Bibliometric Analysis of Studies on Preschool Mathematics Education with VOSviewer

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Abstract. Scientific research demonstrates that mathematical skills acquired in early childhood play a critical role in individuals' academic success in later education. This has increased the need for qualified scientific knowledge and systematic analyses of the literature to support mathematical development, particularly in the preschool period. In this context, this study examines 748 academic publications on the theme of preschool mathematics education, published in the Web of Science database between 2015 and 2025, using bibliometric analysis. The findings reveal that the number of publications in the relevant field has increased over time, providing a comprehensive view through structural variables such as publication types, countries, institutions, authors, journals, and most cited studies. Furthermore, conceptual trends, collaboration networks, and research focuses in the field were analyzed through keyword analysis and thematic clustering. According to the results obtained, this study aims to map academic trends in the field of preschool mathematics education and to provide researchers and relevant stakeholders with a holistic, systematic and guiding perspective on the current status of the literature and its development directions.

Keywords. Mathematics, early mathematics, preschool, bibliometric analysis.

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Preschool education is a critical period in terms of development, where the basic building blocks are laid in the areas of cognitive, social, affective and psychomotor development of the individual. During this period, children's experiences form the foundations of the knowledge, skills and attitudes they will acquire in their later lives (OECD, 2017). While the mental development of children between the ages of 3 and 6 is particularly rapid, the importance of structured educational environments to support this process is increasingly emphasized (UNESCO, 2022). Research has shown that as the quality of pre-school education increases, children's competencies in not only social-emotional but also academic areas improve (Barnett, 2011).

Mathematics education plays a fundamental role in the cognitive development, problem-solving skills, and analytical thinking of individuals (Clements & Sarama, 2009). The basis of this education is laid in early childhood. Mathematical concepts acquired in the preschool period are related to academic success in later years and contribute to children's understanding of the relationships they establish with their environment (Ginsburg, Lee, & Boyd, 2008). In this developmental context, mathematics education is considered as a holistic learning area that is not limited to numbers and operations in the preschool period; it supports basic cognitive processes such as patterning, establishing relationships, spatial thinking, sorting, classification, and problem solving (Clements & Sarama, 2009; National Research Council, 2009).

Introducing children to mathematical concepts at an early age positively affects not only their success in later school life, but also their logical thinking and decision-making skills (Ginsburg et al., 2008, Clements, & Sarama, 2011; Braak, Lenes, Purpura, Schmitt, & Storksen, 2011; Sarama, Lange, Clements & Wolfe, 2012; Maričić & Stamatović, 2017;). Research shows that mathematical competencies developed in the preschool period are strong predictors of success at primary and secondary school levels (Nguyen et al., 2016). In this direction, the need to acquire scientific knowledge regarding the construction of children's mathematical skills from an early age has increased significantly, and research in this area has accelerated in recent years.

These studies conducted in early childhood not only help understand children's current cognitive competencies, but also guide the design of teaching practices, teacher training, and program development processes (National Research Council, 2009; Sarama & Clements, 2021). Scientific findings enable evidence-based planning of educational practices, allowing children's basic mathematical skills such as number concept, pattern recognition, sequencing, comparison and spatial awareness to be supported in a versatile way (Van Nes, 2009). Therefore, scientific studies conducted

in the field of early childhood mathematics education contribute not only to the production of theoretical knowledge, but also to the development of effective teaching strategies for the field and serve as a guide for all stakeholders in education.

In recent years, there have been significant academic developments in the field of preschool mathematics education at both national and international levels, and different approaches, teaching techniques, and material use have been the subject of research. With the increasing academic interest in this area, numerous qualitative, quantitative, and mixed-method studies focusing on preschool mathematics education have been conducted. These studies diversify into many subthemes such as teacher competencies, curriculum, game-based learning, use of digital tools, STEAM applications, support of spatial skills, and culture-specific mathematical development (Sarama & Clements, 2021).

The field of preschool mathematics education is in a rapid transformation under the influence of multidisciplinary approaches. However, the content diversity of the studies conducted in the field does not provide a systematic view of which topics are at the forefront, which themes are developing, or which aspects have not been studied sufficiently. The increase in scientific productivity in the field of preschool mathematics education necessitates a systematic examination of the existing literature and analysis of publication trends and knowledge production networks (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021). In recent years, with the development of digital technologies, access to scientific publications and the methods of analyzing these publications have diversified significantly. Thanks to web-based databases and advanced analysis tools, academic literature can be scanned and interpreted more systematically (Drijvers, Grauwin, & Trouche, 2020). In this context, the bibliometric analysis method; It provides the opportunity to objectively reveal trends in academic literature, the most productive researchers, collaboration networks, keyword densities, and development dynamics in the field (Aria & Cuccurullo, 2017; Moral-Muñoz et al., 2020).

The bibliometric analysis method allows analyzing the knowledge in the literature with numerical criteria, revealing which studies stand out, who contributes to this field, and which themes gain importance over time (Zupic & Čater, 2015). Bibliometric analysis not only defines academic production; it also provides strategic information to guide future research (Donthu et al., 2021). When we look at the literature, it is seen that the number of studies conducted using the bibliometric technique is increasing in the publications of researchers who realize the importance of such studies in many fields (Thompson, 2018; Aksu & Güzeller, 2019; Sönmez & Bozdoğan 2020; Çelik, 2022; Dede & Özdemir, 2022).

A systematic review conducted by MacDonald and Murphy (2019) covered mathematics education research for children under four years of age. This study emphasized children's mathematical competencies and educators' attitudes and noted that educators were uncertain about supporting mathematics learning (MacDonald & Murphy, 2019). Furthermore, a bibliometric study conducted by Çelik (2022) contributed to the literature by systematically presenting the topics, methods, and educator-focused themes of early childhood mathematics education research published in Turkey between 2016 and 2020 (Çelik, 2022).

In this context, the main purpose of this research is to examine the academic studies published between 2015 and 2025 in the field of preschool mathematics education using the bibliometric analysis method and to reveal the general trends, leading researchers and research themes of the field. Thus, this study aims to systematically map the existing literature and shed light on future studies by identifying research gaps in the field. In a pedagogically critical field such as preschool mathematics education, it is thought that such an analysis will contribute to the formation of research policies, the identification of new research gaps and the determination of scientific impact areas (Zupic & Čater, 2015).

In this context, the research questions of the study were determined as follows:

1. What is the numerical distribution of studies on preschool mathematics education by year?

2. What is the distribution of studies on preschool mathematics education by publication type?

3. What is the distribution of studies on preschool mathematics education by country of publication?

4. What is the distribution of studies on preschool mathematics education by the institutions where their authors work?

5. What is the distribution of studies on preschool mathematics education by authors?

6. What is the distribution of studies on preschool mathematics education by the sources they are published in?

7. Which publications have the greatest among studies on preschool mathematics education?

8. What are the most frequently used keywords in studies on preschool mathematics education?

Bibliometric analysis provides important data to quantitatively reveal publication trends in the field of preschool mathematics education. However, it is necessary to clearly define how these

findings contribute to the literature and practice. The research problems addressed in this study aim to provide valuable information to researchers, educators, and policymakers working in the field of preschool mathematics education. Determining the distribution of publications by year, type, country, institution, author, and source (Problems 1-6) will reveal the focus and geographic distribution of research in this field and guide future research. Furthermore, identifying the most influential publications and frequently used keywords (Problems 7-8) will help identify theoretical and conceptual trends in the existing literature, enabling the direction of new research. Thus, the results of this study will contribute to the development of academic knowledge and to more informed and strategic decisions for practice.

