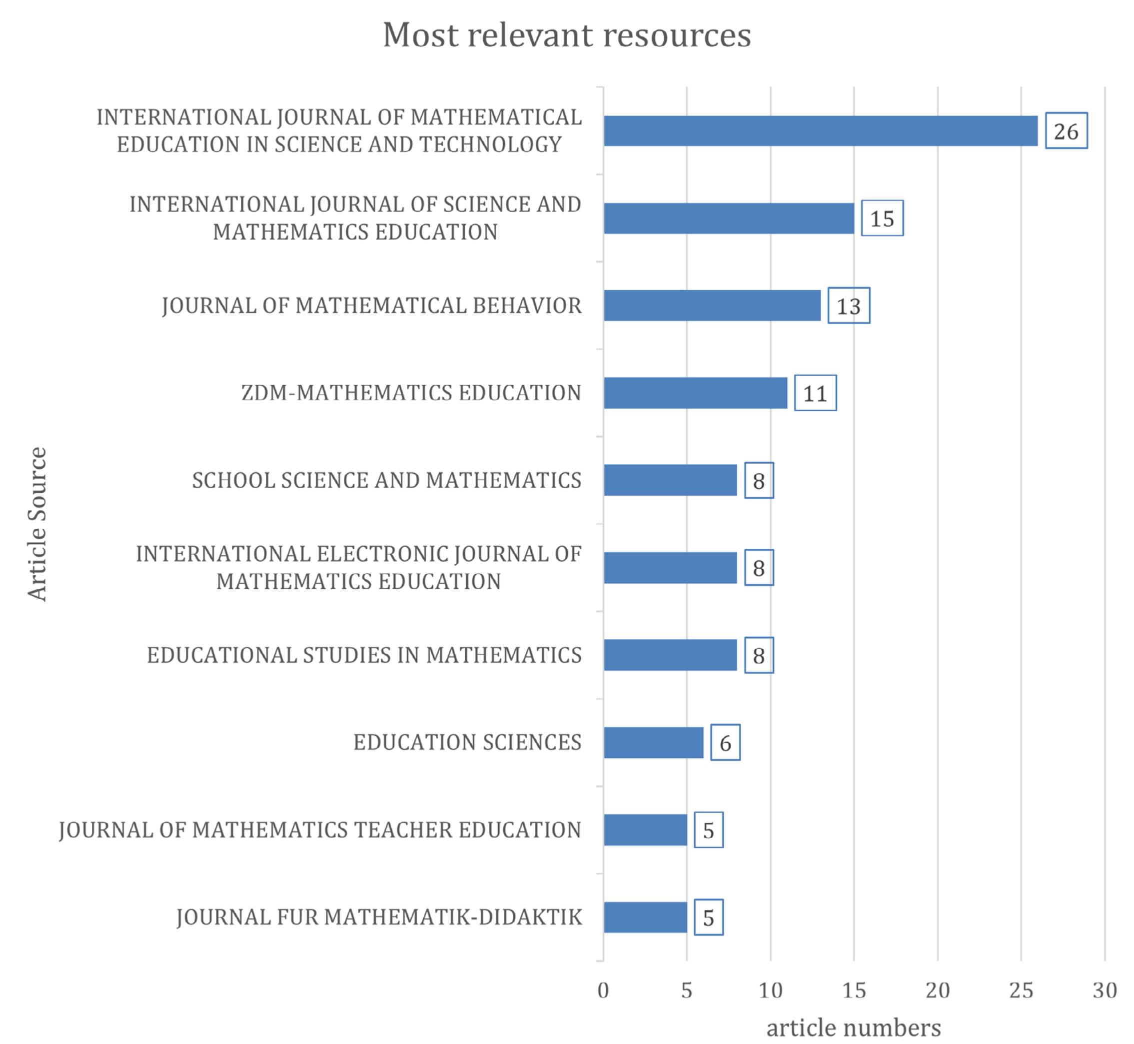
Figure 4
Chart of the most relevant sources



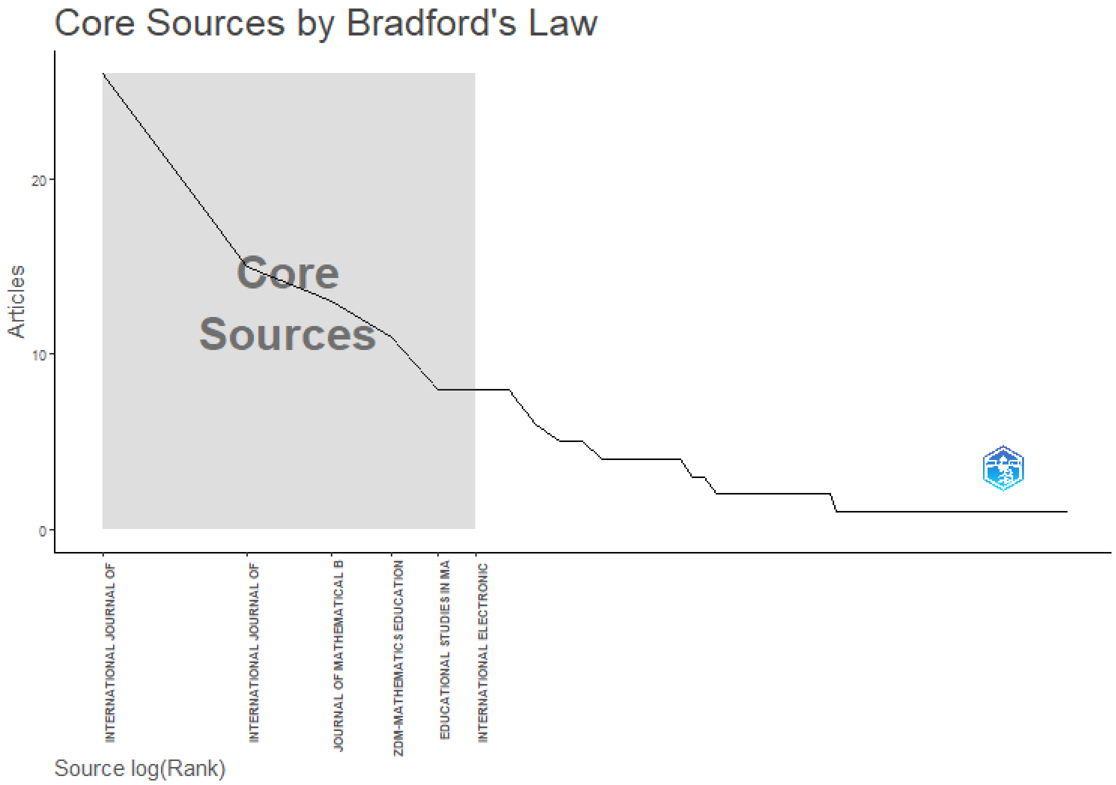
Note. Prepared by the authors (2025).

