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A Bibliometric Study on Mathematics Anxiety in Primary Education

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Abstract: Mathematics anxiety, stemming from negative perceptions and feelings of tension among students, significantly impacts academic outcomes and attitudes at all ages, starting from Primary Education. Thus, this study aimed to investigate the existing scientific literature on mathematics anxiety in this context. A bibliometric analysis was developed using the Core Collection of the Web of Science database, resulting in 360 scientific publications. The distribution of publications by journal, institution, country, and authorship, as well as the temporal evolution of them and the co-occurrence of keywords, was analysed and visualised through the SciMAT and VosViewer software. Findings reveal a growing interest in mathematics anxiety within the scientific community, particularly concerning its correlation with gender stereotypes and students' mathematical perceptions at the primary level. Moreover, the distribution of publications highlights the United States as the primary contributor to this research, with a notable majority of distinguished female authors.

Keywords: mathematics anxiety; primary education; bibliometric analysis; gender

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Citation: Sagarduy, A.; Arrieta, N.; Antón, A. A Bibliometric Study on Mathematics Anxiety in Primary Education. *Educ. Sci.* **2024**, *14*, 678. https://doi.org/10.3390/educsci14070678

Academic Editor: Daniel Muijs

Received: 29 April 2024
Revised: 7 June 2024
Accepted: 19 June 2024
Published: 21 June 2024

1. Introduction

Despite the fact that learning mathematics constitutes a basic pillar in the comprehensive training of students [1], there is a negative perception on the part of the students towards this discipline, stereotyping it as a complex subject with important detachments [2]. There is enormous variability in terms of the emotions and feelings that people experience in different mathematical contexts. Sometimes, mathematics is perceived as a set of rules and disconnected numbers that must be memorised mechanically, which generates displeasure and discomfort among students [3]. This unfavourable perception of mathematics is significantly manifested in the results of the last Programme for International Student Assessment (PISA) test, focused on mathematical competence, where the skills of 15-year-old students are evaluated in various disciplines, and where anxiety and unfavourable perceptions impact student achievement [4].

This adverse attitude and predisposition towards mathematics is known as mathematics anxiety [5,6]. This emotional response has been defined as the set of feelings of tension, worry, and fear that hinder the successful completion of tasks that involve the manipulation of numbers and mathematical reasoning, both in the school environment and in a daily context [7–9]. Indeed, the significant effects of math anxiety extend beyond academic performance, impacting students' emotional well-being and educational experience. Research has shown that math anxiety can lead to the avoidance of math-related tasks, diminished self-confidence, and increased stress levels, ultimately hindering students' ability to reach their full potential in mathematics and related fields [10].

Conversely, in mathematics anxiety, the following two dimensions are identified: a cognitive dimension, which encompasses concerns about failure in mathematical tasks, and an affective dimension, which encompasses the emotions of nervousness and tension

in test situations. These dimensions reinforce the complexity of mathematics anxiety and highlight that it goes beyond simple negative emotions [11].

According to Pekrun's control–value theory [12], math anxiety arises from the interaction between perceived control over learning outcomes and the value attributed to success in mathematics. This theory suggests that students experience math anxiety when they perceive low control over their performance and high value in succeeding in mathematics. Regarding the factors that influence this phenomenon, Fernández and Ayán propose the existence of both external and internal causes [13]. The external causes include those related to the context of the individual (school environment, family environment, gender stereotypes, etc.) and the internal causes include those that start from the individual themself (self-regulation ability, performance, etc.). Regarding the factors of external origin, it has been shown that the pedagogical strategies used in the classroom are directly related to students' levels of mathematics anxiety and mathematical performance [14]. In addition, the mathematics anxiety experienced by teachers represents a limiting factor in the development of mathematical competence in the classroom [15]. The experience of mathematics anxiety by teachers seems to have a direct influence on the attitude of students towards the discipline and, consequently, on their own level of mathematics anxiety [16–18]. Likewise, other studies propose the existence of a direct relationship between the probability of a student experiencing mathematics anxiety and the mathematics anxiety experienced by their parents [19,20]. Regarding gender stereotypes, a recent study by Doz et al. reveals that girls tend to experience greater mathematics anxiety than do boys in the context of Primary Education [21]. However, no differences are found in relation to the gender variable in terms of precision in solving mathematical problems or in the perception of the difficulty of such problems. This finding aligns with those of other studies, highlighting the influence of mathematical gender stereotypes on anxiety and mathematical self-concept [22–25].

In contrast, among the internal causes, Blair and Ku find a negative correlation between self-regulation ability and levels of mathematics anxiety [26]. As students mature and develop their executive function skills, they demonstrate an increased ability to regulate their emotional response. In this sense, numerous studies have shown the negative effect of high levels of mathematics anxiety on performance [27–29]. However, math performance is commonly considered an outcome of math anxiety rather than just a precursor, as the relationship between math anxiety and math performance is bidirectional [17]. Conversely, Živković et al. find a positive correlation among mathematical performance, self-efficacy, and the enjoyment of mathematics [30].

Some of these factors are included among the tools used to measure mathematics anxiety. One of the first psychometric scales was the Mathematics Anxiety Rating Scale (MARS), developed by Richardson and Suinn [7]. Subsequently, specific scales have been adapted and developed for the context of Primary Education. The first scale was a shortened version of the MARS [31], followed by the Mathematics Anxiety Scale for Children (MASC) [32], and the Abbreviated Math Anxiety Scale (AMAS) [33]. Other tools, such as the Scale for Early Mathematics Anxiety (SEMA) [34], the Child Mathematical Anxiety Questionnaire (CMAQ) [35] and its revised version (R-CMAQ) [36], and the Mathematics Anxiety Scale for Young Children (MASYC) [37], have since been developed.