Method

This research was carried out to examine the scientific studies carried out in the field of mathematics education in the preschool period. The study used the bibliometric analysis approach, one of the quantitative research methods. Bibliometric analysis is a powerful method that allows the systematic examination of publications in a specific academic field to reveal development trends, collaboration structures, and research gaps. Thanks to this method, which is based on objective criteria such as the number of publications, number of citations, authors, countries, institutions, and keywords, the direction and dynamics of knowledge accumulation in the field can be analyzed in detail (Ellegaard & Wallin, 2015; Zupic & Čater, 2015; Donthu et al., 2021). Especially in developing research areas such as preschool mathematics education, bibliometric studies provide important contributions in terms of mapping trends in the literature and guiding future studies. In this context, the study aims to reveal the general appearance of the field by analyzing scientific publications on preschool mathematics education within the framework of various parameters.

Data Collection Process

The Web of Science (WoS) Core Collection was chosen as the data source in the study. WoS is one of the most established and comprehensive citation indexing systems in the academic world, developed by the "Institute for Scientific Information" (ISI) in the early 1960s and later taken over by Thomson Reuters (Falagas et al., 2008; Adriaanse & Rensleigh, 2011;). This platform, which is frequently preferred in bibliometric analyses, offers high reliability and wide coverage, especially in interdisciplinary publication searches (Boyle & Sherman, 2006). Today, WoS, managed by Clarivate Analytics, has a rich data pool containing more than 171 million publications. These publications include articles, conference proceedings, books, reports, and other academic documents.

The main indexes within WoS include Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI), Emerging Sources Citation Index (ESCI), Conference Proceedings Citation Index – Science (CPCI-S), Conference Proceedings Citation Index – Social Sciences & Humanities (CPCI-SSH) and Book Citation Index (BKCI-S and BKCI-SSH). Through these indexes, it is possible to access publications from different disciplines, analyze citation relationships and monitor the development of research areas. In this respect, WoS stands out as a strong reference source, especially in bibliometric studies aimed at literature mapping, trend determination and revealing scientific collaborations.

The data of the study were obtained as a result of a systematic scanning process conducted through the Web of Science (WoS) database in April 2025. In the data collection process, all collections within WoS were taken into account in order to comprehensively analyze the literature related to preschool mathematics education. The keywords used in the scanning were determined as "preschool mathematics", "early childhood mathematics", "early mathematics" and "kindergarten mathematics", and it was aimed to reach a broader set of results by using the logical conjunction "OR" (or) between these expressions. In this way, all different terminologies used in the literature were included in the scanning scope.

The search field was selected as "all fields" and thus, studies matching all relevant sections including title, abstract, keywords and other bibliographic information were included. As a result of the search, a total of 748 academic publications published between 2015 and 2025 were reached. The bibliometric information of these publications (such as author, publication year, country, institution, source journal, number of citations and keywords) formed the basis of the analysis process by creating the dataset. To ensure the accuracy of the dataset and the validity of the analyses, publications retrieved through the Web of Science database search strategy were not limited solely to automatic filters but also underwent a comprehensive manual review process to assess content relevance. During this process, titles, abstracts, and keywords were carefully examined, and publications not directly related to preschool mathematics education were excluded from the study. This ensured that the resulting publications accurately represented the designated research area. This comprehensive dataset provided the opportunity to evaluate research trends and production dynamics in the field of preschool mathematics education. Indicators such as publication numbers, citation numbers, keyword networks, country, institution, journal and author networks were evaluated. The data were visualized with graphs and network maps, and thematic developments were presented in detail.

Data Analysis

Within the scope of the research, bibliographic data belonging to a total of 748 academic publications published in the field of preschool mathematics education between 2015 and April 2025 were organized in accordance with the bibliometric analysis method and made ready for analysis. In this process, the obtained data set was classified and analyzed according to various bibliometric variables (year, author, country, institution, publication type, keywords, citation counts, etc.). The data were categorized based on the sub-problems of the research; frequency and percentage values were calculated in line with the obtained findings and presented visually through graphs. In addition, VOSviewer (Version 1.6.16) software was used to visualize structural relationships such as collaborations, keyword matches, and citation networks in the field. The software in question made an important contribution in terms of revealing the basic clusters, densities, and relationships in the literature by allowing bibliometric data to be analyzed with scientific mapping techniques.

Results

In this section of the research, findings related to the research conducted in the field of pre-school mathematics education are presented in line with the sub-objectives of the research.

Research Question 1: What is the distribution of academic studies published in the field of preschool mathematics education by year?
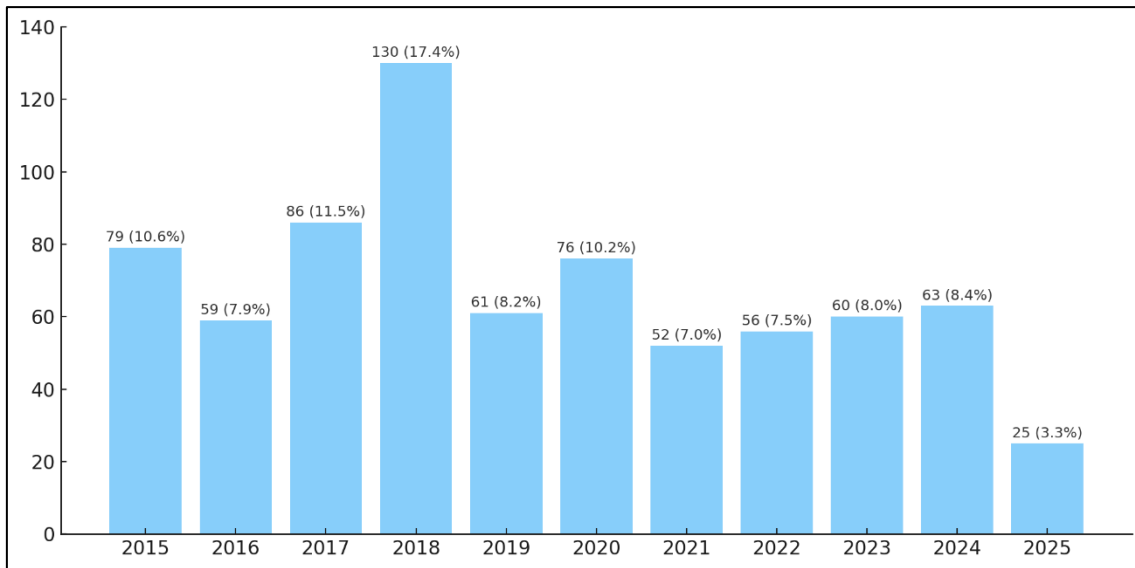
Graph 1. Numerical distribution of research on pre-school mathematics education by year (WoS, April 2025)

The distribution of academic studies published in WoS in the field of preschool mathematics education by year is presented in Graph 1. When Graph 1 is examined, it is seen that the years with the highest number of publications on early childhood mathematics education are 2018 (f=130) and 2017 (f=86). These years are followed by 2015 (f=79) and 2020 (f=76), respectively. The reason why the number of publications for 2025 (f=25) is lower than other years is that the data does not yet cover the entire year as of the date of the research (April 2025).