Core Sources by Bradford s Law

Bradford's law, in simple terms, shows that among the increasing number of publications, the distribution of publications by source indicates that a small number of sources contain a significant portion of the publications. According to Figure 5, the sources ranked in the top six are "International Journal of Mathematical Education in Science and Technology," "International Journal of Science and Mathematics Education," "Journal of Mathematical Behavior," "ZDM-Mathematics Education," "Educational Studies in Mathematics," and "International Electronic Journal of Mathematics Education," and these represent Zone 1, the area of core sources.

Figure 5

Distribution of publications according to Bradford's law (adapted from Biblioshiny)



Note. Prepared by the authors (2025).

Table 2

Source list for Area 1 (Zone 1) according to Bradford's law

Sıra No (103)	Kaynak	Makale Sayısı	Kümülatif Frekans	%
1	International Journal of Mathematical Education in Science and Technology	26	26	11,06
2	International Journal of Science and Mathematics Education	15	41	6,38
3	Journal of Mathematical Behavior	13	54	5,53
4	ZDM-Mathematics Education	11	65	4,68
5	Educational Studies in Mathematics	8	73	3,4
6	International Electronic Journal of Mathematics Education	8	81	3,4
Toplam (235)		81		%34,45

Note. Prepared by the authors (2025).

In other words, according to Table 2 and Bradford's law, 6 out of the total 103 sources account for the presence of approximately one-third (about 35%) of the articles in Zone 1.

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Most Relevant Authors

The aim of this analysis is to identify the leading authors in the field. The top 10 most significant contributors to the field of KM in mathematics education are listed in Table 3.

Table 3
Most relevant authors

Yazarlar	Makale Sayısı
Bansilal S	5
Yang DC	5
Makonye JP	4
Barbieri CA	3
Estande JL	3
Giberti C	3
Lee MEU	3
Luneta K	3
Sianturi IAJ	3
Akdeniz DG	2

Note. Prepared by the authors (2025).

According to Table 3, Bansilal, S. and Yang, D.C. are seen as the two authors who have made the greatest contributions in the field of CT in mathematics education. Among the top 10 authors, Akdeniz D.G. ranks last with 2 articles. While it is observed that another 32 authors out of a total of 580 have also contributed to the field with 2 articles each, the remaining authors have published 1 article each.

Countries' Scientific Production

Data on the article productivity of countries regarding CT in mathematics education are presented in Figure 6.

According to the data in Figure 6, among the top 10 countries with the highest article productivity, the USA ranks first in terms of article productivity (n=180), and there is a more than twofold difference compared to Turkey, which is in second place (n=68). China is third (58), followed by South Africa (49), Germany (33), Israel (17), Belgium (15), Ireland (15), the UK (15), and Australia (14) in last place. Additionally, the total number of articles on CT in mathematics teaching from the top 10 countries (n=467) constitutes approximately 70% of the total number of articles (n=673) from the complete list of 50 countries.

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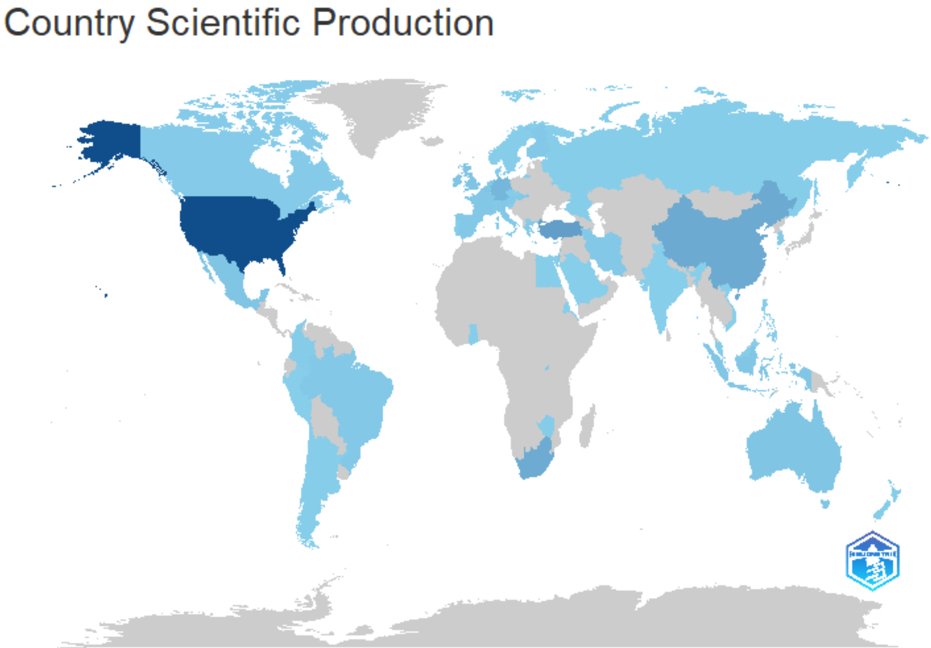
Figure 6
Countries' scientific production (taken from Biblioshiny visuals)



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Most Global Cited Documents

The 10 most cited articles related to CT in mathematics teaching can be seen in Figure 7.

The most globally cited article (n=107) is the one titled "Developing an assessment-centered e-Learning system for improving student learning effectiveness," written by Wang T.H. (2014). The second most cited article, with 86 global citations, is titled "Promoting self-explanation to improve mathematics learning: A meta-analysis and instructional design" (Rittle-Johnson, 2017). The other articles received 56, 51, 45, 42, 37, 36, 35, and 35 citations, respectively. With 35 citations, the articles "Study on Sixth Grade Students' Misconceptions and Errors in Spatial Measurement: Length, Area, and Volume" (Sisman, 2016) and "Improving the judgment of task difficulties: prospective teachers' diagnostic competence in the area of functions and graphs" (Ostermann, 2018) are ranked 9th and 10th in the top 10 article list.