To effectively advance the research on mathematics anxiety, it is imperative not only to examine the manifestations, causes, and tools of this emotional response, but also to understand its evolution and trends in the academic literature. Here, bibliometric analysis emerges as an indispensable tool. The interest in this strategy is motivated by the need to evaluate the progress of scientific production and its influence, and to understand the situation of the field in which such investigations are carried out [38]. Similarly, Cardona et al. indicate that through bibliometric studies, trends can be detected, and patterns that facilitate the identification of advances and the level of scientific development in a specific area, for which various bibliometric indicators are used, can be established [39].

To date, two studies have analysed publications on mathematics anxiety through a bibliometric approach—those of Ersozlu and Karakus [40] (Web of Science (WoS) and

Radevic and Milovanović [41] (Scopus))—but neither of these studies has focused on a specific topic in the child population in general or in the Primary Education context particularly. Primary students represent a unique population with distinct developmental characteristics that make them particularly susceptible to math anxiety-related issues [42]. Their formative years are crucial to establish the bases of mathematical skills and attitudes that can influence their academic trajectory and emotional well-being throughout their lives [43]. Consequently, understanding and addressing math anxiety in Primary Education is essential for fostering positive learning experiences and outcomes. Therefore, the main objective of this study is to quantitatively analyse the existing scientific literature on mathematics anxiety in Primary Education to provide a panoramic view of the existing scientific findings. To achieve this objective, we propose the following specific objectives: to offer an overview of the evolution of the research on mathematics anxiety in this educational context; to identify the co-occurrence of the keywords used and analyse their impact in the area; and to identify the most active and relevant journals, institutions, countries, and authors to establish patterns of development, collaboration, and evolution over time.

2. Materials and Methods

Next, the method used to collect the data and the procedure used for the analysis and visualisation of the data are described.

2.1. Data Sample

First, the search syntax was identified from the keywords "math* anxiety" and "child", "primary school", or "primary education" in the journals indexed in the Core Collection of the WoS database to collect the largest possible number of scientific publications related to mathematics anxiety in Primary Education. Boolean operators (AND-OR) were used to improve the outcome of the publication search.

The following citation indices were selected within the Core Collection: the Social Science Citation Index (SSCI), Science Citation Index Expanded (SCIE), Arts and Humanities Citation Index (AHCI), and Emerging Source Citation Index (ESCI).

In this study, only articles, reviews, and early access articles were included for analysis, as they contained full information about the research ideas and results, and most of the publications were classified into the three categories. Book reviews, minute documents, book chapters, and editorial materials were excluded from this study in order to focus on original, peer-reviewed research that will provide significant contributions to scientific knowledge. These types of documents, although important in other contexts, may not offer the same level of scientific rigor or relevance to the objectives of the bibliometric study. A depuration of the database was also carried out to remove duplicated and non-related manuscripts. Finally, a total of 360 publications or metadata were included in the bibliometric analysis. Institutional access was required to download and analyse the content of many of the publications included in this study. This search was carried out in the second quarter of 2023, and the year of publication of the documents was not limited.

2.2. Data Analysis and Visualisation

For the analysis and visualisation of the metadata imported from the WoS, SciMAT-v1.1.04 and VOSviewer 1.6.19 were used.

2.2.1. SciMAT

A cleaning of the data corpus was carried out by combining or discarding terms that SciMAT recognised as synonyms based on the programmed differences (1 difference). This data cleaning process was carried out for the identification of both keywords and authors. For the analysis of the keywords, the keywords selected by both the author and the WoS journals were used. The data reduction frequency was set to 1 since the data volume was not large. The network was constructed by means of the co-occurrence of terms, with a minimum frequency of co-occurrence of 1. The measure of similarity of the

equivalence index was used to normalise the network due to its effectiveness in highlighting the structure of the network and facilitating the interpretation of the results [44]. For the clustering of keywords, the algorithm of simple centres was used with a minimum network size of 3 and a maximum size of 7 keywords. The main mapper was used routinely to determine associations among the documents. It refers to the algorithm used to map the thematic structure of the citation network as it identifies the main or dominant themes in the field of study. As a bibliometric measure of quality, the h index was used to select the number of documents since it is a measure to evaluate the influence and relevance of the articles.

One of the analyses of the co-occurrence of keywords was performed using the centrality and density of Callon [45]. Centrality measures the importance of a topic in the development of the entire field of research being analysed. Conversely, density measures the strength that unites a topic with the rest of the keywords of the analysed research area.

2.2.2. VOSviewer

VOSviewer visualisation maps were used to represent the results obtained from the bibliometric analysis. To refine the data and reduce the degree of variation in the terminology, a synonym dictionary file, also known as a Thesaurus, was generated. This file groups similar or related terms, facilitating the analysis by consolidating related concepts under a single label. In the maps, the nodes represent each element of the network, and the clusters represent a group of nodes closely related to each other. The colour, size, and centrality of the clusters, as well as the distance between them, provided information on the relationships or links between the elements analysed. The colour of the cluster represented the independence of the categories between the elements that made up the network. The intensity of the colour indicated the importance of the element within the category. The size of the cluster, similar to the intensity of colour and its centrality, represented the number of elements it encompassed, that is, the importance it had within the network. The distance between the nodes represented the degree of relationship between them and was expressed as the total strength of the link (total link strength), which indicates the total strength, that is, the sum total, of the links connecting the nodes.

3. Results

The results obtained from the bibliometric analysis are presented below. The first four sections show the distribution of publications by journal, institution, country, and authorship. Next, the distribution of publications by year of publication is presented, and finally, the co-occurrence of keywords where the network map is analysed, as well as the parameters of centrality and density of Callon, are analysed.

3.1. Distribution by Journal

The 360 publications analysed in this study were distributed in a total of 180 journals. *Frontiers in Psychology* topped the list, with a total of 35 papers (9.72% of the total) and 809 citations and a total link strength of 182. The most cited article in this journal was that of Carey et al. [46], with a total of 163 citations.