When the graph is examined as a whole, it is not possible to say that there was a linear upward trend in the number of academic studies published in the field of preschool mathematics education between 2015 and 2025. A notable increase is observed in 2017 (f=86) and especially 2018 (f=130); these periods stand out as years of intensified academic interest in the field. However, it is noteworthy that there was a relative decrease in the number of publications following these peak years.

The decrease in the number of publications to 52 in 2021 indicates a significant decline compared to previous years. This may be associated with the potential impact of the global COVID-

19 pandemic on academic production processes. The disruption of research activities during the pandemic, the difficulty of data collection, and shifting academic priorities can be considered among the main reasons for this decline.

While a partial recovery in the number of publications was observed in 2023 and 2024, since the data for 2025 (as of April) does not reflect the entire year, it is anticipated that the low number of publications for this year (f=25) may increase in the future. Consequently, when the relevant period is examined, rather than a consistently increasing publication trend in the field, there is a fluctuating production pattern with periodic increases and decreases. This suggests that scientific production in the field of preschool mathematics education is influenced by various factors, and that, in this context, time-dependent analyses should be interpreted with caution.

Research Question 2: What is the distribution of academic studies published in the field of preschool mathematics education according to publication types?
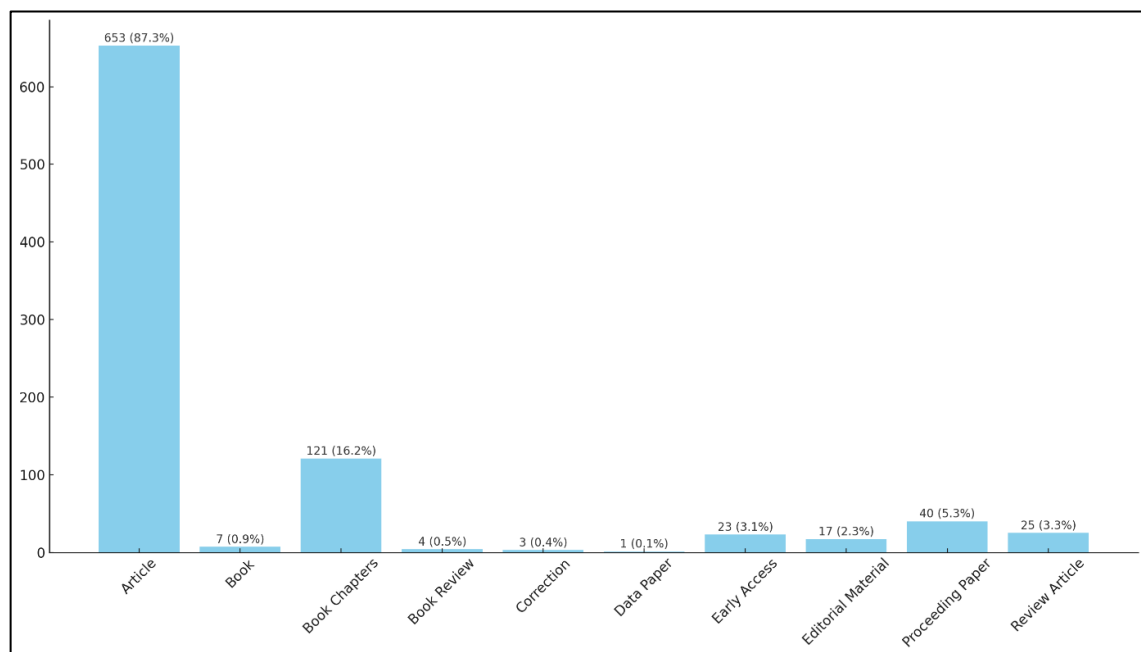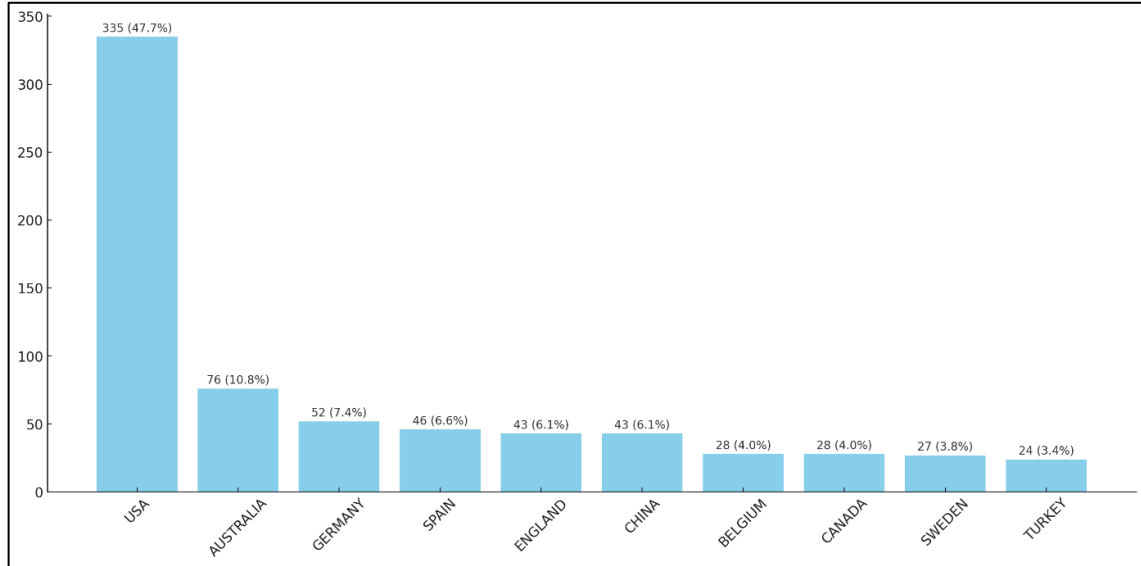

Graph 2. Distribution of the number of publications on pre-school mathematics
education by publication types (WoS, April 2025)

The distribution of academic studies published in WoS on preschool mathematics education by publication type is given in Graph 2. When the data presented in Graph 2 is examined, it is seen that the majority of academic studies published in the field of preschool mathematics education are articles (87.3%). Articles are followed by book chapters (16.2%) and papers (5.3%). This situation shows

that academic production in the field of preschool mathematics education is mostly in the form of articles, while book chapters and papers are relatively less preferred.

Research Question 3: What is the distribution of academic studies published in the field of preschool mathematics education by country?

Graph 3. Countries where publications on pre-school mathematics education are published - Top 10 countries (WoS, April, 2025).

The distribution of academic studies on preschool mathematics education published in the WoS database by country is presented in Graph 3. Although there are a total of 58 countries in this category, only the top 10 countries with the highest number of publications are included in the chart.