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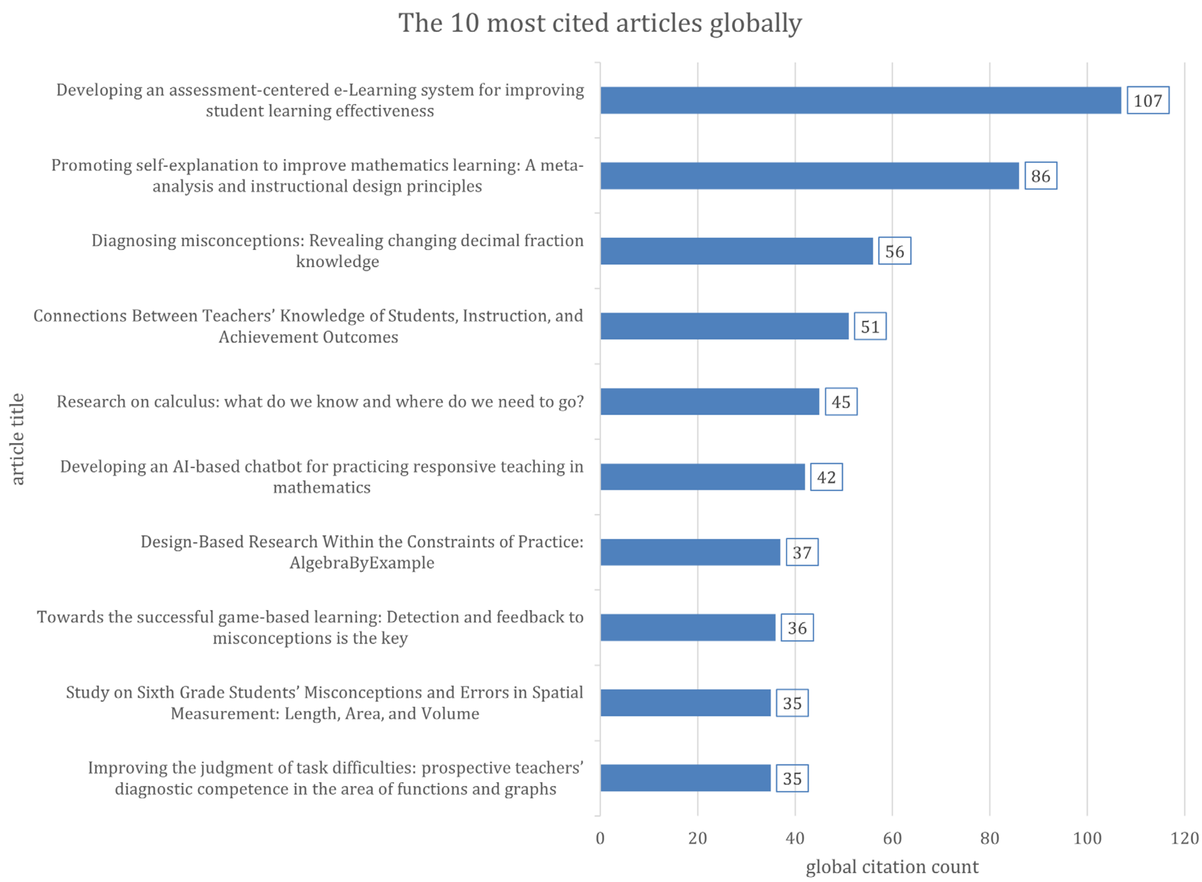
Figure 7
The 10 most globally cited articles (Most Global Cited Documents)



Note. Prepared by the authors (2025).

In the following scientific mapping section of KM, findings concerning analyses that reveal the scientific network structure are presented.

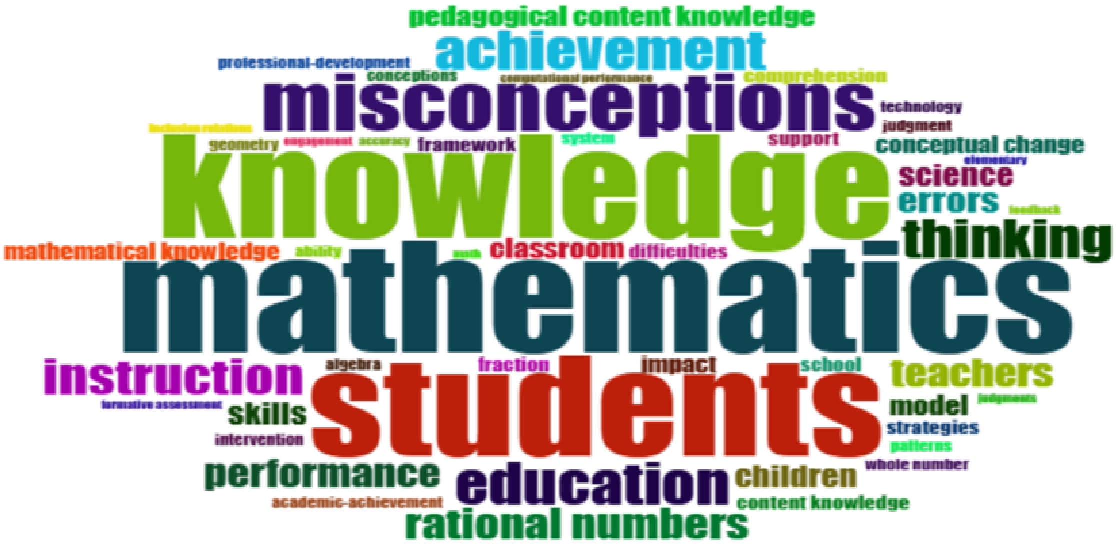
1. KY Bilimsel Haritalama

This section includes analyses related to scientific mapping. These analyses present findings regarding intellectual interactions and structural connections among the components within the "research theme-scientist-publication" triangle. In other words, analyses such as word clouds and topic trend analyses that reveal the scientific network structure among these components, thematic maps, factor analysis, co-cited authors, co-cited references, co-authorship based on author and institution criteria, international collaboration networks, and co-occurrence networks of keywords used by authors, as well as analyses indicating which of these stood out in which years, are provided.

(Word Cloud & Trend Topics) (Biblioshiny)

By using a word cloud, an analysis of the concepts used as keywords in the articles is conducted with the aim of revealing the content of the articles and helping to determine the overall structure of the study. The word cloud related to KY misconceptions is given below (Figure 8). The size of the concepts and their distance from the center of the cloud provide information about the relevance of the articles to the topic.