The analysis of the network map revealed two well-differentiated clusters. The first cluster, represented in red, included journals such as *Frontiers in Psychology*, *Contemporary Educational Psychology*, *Annals of the New York Academy of Sciences*, *Journal of Experimental Child Psychology*, *PLOS One*, *Developmental Science*, and the *British Journal of Educational Psychology*. The second cluster, represented in green, included journals such as *Learning and Individual Differences*, *Journal of Cognition and Development*, *Journal of Educational Psychology*, *Journal of Experimental Education*, *Mathematics Education Research Journal*, and *Journal of Early Childhood Teacher Education* (Figure 1a).

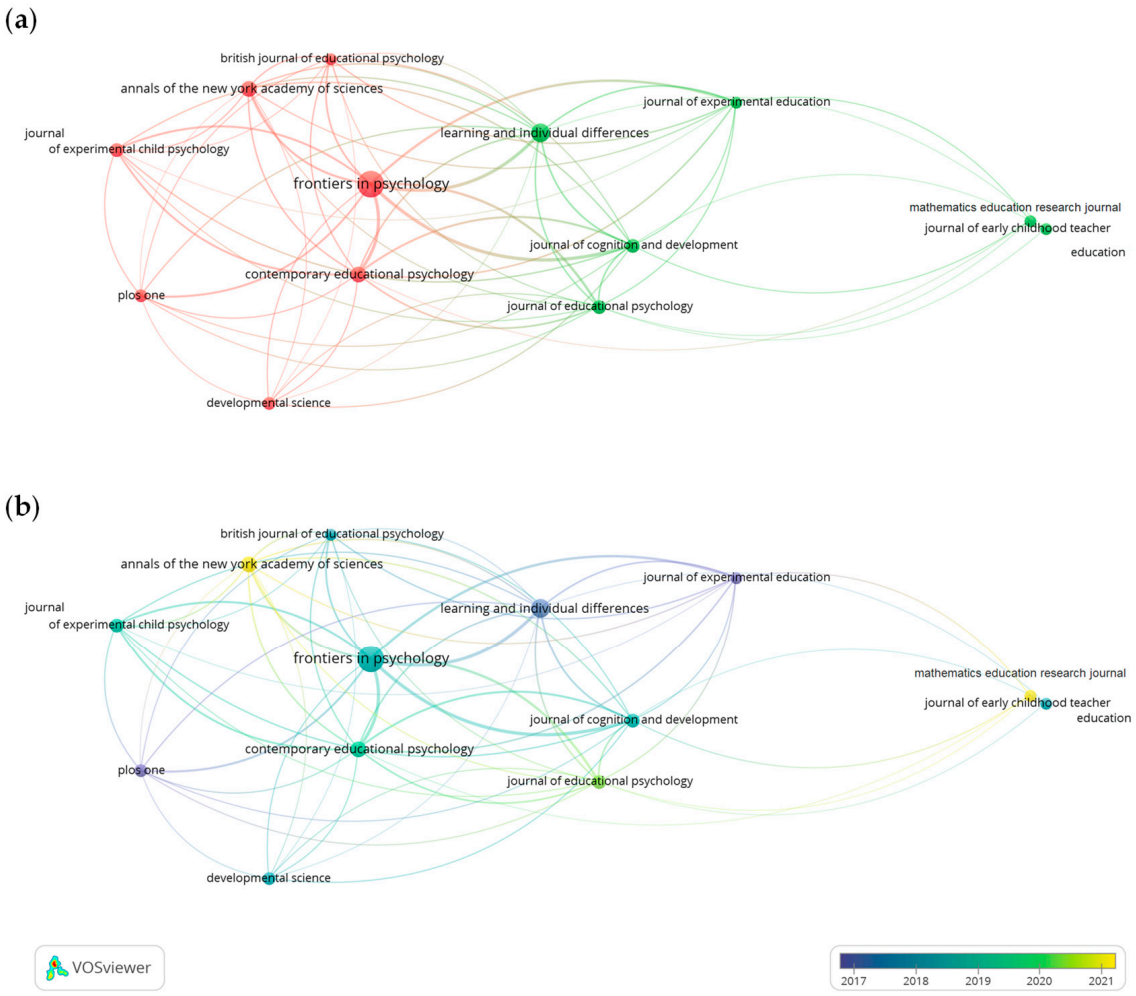

Figure 1. Network (**a**) and temporal (**b**) visualisations of the distribution of publications by journal based on the number of citations.

In addition, the analysis of the temporal visualisation map based on the distribution of publications by journal provided significant information on the current situation of the journals and their impact on the academic community. *Annals of the New York Academy of Sciences* and *Mathematics Education Research Journal* stood out due to their topicality, as illustrated in Figure 1b.

Table 1 presents the results of the map analysis, highlighting the 13 journals that met the requirements of having at least 5 publications and 15 citations. The journals are published by seven different editorials. Among them, Elsevier, Wiley-Blackwell, and Taylor and Francis stand out, since they had published 9 of the 13 contributions. These journals were organised according to the number of publications, total link strength, and number of citations.

3.2. Distribution by Institution

A total of 394 institutions that participated in the 360 publications analysed in this study were identified. Only those institutions with at least 5 publications and 50 citations were considered. Thus, 22 of the 394 institutions met this criterion and are presented in Table 2, and are ordered according to the total link strength and where the data on the number of publications and citations were also collected.

Table 1. Journals sorted by total link strength.

Journal	Editorial	Total Link Strength	Publications	Citations
Frontiers in Psychology	Frontiers Media	35	182	809
Learning and Individual Differences	Elsevier	15	83	337
Contemporary Educational Psychology	Elsevier	10	101	224
Annals of the New York Academy of Science	Wiley-Blackwell	10	54	19
Journal of Cognition and Development	Taylor and Francis	7	94	387
Journal of Educational Psychology	American Psychological Association	7	63	93
Journal of Experimental Child Psychology	Elsevier	7	51	305
PLoS ONE	Public Library of Science	6	38	394
Developmental Science	Wiley-Blackwell	6	21	134
Journal of Experimental Education	Taylor and Francis	5	55	206
British Journal of Educational Psychology	Wiley-Blackwell	5	43	134
Mathematics Education Research Journal	Springer	5	11	26
Journal of Early Childhood Teacher Education	Taylor and Francis	5	6	29

Note: The colors used in the table indicate different clusters in the network, corresponding to the colors in the network visualization.