When the graph is examined, it is seen that the most publications in the field of preschool mathematics education were made in the United States (f=335), Australia (f=76) and Germany (f=52). This finding shows that the importance given to preschool mathematics education research in these countries is high and that academic production in the field is concentrated in certain countries. The lower number of publications in other countries indicates that the field has not yet developed equally on a global scale.

To determine the most effective countries in preschool mathematics education research, the citation analyses of the countries were examined. While conducting the citation analysis, the criteria that a country should have at least 1 publication, and 1 citation were selected in the VOSviewer program. 48 countries out of a total of 58 countries met these criteria. The analyses were continued with the 36 countries that have the most connections and relationships with each other out of these

48 countries. When Figure 1 is examined, it is seen that the USA is the leading country in terms of effectiveness in the relevant literature. Australia and Germany come right after.
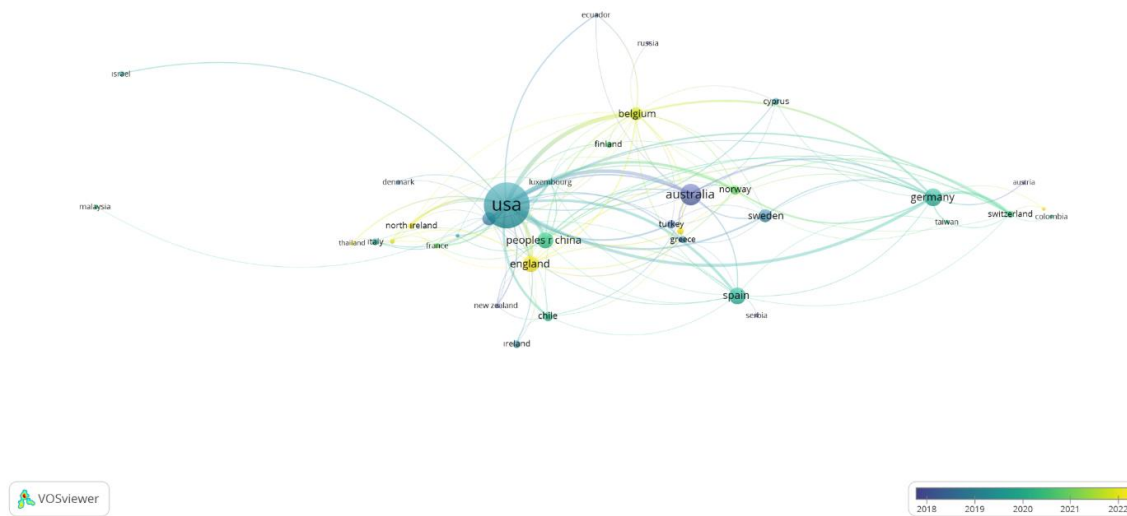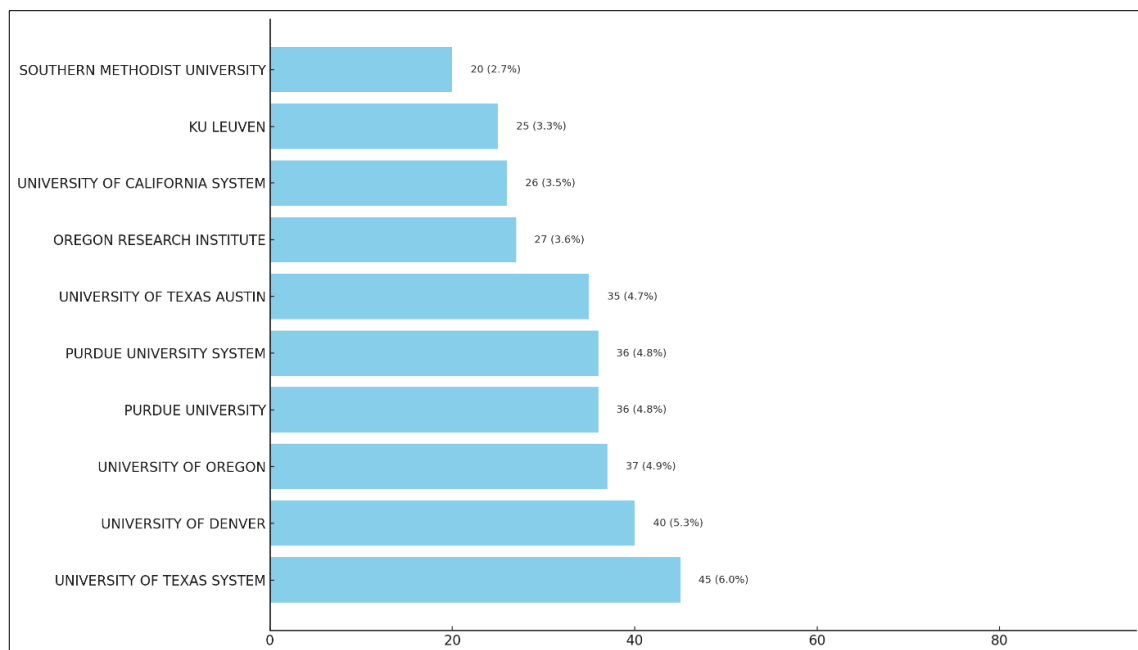

Figure 1. Visualization of countries by citation count.

Research Question 4: What is the distribution of academic studies published in the field of preschool mathematics education according to the institutions where the authors work?

Graph 4. Institutions where publications on pre-school mathematics education are published - Top 10 institutions (WoS, April, 2025).

The distribution of academic studies on pre-school mathematics education published in WoS according to the institutions where their authors work is shown in Graph 4. Since the number of

institutions in this category is high (n=663), only the top 10 institutions according to the number of publications are included in the table.

When the data presented in Graph 4 is examined, it is seen that the University of Texas System (f=45), University of Denver (f=40) and University of Oregon (f=37) stand out among the institutions to which authors publishing in the field of preschool mathematics education are affiliated or supported. These universities are among the most productive institutions in terms of the number of publications in the relevant field and make significant contributions to the literature on early childhood mathematics education.