Figure 8
Word Cloud

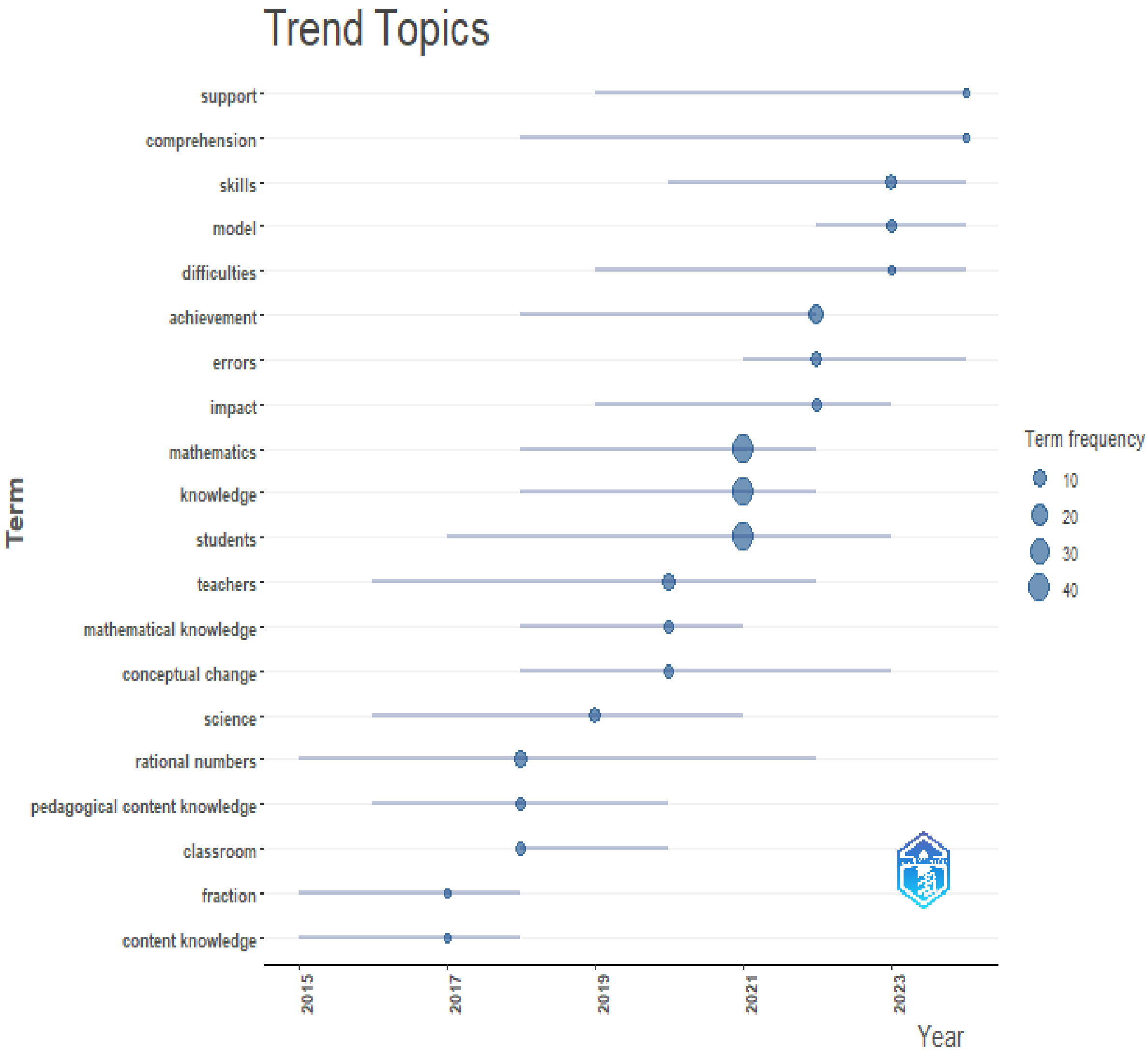


Note. Prepared by the authors (2025).

The words that appear most frequently in the word cloud, at least 10 times or more, can be listed as follows: “mathematics” (n=40), “knowledge” (n=37), “students” (n=36), “misconceptions” (n=21), “education” (n=15), “achievement” (n=14), “thinking” (n=14), “instruction” (n=13), “rational numbers” (n=13), “performance” (n=10), and “teachers” (n=10). Additionally, a trend topics analysis was conducted using the “keyword plus” criterion, which allows access to more keywords in the articles, in order to determine the areas in which the articles have shown trends over the years. The findings related to the analysis are presented in Figure 9.

According to Figure 9, while there was a trend between 2015 and 2018 in fractions and content knowledge, rational numbers extended from 2015 to 2022. Between 2018 and 2020, studies were conducted on nearly all topics, whereas in 2021, subjects involving students, knowledge, and mathematics concepts included the highest number of studies. By 2024, there is a trend towards article topics containing the terms support, comprehension, skills, model, difficulties, and errors.

Figure 9
Topic trend (Trend Topics)

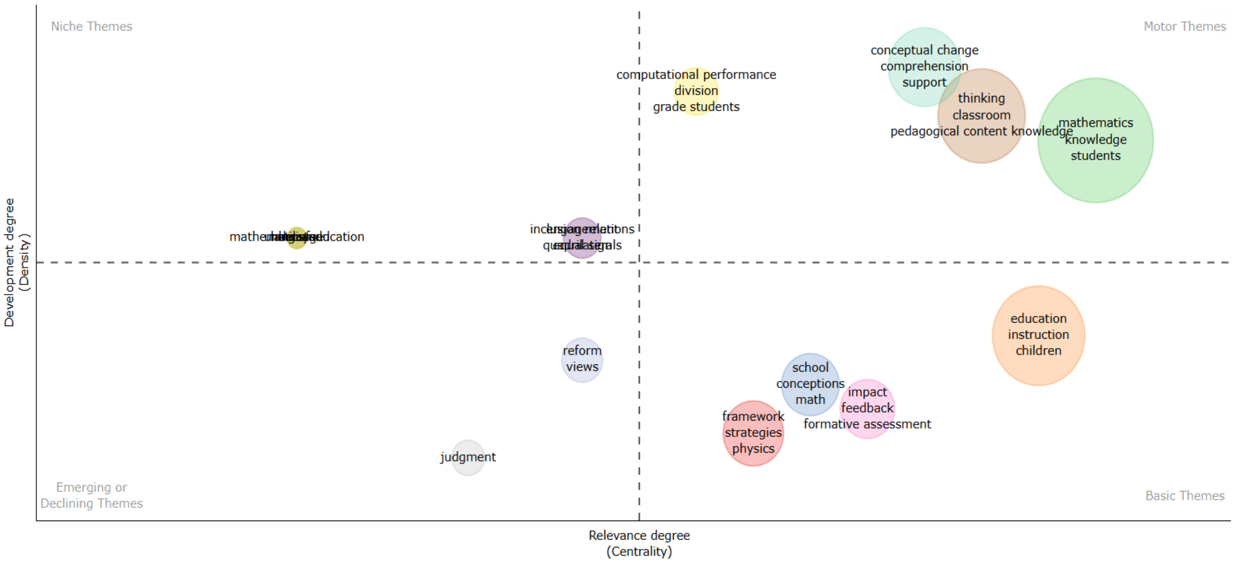


Note. Prepared by the authors (2025).

Thematic Map

In the analysis of the thematic map, it was aimed to analyze the concepts located at the center of the field of study and those with higher density, by considering the keyword plus option. Accordingly, information such as the development and intensity of the research topics and which topics are in a central position were obtained. The map related to the analysis is shown in Figure 10. In the thematic map, the parameters were not changed (for example, the clustering algorithm was kept as Walktrap, and a maximum of 3 concepts were evaluated in each cluster).