Table 2. Institutions ordered by total link strength.

Institution	Total Link Strength	Publications	Citations
University of Chicago	323	18	1615
University of Cambridge	208	10	729
University of Trieste	192	12	232
University of Padua	183	13	217
Florida State University	179	7	418
Stanford University	141	8	470
University of Ottawa	124	9	150
University of California Los Angeles	119	6	376
New York University	119	5	293
University of Oxford	113	9	169
University of Haifa	112	7	135
Temple University	104	5	350
Ohio State University	101	6	220
Tomsk State University	98	5	212
University of Colorado	93	5	247
Pontificia Universidad Católica de Chile	80	7	74
Purdue University	77	7	71
University of Florence	77	5	61
University of Minnesota	74	8	170
Columbia University	57	6	92
University of Jyväskylä	56	5	135
Beijing Normal University	56	12	82

Note: The colors used in the table indicate different clusters in the network, corresponding to the colors in the network visualization.

The network map showed two clearly differentiated clusters based on similarities in their characteristics and citation relationships (Figure 2a). The first cluster, represented in red, was composed of institutions such as the University of Chicago (US), University of Florida (US), University of Ottawa (US), University of California Los Angeles (US), University of Haifa (Israel), Temple University (US), Ohio University (US), Tomsk University (Russia), Pontificia Universidad Católica de Chile (Chile), Purdue University (US), University of Minnesota (US), and Columbia University (US). The second cluster, represented in green, included the University of Cambridge (England), University of Trieste (Italy), University of Padua (Italy), Stanford University (US), New York University (US), University of Oxford (England), University of Colorado (US), University of Florence (Italy), University of Peking (China), and the University of Jyväskylä (Finland).

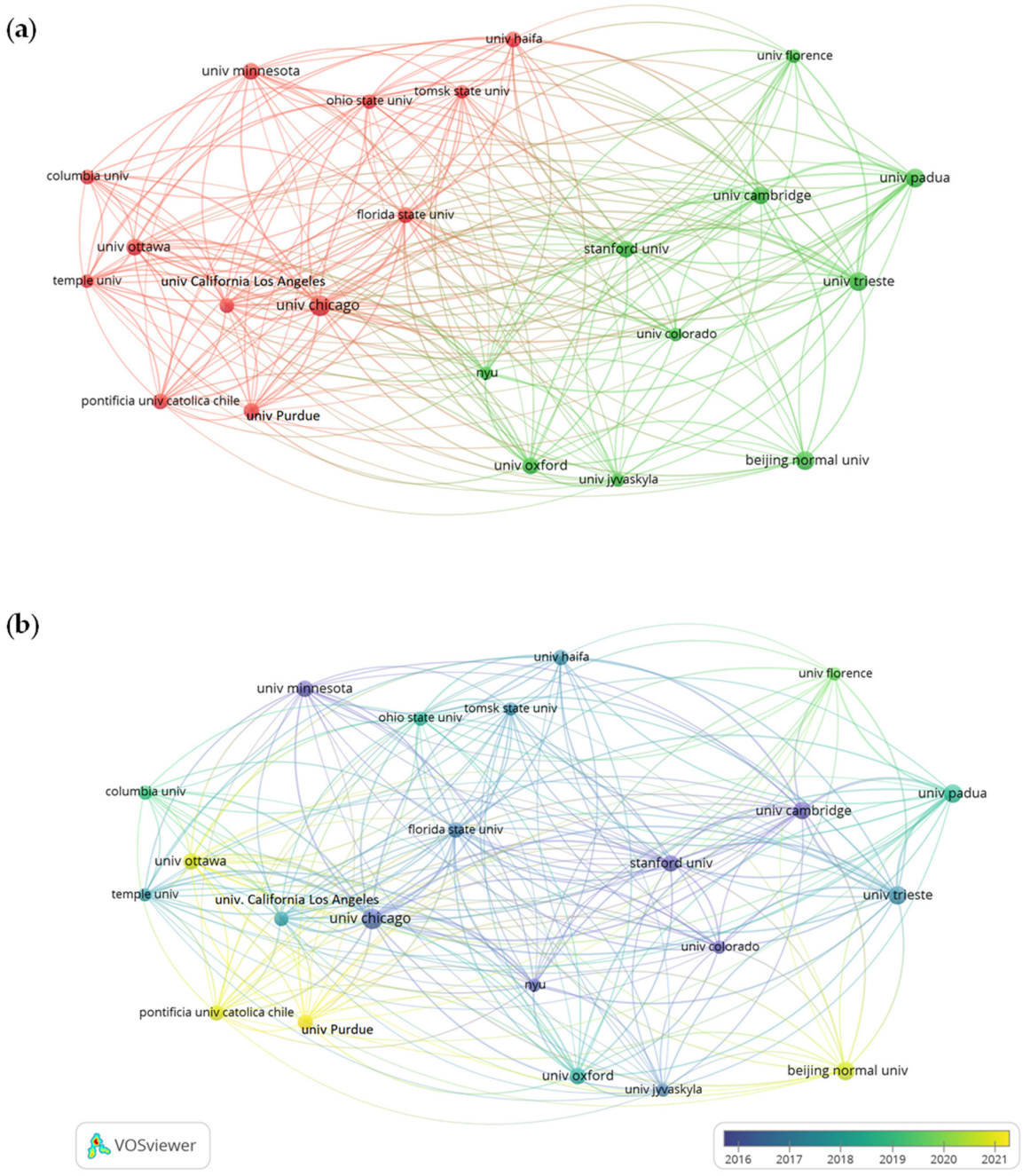

Figure 2. Network (**a**) and temporal (**b**) visualisations of the distribution of publications by institution based on the number of citations.