Citation analysis was conducted to determine the most effective universities in the preschool mathematics literature. Criteria were determined such that a university should have at least 1 publication count and at least 50 citation counts. 89 out of 609 universities met this criterion. In Figure 2, the analysis continued with the 87 universities that have the most connections and relationships with each other out of these 89 universities. When Figure 2 is examined, it is seen that the leading universities in terms of effectiveness in the relevant literature are Purdue University (1277) and University of Denver (969).
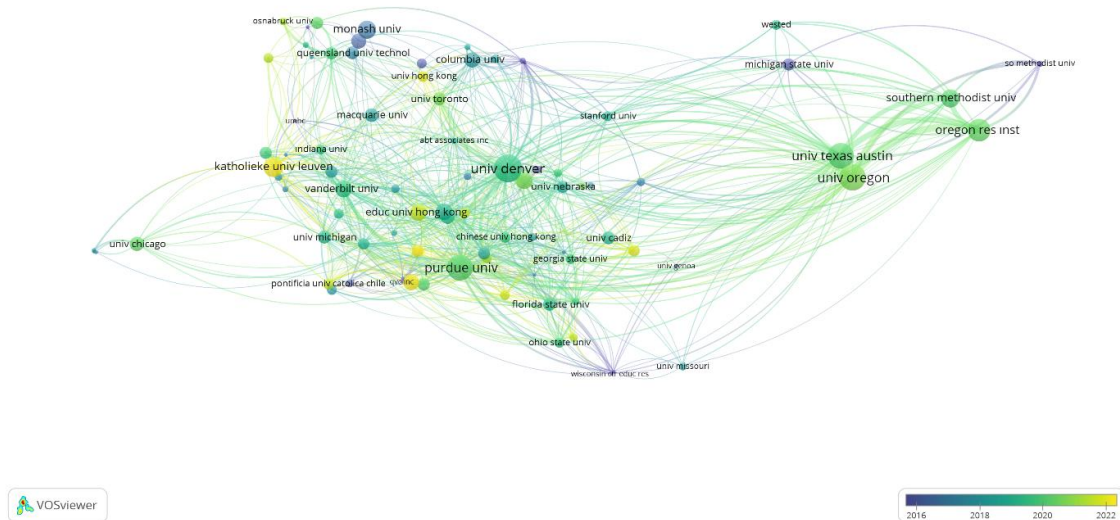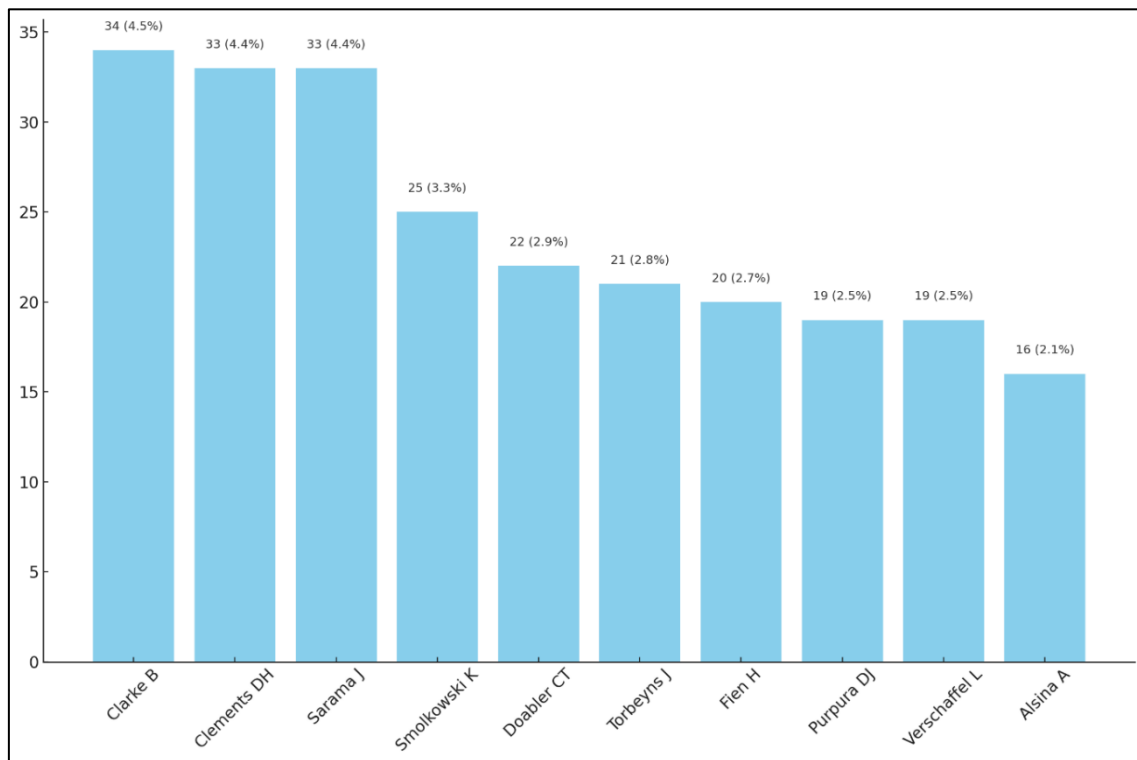

Figure 2. Visualization of institutions by citation count

Research Question 5: What is the distribution of academic studies published in the field of preschool mathematics education by authors?

Graph 5. Distribution of publications on pre-school mathematics education by authors - Top 10 authors (WoS, April 2025).

The distribution of academic studies published in WoS on early childhood mathematics education by authors is shown in Graph 5. Since the number of authors in this category is high (n=1573), only the top 10 authors by number of publications are included in the table.

When the data presented in Figure 5 is examined, it is seen that Clarke B. (f=34), Clements D.H. (f=33) and Sarama J. (f=33) stand out among the authors who published in the field of early childhood mathematics education. This finding shows that these authors are the top three authors who have published the most in the field of preschool mathematics education and contributed the most to the literature.

Citation analysis was applied to determine the authors who are influential in the literature in studies on preschool mathematics education. After determining the criteria that an author should have at least 1 article and receive at least 50 citations in the citation analysis, it was found that 165 out of 1615 authors met this condition. The analyses were continued with the 139 authors who had the most connections and were related to each other out of these 165 authors. When Figure 3 is examined, it is