Figure 10
Thematic map for additional keywords (Thematic Map) (Biblioshiny)



Note. Prepared by the authors (2025).

When examining Figure 10, it is seen that the concepts of mathematics, knowledge, and students, which form one of the clusters with the highest values in terms of density, centrality, and number (cluster size) in the upper right section of the graphic, are among the motor themes. In the lower right section, the word group with the highest density and centrality, but which is considered a basic theme despite not being the subject of much research, is seen as education, instruction, and children. In the upper left section (Niche themes), there is a cluster that includes the concepts of inclusion relations and quadrilaterals, which have high density but low presence at the core of the articles. It is understood that these concepts do not occupy a central position in studies related to KY. In the lower left section of the graphic, the concept with the lowest value in terms of centrality, density, and number in KY article studies is judgement.

Faktorial Analysis

In this analysis, which determines the relationships between concepts and the overall conceptual structure, multiple correspondence analysis is taken as the basis. It was applied to the authors' keywords and three concept clusters were formed. These concept clusters are shown in Figure 11.

According to the multiple correspondence analysis, the concepts in Figure 11, based on the best dimension reduction value, correspond to approximately 23% of all keywords. When examining the conceptual depth of the studies, in the red cluster—which forms the largest area—concepts such as teacher/knowledge, university/mathematics/education, prospective/

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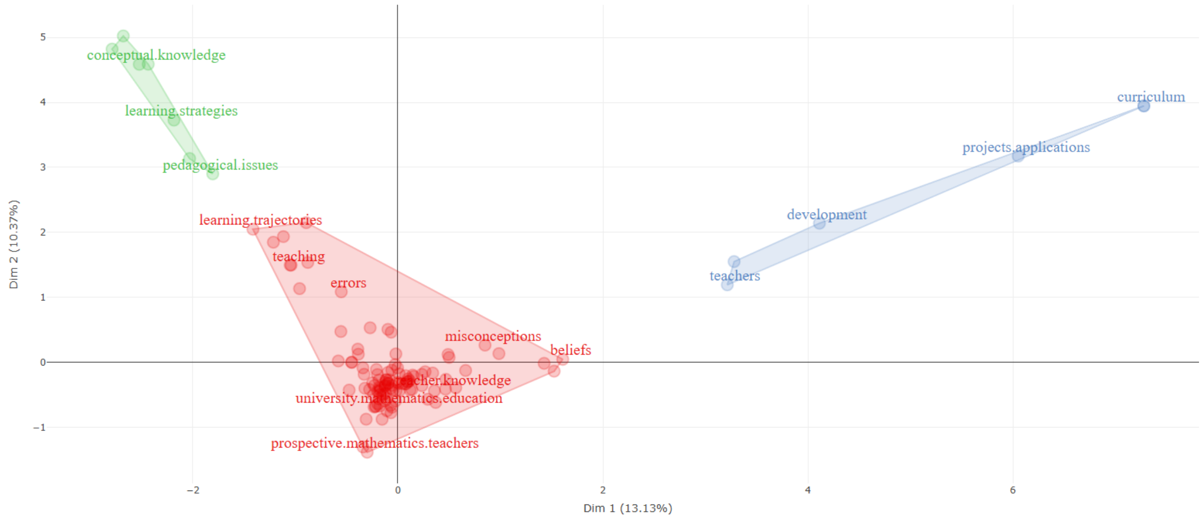
mathematics/teachers, beliefs, misconceptions, errors, teaching, and learning/trajectories are observed. In the second largest blue region, the concepts of teachers, development, projects/applications, and curriculum are seen. In the third region, shown in green, the concepts of conceptual/knowledge, learning/strategies, and pedagogical/issues are present. The considerable distance between the concepts in the second and third areas suggests that the concepts are less related to each other.

Figure 11
Factor analysis (Faktorial Analysis, Method: Multiple Correspondence Analysis, Field: Author Keywords) (Biblioshiny)



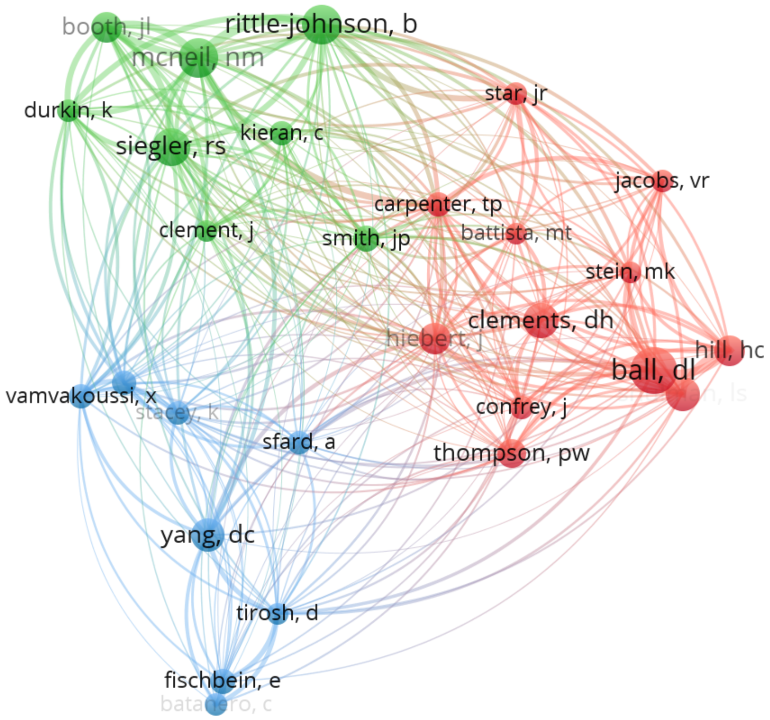
Note. Prepared by the authors (2025).

(Co-Citation-Cited Authors) (VOSviewer)

In the co-citation analysis, the situation where two authors are cited together is examined based on the "authors" criterion. The visual representation of this analysis is provided below in Figure 12. Authors who have been co-cited at least 20 times were included in the analysis, and 28 such authors were identified.

According to the co-citation analysis, as shown in Figure 12, it is observed that three different clusters have formed. Based on the size of the node representing the author, Ball, D.L. is central in the red cluster; Rittle-Johnson, B., Siegler, R.S., and McNeil, N.M. are central in the green cluster; and Yang, D.C. is central in the blue cluster. While these authors occupy central positions, in terms of being co-cited across clusters, Hiebert, J. stands out first, followed by Smith, J.P., Carpenter, T.P., Clement, J., and Sfard, A., who are also centrally positioned authors receiving co-citations.