In contrast, the temporal visualisation network map, built to take into account the distribution of publications by institution based on the citations, allowed us to identify the University of Ottawa, the Pontificia Universidad Católica de Chile, Purdue University, and the University of Peking as those institutions that were most notable for their production and more current publications (Figure 2b).

3.3. Distribution by Country

The 360 publications analysed in this study were published in a total of 42 countries. Those countries with a minimum of 5 publications and 50 citations were included. Thus, 19 of the 42 countries met this criterion. Table 3 presents the results according to the total link strength, the number of publications, and the number of citations.

Table 3. Countries ordered by total link strength.

Country	Total Link Strength	Publications	Citations
US	1229	118	4165
UK	727	39	1192
Italy	447	28	445
Germany	399	33	527
Canada	297	18	499
People's Republic of China	226	30	172
Israel	193	12	165
Spain	187	19	123
Austria	171	8	251
Finland	170	7	139
Poland	146	7	55
Russia	132	5	212
Netherlands	124	8	209
Chile	121	9	74
Belgium	120	13	229
Turkey	74	18	159
Switzerland	58	8	160
Australia	44	13	120
Taiwan	23	7	145

Note: The colors used in the table indicate different clusters in the network, corresponding to the colors in the network visualization.

The bibliometric network map, built to take into account the distribution of these publications based on the number of citations in the country, showed a network formed by six clusters, represented by different colours (Figure 3a). The US had the greatest bond strength (1229), the greatest number of publications (118), and the greatest number of citations (4165) (Figure 3b). Most importantly, the cluster represented in red was composed of the US, Canada, the Netherlands, Australia, and Taiwan. The second cluster, represented in green, included the UK, Italy, Israel, and Russia. The third cluster, represented in dark blue, was made up of Germany, Austria, Finland, and Switzerland. The fourth cluster, represented in yellow, included Poland, Belgium, and Turkey. The fifth cluster, represented in purple, included Spain and Chile. Finally, the sixth and last cluster, represented in light blue, included China.

Conversely, in the analysis of the temporal distribution of these publications, China, Spain, Poland, and Chile stood out as having the highest number of current publications (Figure 3c).

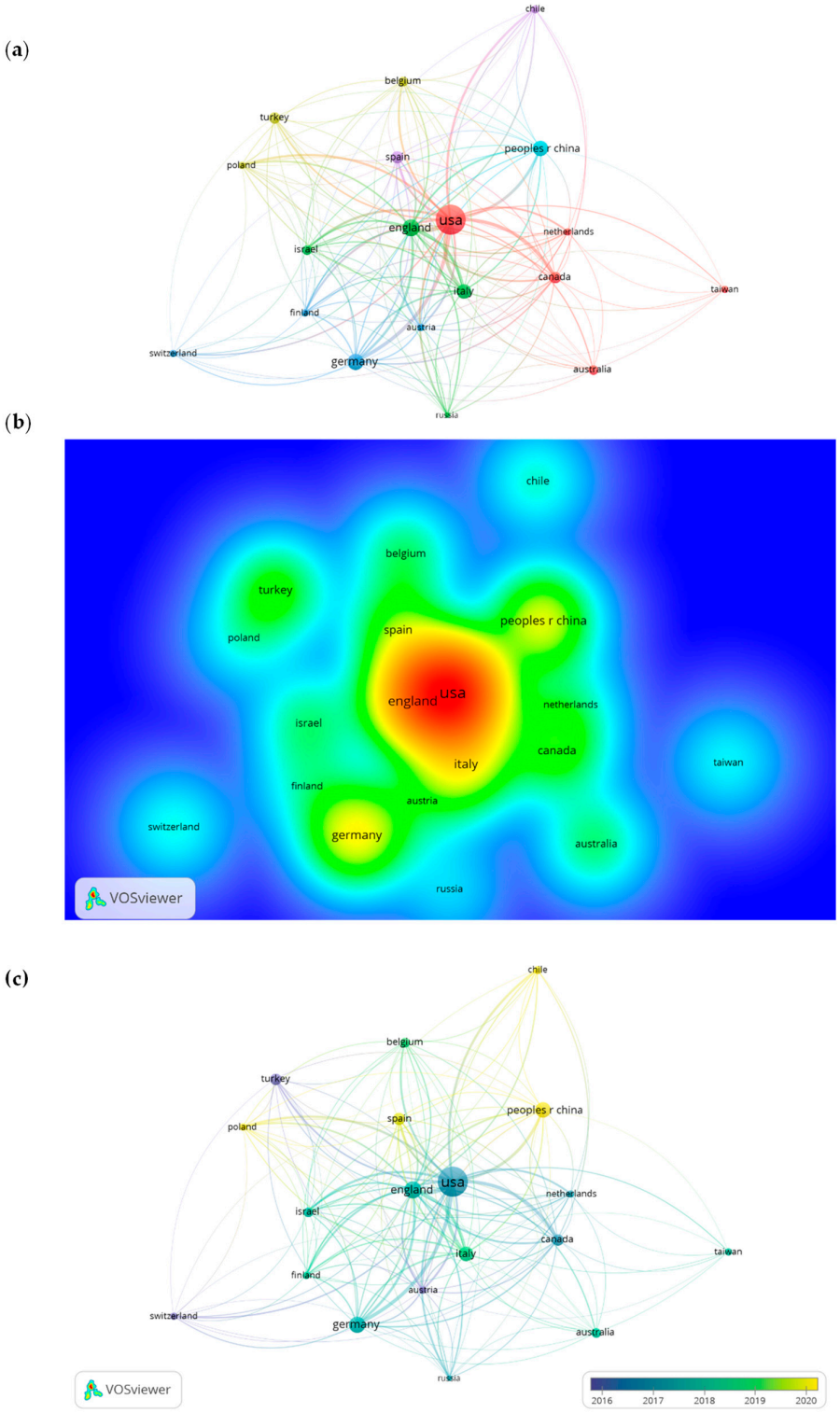

Figure 3. Network (**a**), density (**b**), and temporal (**c**) visualisations of the distribution of publications by country based on the number of citations.