seen that the three most influential authors in the field are Purpura DJ. (1072), Clements D.H. (750), Sarama J. (513), respectively.
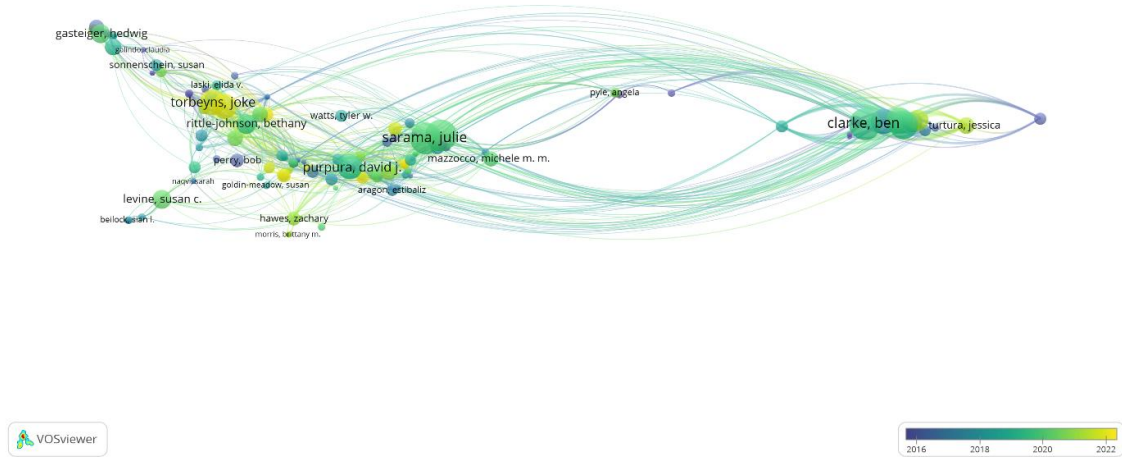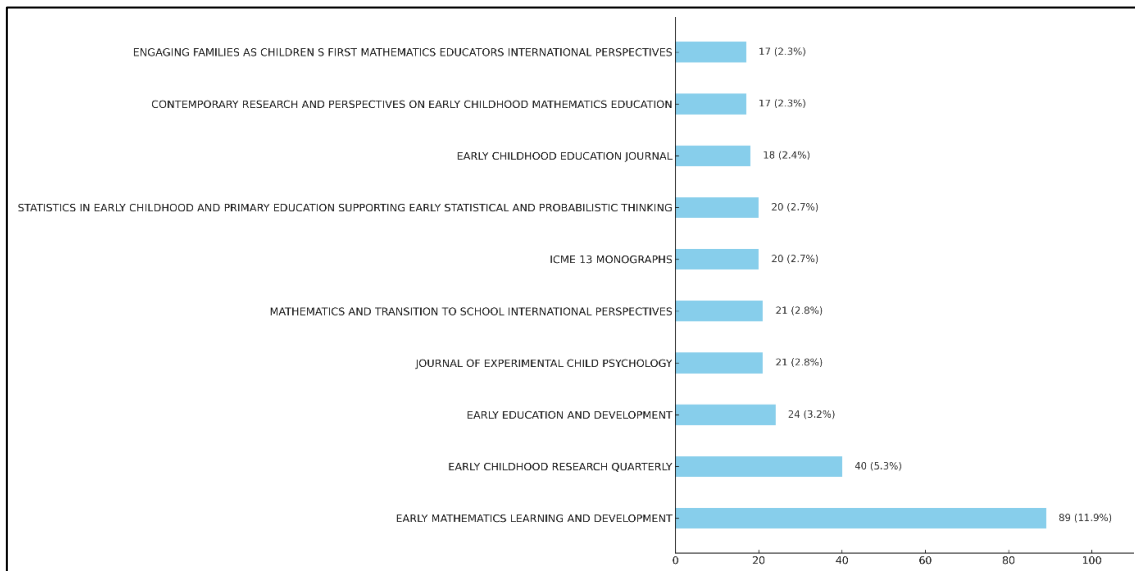

Figure 3. Visualization of authors according to citation counts

Research Question 6: What is the distribution of academic studies published in the field of preschool mathematics education according to the sources they were published in?

Graph 6. Sources of publications on preschool mathematics education - Top 10 Sources (WoS, April 2025)

The distribution of academic studies published in WoS on preschool mathematics education according to the sources they were published in is given in Graph 6. Since the number of sources in this category is high (n=270), only the first 10 sources according to the number of publications are included in the table.

Citation analysis was applied to determine the sources that are effective in the literature in studies on preschool mathematics education. After determining that a source should have at least 1 article and at least 10 citations as a criterion in the citation analysis, it was seen that 107 out of 250 sources met this condition. The analyses were continued with the 88 sources that have the most connection strength and are related to each other out of these 107 sources. When Figure 4 is examined, it is seen that the three most effective sources in the field are Early Childhood Research Quarterly (1305), Early Education and Development (675), Journal of Experimental Child Psychology (622), respectively.
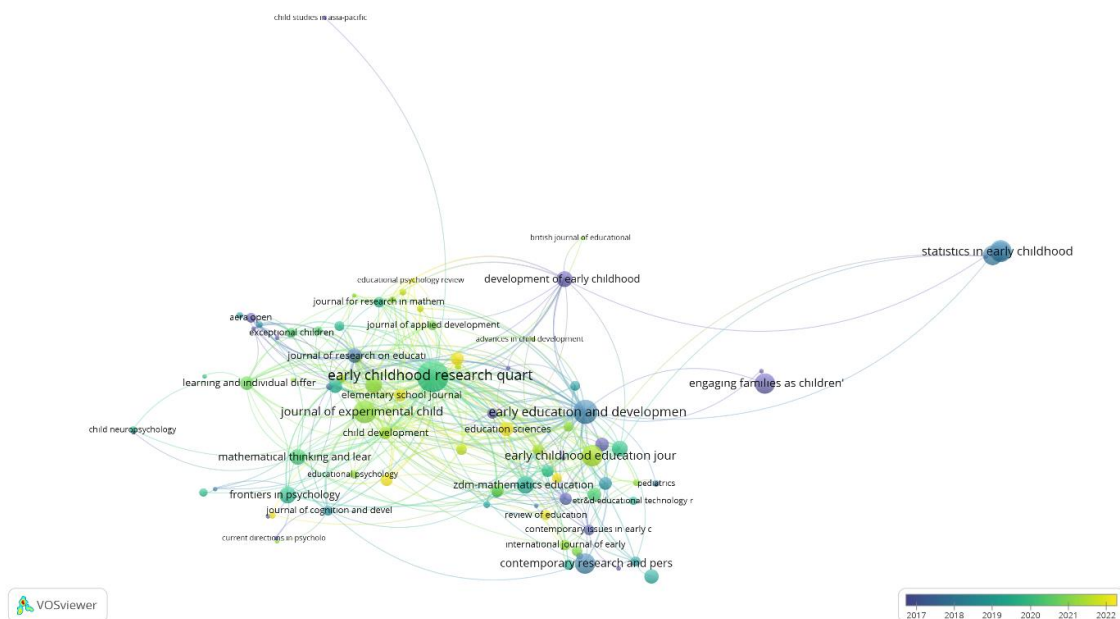
Figure 4. Visualization of sources according to citation counts

Research Question 7: Which are the most influential scientific publications among academic studies published in the field of preschool mathematics education?

A citation analysis was conducted to determine the cornerstone, popular, most remarkable and most influential publications in the literature on preschool mathematics education. In the citation analysis, the minimum number of citations an article should receive was determined as at least 10,

and it was revealed that 125 of the 748 publications met this requirement. Table 1 shows the 10 most influential publications in the field. According to Table 1, it is seen that the publication with the highest impact in the literature is the article titled "Which preschool mathematics competencies are most predictive of fifth grade achievement?" written by Nguyen et al.

Table 1.

The Most Influential Scientific Publications Among the Studies Conducted

Order	Authors	Article Title	Number of Citations
1.	Nguyen et.all (2016)	Which preschool mathematics competencies are most predictive of fifth grade achievement?	232
2.	Schmitt, et.all (2017)	Examining the relations between executive function, math, and literacy during the transition to kindergarten: a multi-analytic approach	183
3.	Purpura et.all (2017)	Foundations of mathematics and literacy: The role of executive functioning components	175
4.	Clements, et.all (2016)	Learning executive function and early mathematics: Directions of causal relations	161
5.	Purpura, et.all (2017)	Causal connections between mathematical language and mathematical knowledge: a dialogic reading intervention	135
6.	Missall, et.all (2015)	Home numeracy environments of preschoolers: examining relations among mathematical activities, parent mathematical beliefs, and early mathematical skills	125
7.	Rittle-Johnson, et. all (2018)	The roles of patterning and spatial skills in early mathematics development	112
8.	Rittle-Johnson, et. all (2017)	Early math trajectories: low-ıncome children's mathematics knowledge from ages 4 to 11	110
9.	Hawes, Z, et.all (2017)	Enhancing children's spatial and numerical skills through a dynamic spatial approach to early geometry instruction: effects of a 32-week intervention	109
10.	Susperreguy, MI, Davis-Kean, PE (2016)	Maternal math talk in the home and math skills in preschool children	103

Research Question 8: What is the keyword analysis of academic studies published in the field of preschool mathematics education?