Figure 12
Co-Citation-Cited Authors

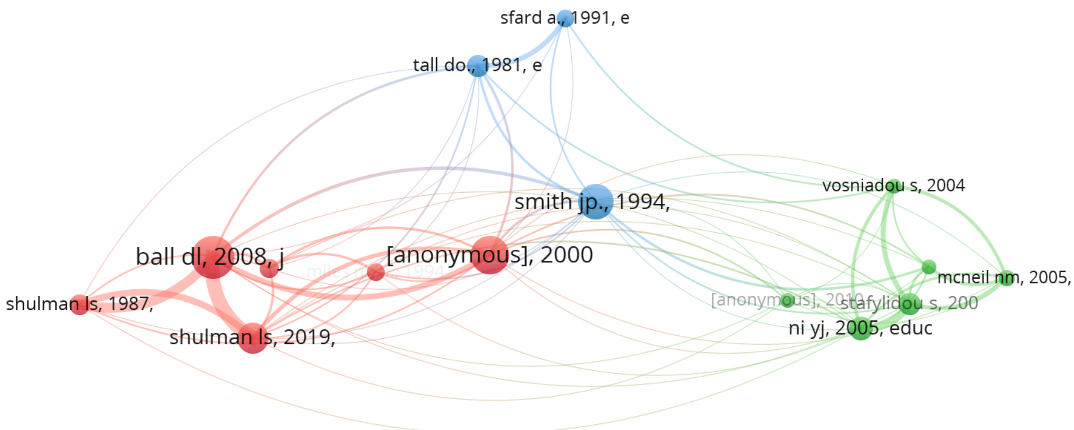


Note. Prepared by the authors (2025).

(Co-Citation - Cited References)

Considering the references in co-citation analysis, Figure 13 was obtained. In the analysis, the minimum number of times a reference was cited was set at 10, and it was observed that 15 references met this criterion.

Figure 13
Co-Citation - Cited References (VOSviewer)



Note. Prepared by the authors (2025).

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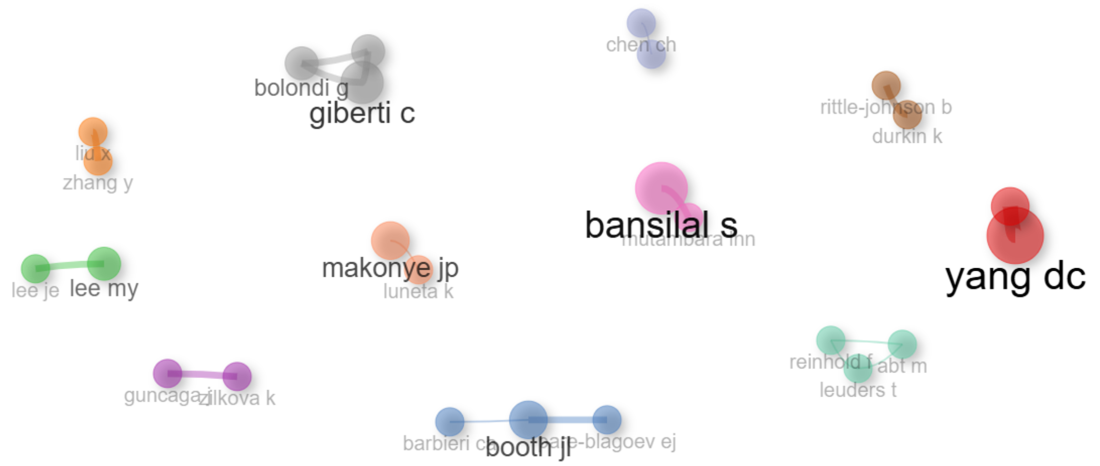
When Figure 13 is examined, three clusters can be seen. In the red cluster, Ball (2008) is positioned as the central reference, while in the blue cluster, Smith (1984) holds the central position, and in the green cluster, Stafylidou (2004) is at the center. In addition, Anonymous (2000) and Smith (1994) are centrally positioned references connected to all clusters.

Co-Authorship Analysis by Author Criteria (Co-Authorship – Authors)

The analysis of co-authorship among authors is formatted in Figure 14. The Walktrap algorithm was used for clustering.

Figure 14
Co-Authorship Analysis by Author Criteria (Co-Authorship – Authors) (Biblioshiny)



Note. Prepared by the authors (2025).

Figure 14 illustrates the scarcity of collaboration among authors. In the field of mathematics education on the subject of co-authorship, collaboration is usually observed within small groups of 2-3 authors. However, there are no connections between the clusters, and no collaboration is observed between author groups. Nonetheless, the pink, red, and grey clusters stand out, in that order. In the red cluster, Yang is a prominent author; in the pink cluster, Bansilal; and in the grey cluster, Giberti. Although the pink cluster is positioned centrally, given the lack of connections between clusters, centrality does not appear to be significant in this context.

Co-authorship Analysis by Institute Criterion (Collaboration Network – Institutions)

In the collaboration network, the aim was to examine the collaboration status of institutions regarding KY. For this, the graphic generated in biblioshiny is provided (Figure 15). The Walktrap algorithm was used as the clustering method.

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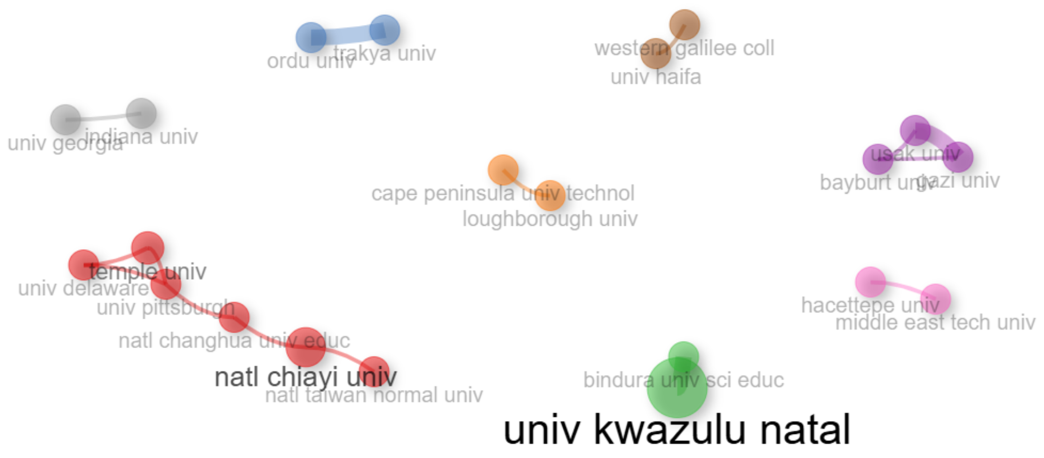
Figure 15
Co-Citation - Cited References (VOSviewer)



Note. Prepared by the authors (2025).