3.4. Distribution by Authorship

In the 360 publications, a total of 933 authors were found. Only the 15 authors that met the established criteria of having a minimum of 6 publications were included in the analysis. Table 4 shows the distribution of authorship ordered according to total link strength. It is noteworthy that 13 out of the 15 authors included in the analysis were women, who represent 87% of the total.

Table 4. Authorship ordered by total link strength.

Authorship	Total Link Strength	Publications	Citations
Levine, Susan C.	332	15	1582
Beilock, Sian L.	296	14	1592
Ramirez, Gerardo	259	12	1484
Gunderson, Elizabeth A.	217	8	1393
Maloney, Erin A.	207	12	497
Passolunghi, Maria Chiara	184	11	185
Pellizzoni, Sandra	145	7	48
Mammarella, Irene C.	144	9	201
Devine, Amy	138	7	632
Menon, Vinod	130	7	457
Szczygiel, Monika	125	6	40
Caviola, Sara	124	7	199
Rubinsten, Orly	109	6	112
Dowker, Ann	98	6	342
Wang, Zhe	80	6	217

Note: The colors used in the table indicate different clusters in the network, corresponding to the colors in the network visualization.

Bibliometric analysis, presented in the form of a network map and based on authorship and citations, revealed the existence of two independent clusters (Figure 4a). Susan C. Levine, from the University of Chicago (US), stood out as the author with the highest number of publications on mathematics anxiety in Primary Education, totalling 15 publications and 1582 citations and with a total link strength of 332. In the same cluster, represented in green, Sian L. Beilock, Gerardo Ramírez, Erin A. Maloney, Elizabeth A. Gunderson, and Monika Szczygiel were also found. The other cluster, represented in red, was composed of Maria Chiara Passolunghi, Irene C. Mammarella, Sandra Pellizzoni, Amy Devine, Vinod Menon, Sara Caviola, Orly Rubinsten, Ann Dowker, and Zhe Wang.

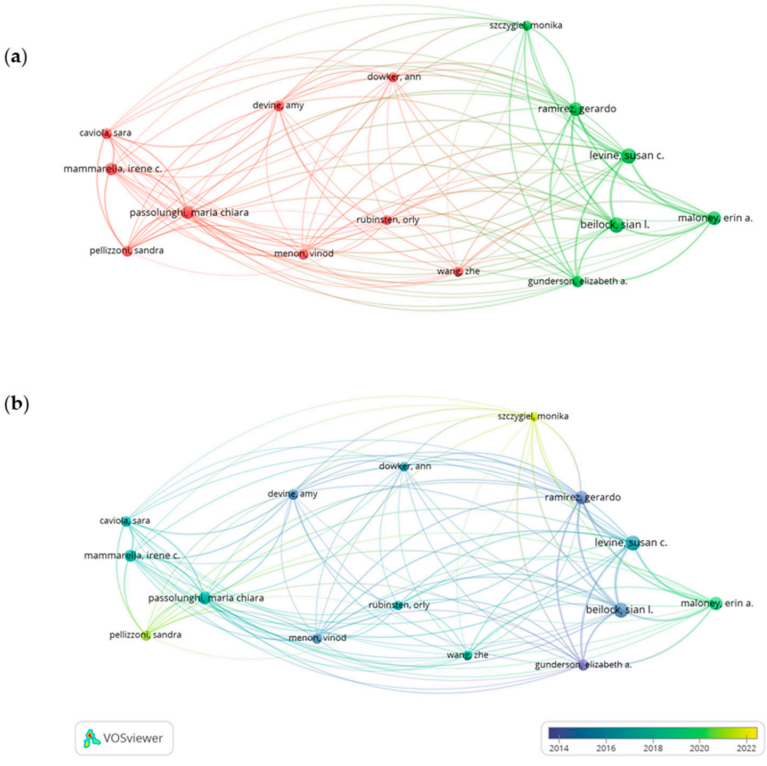

Figure 4. Network (**a**) and temporal (**b**) visualisations of the distribution of publications by authorship based on the number of citations.

When analysing the new trends through the network visualisation of the temporal evolution by authorship, it was observed that Monika Szczygiel and Sandra Pellizzoni were those authors with the highest number of recent publications (Figure 4b).

3.5. Distribution by Year of Publication

The first publication identified on mathematics anxiety in children is entitled "Eye classification, sex, and math anxiety in learning-disabled children-behavioral observations on conservation of volume" and was published by Robinson et al. in *Perceptual and Motor Skills* [47].

Until 2011, there were no more than 10 annual publications, and in 2015, more than 20 publications per year were registered for the first time. The year with the highest number of publications was 2022, reaching a total of 60. During the first quarter of 2023, the year in which this study was carried out, the number of publications was 18. Figure 5 shows the distribution of publications related to mathematics anxiety in Primary Education, which illustrates an upwards evolution.

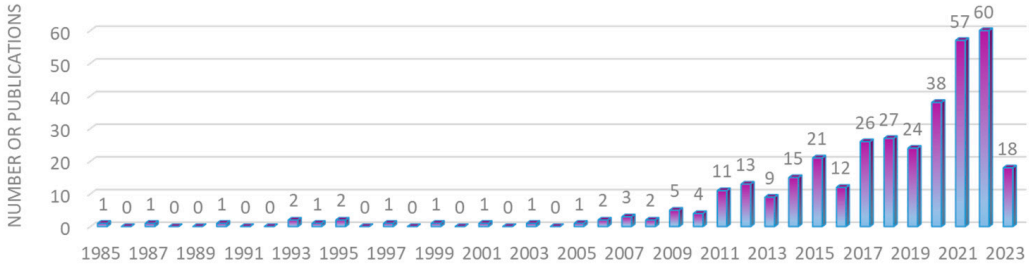

Figure 5. Temporal evolution of publications.