General research areas related to preschool mathematics education and the relationships between these areas are shown in Figure 5.

When Figure 5 is examined, it is understood that academic publications related to preschool mathematics education are grouped under nine clusters according to the cluster analysis in the keyword network graph. The most frequently used keywords in these clusters and those with the highest connection strength are listed as mathematics (f=107, bg=177), early mathematics (f=78, bg=84), preschool (f=57, bg=121), early childhood (f=50, bg=88), mathematics education (f=38, bg=67), early childhood education (f=38, bg=66), kindergarten (f=37, bg=61), early childhood mathematics (f=37, bg=34). The clusters connected by these connection elements are the connection foci of the clusters related to each other.
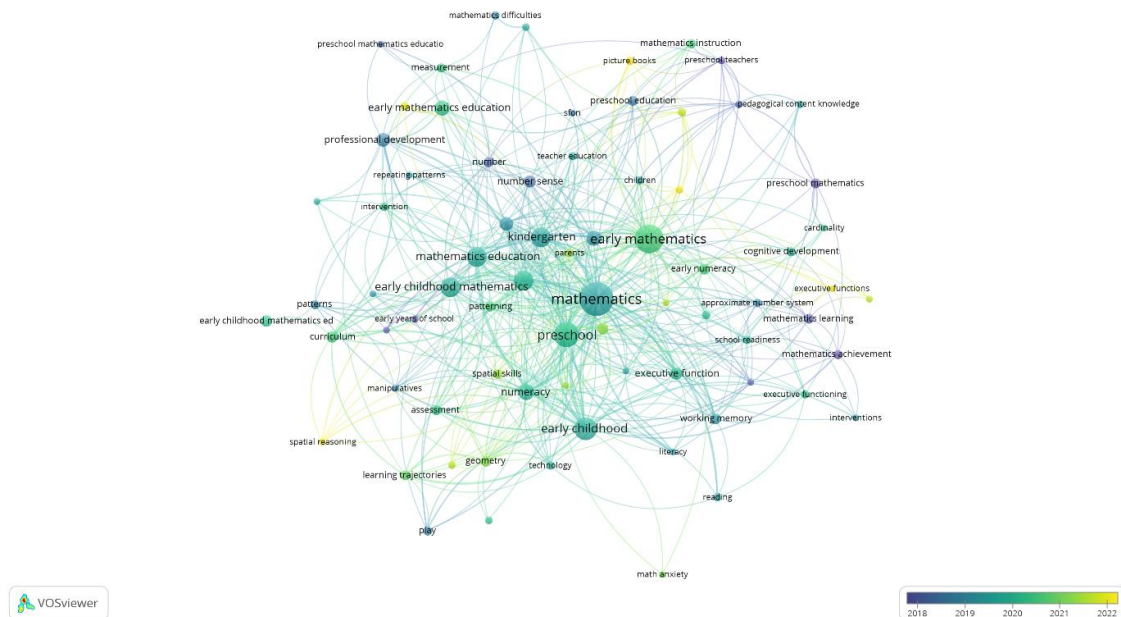

Figure 5. Visualization of the most frequently used keyword links (The circle size indicates the most discussed topic, and the yellow areas indicate current topics. WoS, April 2025)

Discussion and Conclusion

In this study, academic publications on preschool mathematics education in the Web of Science (WoS) database were analyzed in terms of bibliometric variables such as year, publication type, country, institutions to which the authors are affiliated, author, source, cited publications and subject areas. The determined variables were visualized in the form of figures, graphs and tables and a comprehensive bibliometric analysis was performed. The research covers a total of 748 academic studies published between 2015 and April 2025.

When the distribution of publications by year is examined, it is determined that scientific production in the field of preschool mathematics education has increased over time; It reached its peak with 130 publications in 2018 and 86 publications in 2017. This situation shows that the interest in the field has intensified, and research activities have increased in these years.

The findings reveal that academic studies published in the field of preschool mathematics education between 2015 and 2025 did not show a steady increase; on the contrary, they exhibited a production trend that intensified in certain years but decreased in other periods. The increase in the number of publications, particularly in 2017 and 2018, may be related to the increased scientific interest and funding support for early childhood education during this period. This suggests that interest in mathematical learning at an early age has periodically strengthened and that this theme has become prominent on the international research agenda (Çelik, 2022). However, there was a notable decrease in the number of publications in 2021, and one of the main reasons for this decrease can be attributed to the effects of the COVID-19 pandemic. During the pandemic, many research projects were postponed or canceled, field-based studies were restricted, and a general slowdown in the publication process was observed (Raynaud, M., et al., 2021). In this context, it is understood that the volume of academic production is shaped not only by research interest but also by global socioeconomic conditions and crises. Since the data for 2025 only covers the first months of the year, the results for this year should be interpreted with a limited scope. Overall, publication production in the field of preschool mathematics education is characterized by periodic peaks and troughs rather than a steady increase. This situation once again demonstrates, as frequently emphasized in the literature, that scholarly production is sensitive to both content developments and structural and environmental conditions (Aria & Cuccurullo, 2017; Ellegaard & Wallin, 2015).

The research findings show that a large part of the academic studies published in the field of preschool mathematics education consist of articles in peer-reviewed journals. This situation reveals that the field in question attracts increasing scientific interest and research production is mostly carried out through original empirical studies (Donthu et al., 2021).

While articles are at the top of the list of publication types, book chapters and proceedings are other prominent publication types. This classification of publication types not only provides a numerical description but also provides important context for understanding how academic production in the field is structured, which scholarly communication channels are preferred, and in what formats knowledge is disseminated. This data provides researchers with insights into the field's methodological and formal diversity, while also contributing to the guidance and evaluation of research outputs by policymakers and academic planners. When the distribution of publications by country is examined, it is determined that the United States, Australia and Germany are the countries that produce the most publications. The political investments of these countries in preschool education, the established interdisciplinary research culture and the strong structure of cooperation networks between universities can be counted among the main factors supporting the production of scientific publications (Ellegaard & Wallin, 2015; Zupic & Čater, 2015). It is observed that the USA, in particular, has a central position within the global publication network in this field and has a more dominant profile than other countries in terms of citation numbers and publication volume. A similar result was reached in the study conducted by Çelik (2022). The United States' central position in the field of preschool mathematics education in terms of publication numbers and citation density is a multifaceted phenomenon that extends beyond academic interest. In this context, the United States' long-standing and systematic development of public policies for early childhood education directly contributes to the strengthening of research capacity in the field. Comprehensive national programs, particularly those initiated in the 1960s, laid the groundwork for large-scale research examining the developmental impacts of early childhood (Zigler & Styfco, 2010). Furthermore, financial support for early childhood education at the federal and state levels has enabled the diversification and sustainability of interdisciplinary research projects (Barnett & Friedman-Krauss, 2016). Indeed, numerous empirical studies in the literature demonstrate the positive effects of investments in early childhood education on individuals' lifelong cognitive, academic, and social outcomes, and the majority of these studies are conducted in the United States (Yoshikawa et al., 2013). Therefore, the high volume of publications in the field in the United States stems not only from its concentration of researchers but also from its institutional commitment to supporting early childhood education

policies with scientific foundations. This can be considered a structural and strategic element that explains the country's decisive role in the international publication network.