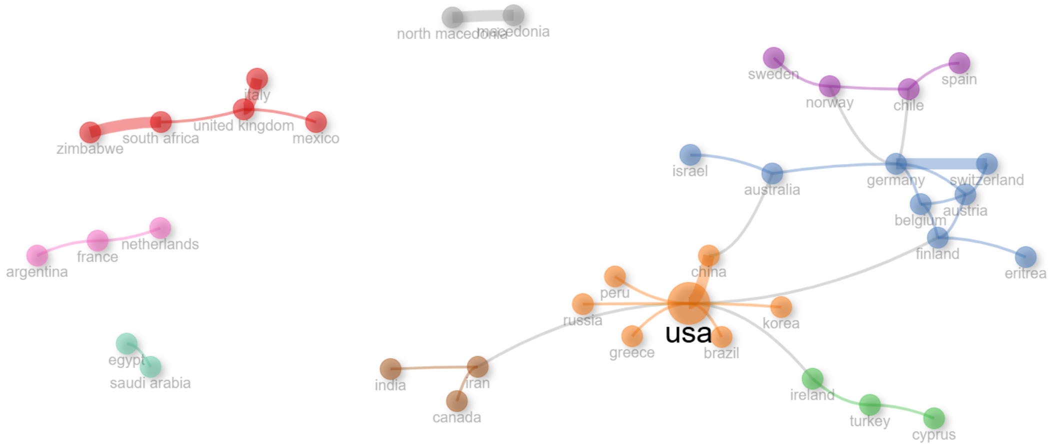
When Figure 15 is examined, although inter-institutional collaboration is not very frequent, the widest collaboration network is seen in the red cluster. Apart from this, collaborations formed within institutes, typically involving 2-3 institutions, are noticeable. Looking at the red cluster, which has the most extensive network, National Chiayi University stands out. In the green cluster, internal collaboration exists only between two universities, with University of Kwazulu-Natal being the dominant party. Additionally, in our country, a collaboration network is observed in the blue cluster between Ordu and Trakya Universities. Similarly, in the purple cluster, there is collaboration between Gazi University and Uşak University, Uşak University and Bayburt University, and Gazi University and Bayburt University. Furthermore, in the pink cluster, there is collaboration between Middle East Technical University (Ortadoğu Teknik Üniversitesi) and Hacettepe University.

Collaboration Network – Countries (Biblioshiny)

In this section of the collaboration network analysis, the status of international collaboration on KM has been examined. Accordingly, Figure 16 has been created, including countries with at least 3 publications. The Walktrap clustering algorithm was used.

In Figure 16, while the orange cluster containing the USA is positioned at the center of the network, collaboration is also observed between the orange cluster and the brown, green (which includes Turkey), and blue clusters. The USA stands out among the countries. Other clusters colored light green, pink, red, and gray represent countries collaborating among themselves. Additionally, a sequential relationship is observed in other clusters, but within the orange cluster, the USA occupies a central position and collaborates with all the countries within its cluster.

Figure 16
International collaboration (Collaboration Network - Countries)



Note. Prepared by the authors (2025).

In Figure 16, while the orange cluster containing the USA is positioned at the center of the network, collaboration is also observed between the orange cluster and the brown, green (which includes Turkey), and blue clusters. The USA stands out among the countries. Other clusters colored light green, pink, red, and gray represent countries collaborating among themselves. Additionally, a sequential relationship is observed in other clusters, but within the orange cluster, the USA occupies a central position and collaborates with all the countries within its cluster.

Author Keyword Co-Occurrence Network (VOSviewer)

The co-occurrence network of keywords used by authors in the context of KY in mathematics teaching—that is, the analysis that identifies which keywords authors prefer and how they are used together—is presented in the graph below (Figure 17).

While the concept of misconceptions is the most frequently used concept within its co-occurrence network, the blue, red, and purple clusters form a triangle (Figure 17). The concept of misconceptions, located at the center of the blue cluster, is used together with concepts such as errors, probability, geometry, assessment, conceptual changes, and algebra. In the red cluster, the most frequently used concept, mathematics education, is generally associated with misconception, teacher knowledge (although the name does not appear, the green dot shown closest to the most frequently used mathematics education concept in the red cluster), measurement, and fractions. In the purple cluster, it is observed that the concept mathematics is used together with concepts such as assessment, number sense, and geometry. Additionally, it is seen that measurement, conceptual change, and assessment are located at the center of the clusters due to their associations with dominant concepts across clusters.

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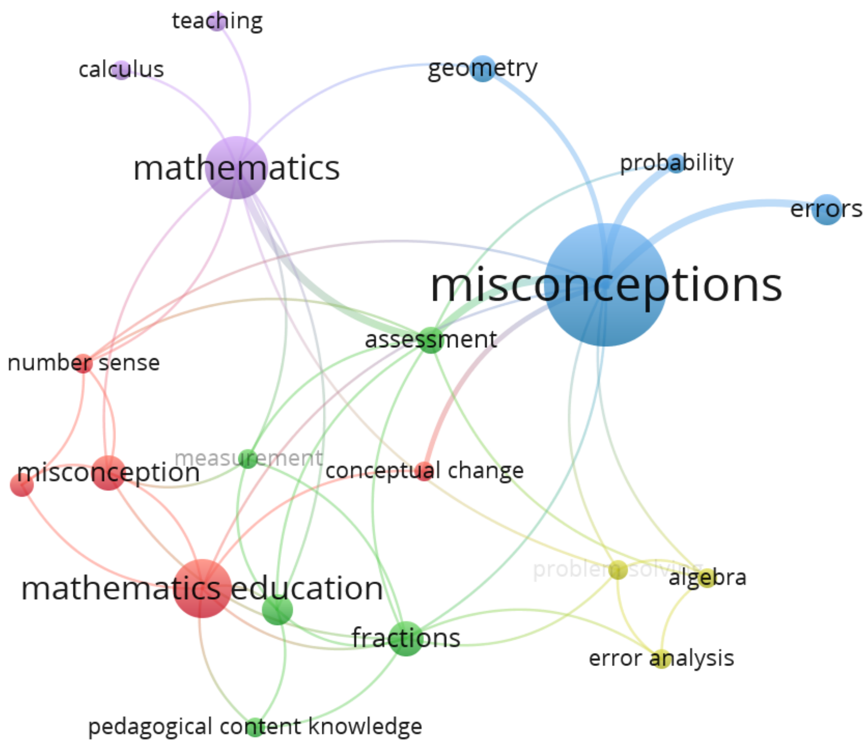
It is also observed that the association of the mathematics education concept with this concept is relatively low.

Figure 17
Author Keyword Co-Occurrence Network



Note. Prepared by the authors (2025).