3.6. Co-Occurrence of Keywords

3.6.1. Callon Density and Centrality Analysis of Keywords

The set of keywords extracted from the co-occurrence analysis was represented in a strategic Callon diagram, based on their range of centrality and density and using the h index as a quality index (Figure 6; Table 5). The keyword "mathematical anxiety" was used as a reference, with a range in both centrality and density of 1. The keywords "gender-stereotype" and "perception", with high values of centrality and density, were located in the upper-right quadrant of Callon's strategic diagram since they showed high values of both centrality and density; therefore, they were considered motor keywords since they were important for structuring the research field (centrality) in addition to being well developed (density). In the lower-right quadrant of the diagram, the keywords "meta-analysis", "parents", "students", "skills", and "mathematical self-efficacy" were identified as having outstanding centrality but low density. These elements were outlined as significant within the scope of research, although they lacked substantial development, suggesting that they were basic and cross-cutting themes. The keywords "emotion" and "representation" were identified in the lower-left quadrant of the diagram, characterised by low centrality and density, suggesting that they were underdeveloped terms with limited importance within the scope of this study. Their marginal presence possibly indicated that they were in an emerging stage or that they could lose relevance in the future. In the upper-left quadrant of the strategy diagram, the keywords "classroom environment", "socioeconomic status", "stereotype", "trainee teacher", and "behavior" were found to be characterised by low centrality but high density. These terms were highly specialised, although their relevance in the field was marginal.

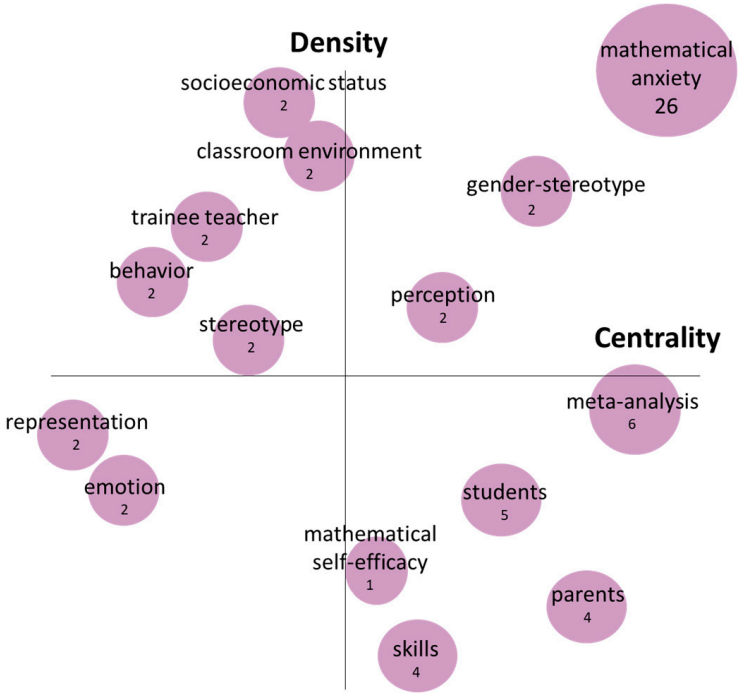

Figure 6. Callon's strategic diagram based on centrality and density.

Table 5. Keywords based on the range of centrality and density of Callon.

Keyword	Centrality Range	Density Range
Math anxiety	1	1
Gender-stereotype	0.8	0.8
Perception	0.67	0.6
Meta-analysis	0.93	0.47
Parents	0.87	0.13
(Students)	0.73	0.27
Skills	0.6	0.07
Mathematical self-efficacy	0.53	0.2
Classroom environment	0.47	0.87
Socioeconomic status	0.4	0.93
Stereotype	0.33	0.53
Teaching staff	0.27	0.73
Behavior	0.2	0.67
Emotion	0.13	0.33
Representation	0.07	0.4

3.6.2. Network Map

An analysis of the keyword co-occurrence network map revealed the existence of three clusters in the bibliometric network. The network was built from keywords with a minimum co-occurrence of 25. Thus, 18 of the 1398 words met this criterion. Table 6 shows the words that make up the network classified from highest to lowest according to their total link strength and the value of co-occurrence. The keyword "math anxiety" had the highest bond strength (1059) and the highest co-occurrence (312).

Figure 7a shows the network map in which the most important cluster, represented in red, included the keywords "mathematics anxiety", "academic achievement", "performance", "mathematics", "self-efficacy", "anxiety", "motivation", "beliefs", and "self-concept". The second cluster, represented in blue, included the keywords "working memory", "girl/boy", "individual differences", and "abilities". The third and last cluster,

represented in green, included the keywords "primary school", "gender differences", "assessment scale", "adolescents", and "mathematical achievements". In contrast, when analysing the new trends over time through the online visualisation of the evolution of the use of the keywords that make up the network, it was highlighted that the keyword "motivation" emerged as the most up-to-date keyword (Figure 7b).

Table 6. Keywords sorted based on total link strength.

Keyword	Total Link Strength	Co-Occurrences
math anxiety	1059	312
academic-achievement	685	172
working memory	601	143
children	587	141
performance	550	130
elementary-school	391	87
gender-differences	353	79
rating-scale	329	80
mathematics	225	63
self-efficacy	203	46
anxiety	181	43
individual-differences	152	37
motivation	141	32
beliefs	126	30
adolescents	122	27
mathematics achievement	112	25
skills	106	27
self-concept	101	25

Note: The colors used in the table indicate different clusters in the network, corresponding to the colors in the network visualization.