The institutions where the researchers who published the most were located were determined as University of Texas System, University of Denver and University of Oregon. The strength of institutional research support systems and early childhood education policies can be considered as factors that may be effective in this success (Ellegaard & Wallin, 2015). In addition, it is seen that Clarke B., Clements D.H. and Sarama J. are among the authors who published the most. It can be said that these authors are the most productive authors in the field. However, when the citation analyses of the authors' works are examined, it is seen that, Purpura DJ. is in the first place. It can be said that the comprehensive and multifaceted studies that the author has been conducting on early childhood mathematics education for many years have strengthened his influence in the literature.

Purpura's high level of citations in the field of early childhood mathematics education stems from its long history of systematic research and its holistic approach to the fundamental components of the field. The author's studies comprehensively analyze the structural components of mathematical skills, especially in early childhood, and reveal significant findings in sub-domains such as numbers and counting, quantitative relations, symbolic-numerical connections, arithmetic operation antecedents, and spatial thinking (Purpura et al., 2017). In addition, Purpura's examination of early mathematics skills, not only as a cognitive structure but also in relation to language development, executive functions, and preschool curriculum, contributed to the interdisciplinary dimension of his studies. In particular, the early intervention models he presented in his applied research and the evidence-based data on the role of these models in predicting academic success have become an important reference point for both researchers and practitioners. When evaluated in this context, Purpura's high citation count is not only related to the high number of publications but also to his work that offers original, theoretically grounded, and practical contributions to the field of early childhood mathematics education. The author's multifaceted approach to the impact of basic mathematical competencies, especially in the preschool period, on long-term academic outcomes has reinforced his central position in the literature.

However, the academic journals hosting the most publications include "Early Mathematics Learning and Development", "Early Childhood Research Quarterly", and "Journal of Experimental Child Psychology". The specialized publication policies and international scientific visibility of these journals indicate that they are preferred platforms for the publication of research (Falagas, Pitsouni,

Malietzis, & Pappas, 2008). When evaluated in terms of the number of citations, the studies that have had the greatest scientific impact in the field of preschool mathematics education are "Which Preschool Mathematics Competencies Are Most Predictive of Fifth Grade Achievement?", "Examining the Relations Between Executive Function, Math, and Literacy During the Transition to Kindergarten: A Multi-Analytic Approach" and "Foundations of Mathematics and Literacy: The Role of Executive Functioning Components". These publications have attracted great attention in the literature because they deeply address the effects of mathematical competencies in early childhood on later educational processes, the role of executive functions in mathematics and literacy development, and the multidimensional relationships between cognitive and non-cognitive factors (Nguyen et al., 2016; Purpura et al., 2017; Schmitt et al., 2017). One of the main reasons for the prominence of these publications is the increasing scientific interest in the role of executive functions (such as working memory, cognitive flexibility, and attention control) that affect the development of mathematical thinking in early childhood on academic success (Diamond, 2013; Blair & Raver, 2015). Indeed, a significant increase in the number of studies focusing on these topics has been observed in the period after 2015; this increase is directly related to both advances in cognitive development theories and the structural importance given to preschool education. Especially in the last decade, with the orientation of education systems towards 21st century skills, supporting children's executive functions such as problem solving, planning, reasoning, and attention has become a priority; empirical studies conducted in this direction have attracted the attention of both policy makers and educational researchers (Zelazo, 2015). In this context, it can be said that these studies with high citation numbers not only provide theoretical contributions but also guide the literature with their practical suggestions and multidimensional analysis approaches. In line with the findings obtained in the study, it was determined that the most frequently used keywords in the field of early childhood mathematics education were "mathematics", "early mathematics" and "preschool". This situation reveals that the basic conceptual framework of the research in the field is largely shaped around these three concepts. The prominence of these key concepts indicates that the acquisition of mathematical concepts at an early age has become a central research theme in the literature. Keyword analysis is critical for bibliometric studies in terms of revealing which topics are at the forefront in the scientific literature, which concepts are frequently repeated, and which theoretical building blocks the field is built on (Donthu et al., 2021).

The findings of the study indicate that the most frequently encountered keywords in the field of preschool mathematics education are "mathematics," "early mathematics," and "preschool." The

prominence of these concepts demonstrates the importance placed on mathematical achievements in early childhood and the general research direction of this field in the literature. However, an examination of the contextual structure of the studies clustered around these keywords reveals that sub-concepts such as number knowledge, sequencing, pattern recognition, spatial relations, and early arithmetic thinking are frequently addressed and prominently featured in the literature. This demonstrates that keyword analysis requires not only word frequency but also the assessment of the thematic scope represented by key terms (Donthu et al., 2021). Indeed, numerous studies have demonstrated that fundamental mathematical skills acquired at an early age can predict children's academic success in later school years (National Research Council, 2009; Sarama & Clements, 2021). In this context, the literature centered around general concepts such as mathematics and preschool education appears to primarily focus on specific areas of mathematical thinking. Furthermore, findings that the development of these skills is not limited to cognitive outcomes but also has positive effects on broader learning outcomes such as social-emotional competencies, academic self-confidence, and school adjustment highlight the holistic impact of mathematical thinking in early childhood (Claessens & Engel, 2013). Therefore, the keywords identified in the study reveal that preschool mathematics education is not only a general area of interest but also a content-structured and interdisciplinary field of research.

Recommendations

In line with the findings of this study, various suggestions can be made for researchers planning to conduct studies in the field of early childhood mathematics education. First, the holistic view provided by bibliometric analyses can be used to see which themes are prominent in the field of research, which concepts are concentrated, and which academic orientations attract attention. In this context, current and original topics can be determined by considering frequently encountered concepts, keywords, and strong research themes in the literature during the planning process of new research. Researchers can create an effective network by analyzing leading academics with whom they can collaborate, institutions with high publication production, and countries with the highest international collaborations. Such collaborations both increase the scientific impact of publications and contribute to the field at a global level. In addition, only the Web of Science database and the VOSviewer program were used in this study; however, performing similar analyses through different databases such as Scopus or ERIC can enable a more comprehensive literature review. Analyses using different bibliometric software (e.g. CiteSpace, Bibliometrix) can provide researchers with more in-depth outputs such as conceptual networks, citation chains, and developmental trends. As a result,

such analyses not only map the current situation but also provide strategic information to guide future research. In this context, bibliometric analyses can serve as an important guide for both novice researchers and academics who want to specialize in the field.

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Conflict of Interest

The authors declare that there is no conflict of interest. The authors contributed equally to the study.

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Ethical Standards

The research was conducted within the framework of the Declaration of Helsinki.

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