However, it can be said that the misconceptions concept has stronger ties with concepts such as assessment, probability, errors, and geometry. Moreover, the strong connection of the mathematics and misconceptions concepts with the assessment concept is also evident.

Usage of Author Keywords by Year Co-Occurrence over Time-Author Keywords (VOSviewer)

The graph prepared to examine the formation of the co-occurrence network of author keywords by year is shown below (Figure 18). The analysis was carried out using keywords that create at least five co-occurrence networks, and the development of these over the years was examined.

Figure 18 is shown together with the year scale. Concepts such as mathematics education (marked in yellow) and conceptual understanding on its left (shown with a red frame) were prominent concepts in 2021. The cluster shown in green, with misconception as a

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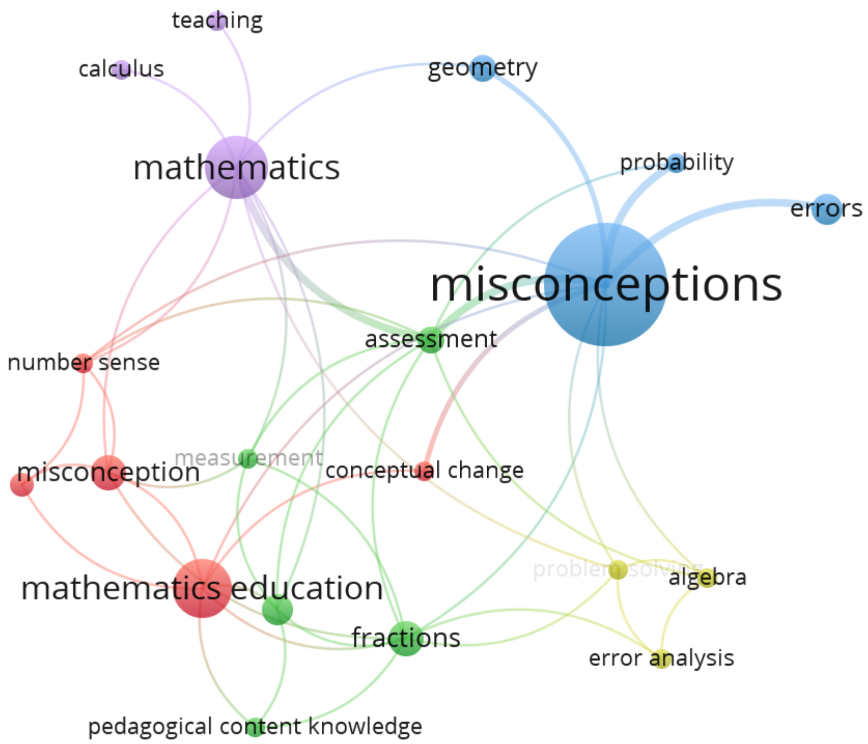
leading concept, was widely used and became a prominent concept around 2020. It is observed that the concepts mathematics, assessment, and errors predominantly established their relationships in 2018.

Figure 18
Usage of author keywords by year (Co-Occurrence-Author Keywords)



Note. Prepared by the authors (2025).

CONCLUSION AND RECOMMENDATIONS

This study presents a comprehensive bibliometric analysis of research conducted on misconceptions in mathematics education. The results of the analysis clearly show that this field has attracted increasing attention in recent years and boasts an impressive annual growth rate of 10.72%. This growth rate indicates that the subject of misconceptions in mathematics education is gaining importance among researchers and that studies in this field are rapidly increasing (Gülmez et al., 2020).

The average document age of 5.27 years provides strong evidence that the literature is fairly current. This situation demonstrates that information in the field is being updated rapidly and that researchers are closely following recent developments. The overall upward trend in publication numbers reveals that this field is gaining greater interest within the academic

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community and that researchers are focusing intensely on this subject. However, the observed downward trend in citation numbers stands out as a noteworthy finding. This suggests that factors such as publication quality, research impact, and academic competition may influence citation dynamics. The decline in citation numbers may highlight the need for researchers to pursue more original and innovative studies, and at the same time, it could point to the necessity of improving publication quality.

The pioneering role of the "International Journal of Mathematical Education in Science and Technology" in this field demonstrates that this publication has become the focal point for research on misconceptions in mathematics education. This journal stands out as a platform where the most up-to-date and influential studies in the field are published. The analysis conducted according to Bradford's law has identified the core sources in the field and has revealed the distribution of publications in detail (Hussain et al., 2023).

This analysis provides valuable information for researchers about which sources they should prioritize. Furthermore, identifying these The fact that Bansilal, S. and Yang, D.C. stand out as the most contributing researchers among the authors highlights their expertise and influence in the field. Examining the work of these researchers offers an important opportunity to understand the most current and effective approaches to misconceptions in mathematics education. The fact that the USA, Turkey, and China are seen as the most productive countries indicates the importance these countries place on mathematics education research and demonstrates their leadership in the field. Examining the education systems and research approaches of these countries can serve as an example for other countries and create opportunities for international cooperation (Jamali et al., 2023).

Word cloud and topic trend analyses revealed that concepts such as "mathematics," "knowledge," "students," and "misconceptions" are at the forefront. These findings clearly demonstrate the focus and central concepts of the research. The frequent use of these terms indicates that there has been intensive work on student knowledge and misconceptions in mathematics education. Thematic map analysis has detailed the fundamental and emerging themes in the area of misconceptions in mathematics education. This analysis shows researchers which topics have been examined in depth and which areas require further study. Identifying emerging themes can play an important role in shaping future research directions (Noyons et al., 1999).

Co-authorship and collaboration network analyses have shown that collaboration among authors and institutions is limited, but international collaboration is more common. This finding indicates that there is potential for greater cooperation among researchers and institutions, and that there are opportunities for development in this area. The prevalence of international collaboration enables the sharing of international perspectives and experiences obtained from different education systems (Oyman Bozkurt & Bozkurt, 2024).

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This comprehensive study provides a detailed overview of the current state, trends, and gaps in the field of misconceptions in mathematics education, offering valuable guidance for future research. Additionally, these findings can make significant contributions to shaping educational policies and improving teaching methods. For example, specific instructional strategies can be developed to address identified misconceptions, or curriculum content can be updated in light of these findings.

For future research, it is recommended to enhance collaboration between authors and institutions, encourage interdisciplinary studies, and investigate misconceptions more deeply. Additionally, topics such as how technology can be used to address misconceptions in mathematics education, how misconceptions arise in different cultural contexts, and how they can be addressed stand out as potential areas for future research.

In conclusion, this bibliometric analysis comprehensively reveals the research dynamics, trends, and potential areas for development in the field of misconceptions in mathematics education. These findings provide valuable insights for researchers, educators, and policymakers, and make significant contributions to efforts aimed at improving the quality of mathematics education.

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