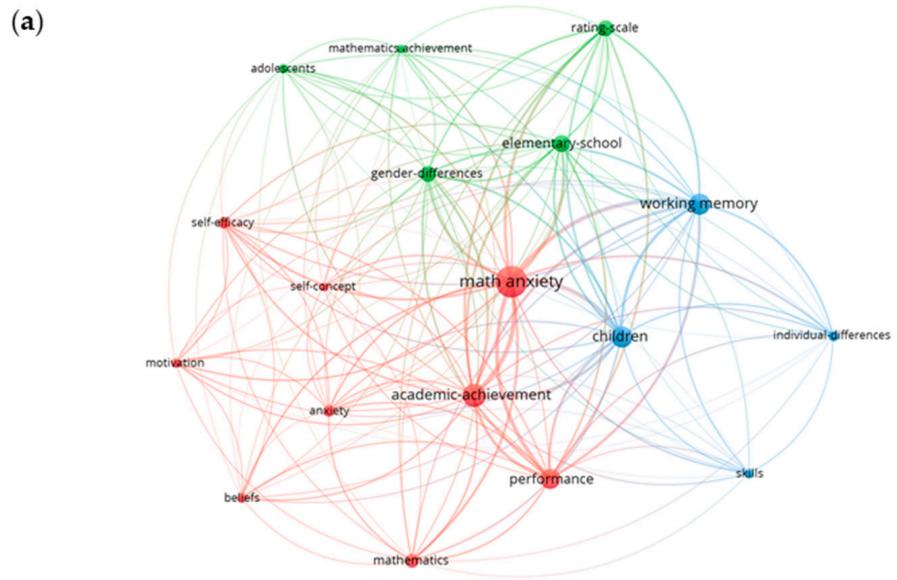

Figure 7. *Cont.*

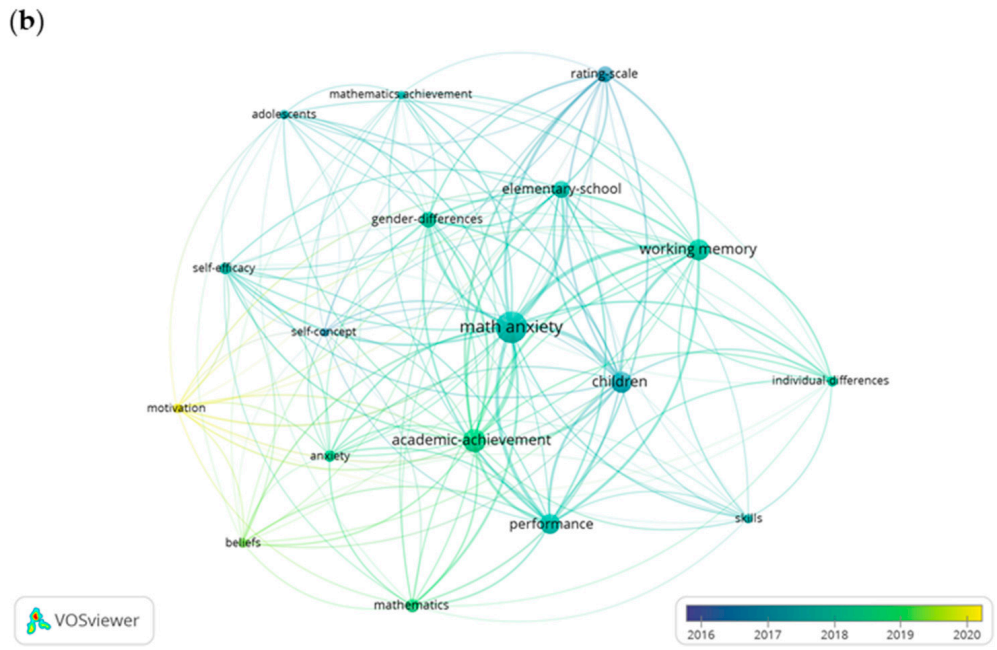

Figure 7. Network visualisation of the keyword co-occurrence map (**a**) and a temporal display of the evolution of the use of the keywords (**b**).

4. Discussion

The bibliometric analysis carried out offers a detailed and exhaustive view of the existing scientific literature on mathematics anxiety focused on Primary Education. The findings reveal significant diversity in terms of the distribution of journals, institutions, countries, authorship, and time evolution. In addition, these findings offer relevant information on the aspects being investigated in relation to mathematics anxiety, which can help us better understand the current state of the knowledge of the subject and thus establish starting points in the design of new research and educational practices.

Regarding the distribution of publications by journal, there is a considerable variety of journals that address this issue. *Frontiers in Psychology* stands out as a leader in terms of the number of papers and citations, indicating its prominence in the field. This finding supports the results of Ersozlu and Karakus [40], demonstrating the significant impact of the articles published in this journal and their influence on other researchers. Furthermore, the network analysis reveals a pattern that supports the central position and importance of this journal, as evidenced by the size of its node and its close relationships and links with other surrounding journals. This finding suggests that these journals take similar approaches to specific topics. In addition, the red cluster seems to be dominated by journals that address issues related to psychology, both in the educational field and in child development. The green cluster seems to be more focused on journals that focus on specific aspects of learning, cognition, and educational psychology. These findings suggest that the journals in the red cluster may have a broader and multidisciplinary scope, while those in the green cluster may be more focused on specific areas.

The distribution of publications based on the number of citations of the institution reveals information about its impact on the scientific community. Thus, the findings highlight the relevance of the University of Chicago, which stands out both in the quantity and quality of its publications, as well as in the numerous and solid collaborations with each of the 21 remaining institutions analysed. The grouping of universities in different clusters seems to be determined by the collaboration networks in research projects, joint publications, or other academic activities established between the universities that comprise them. Likewise, it seems that the universities that make up the red cluster are predominantly located in the US, while those that make up the green cluster are dispersed across different countries. Although all the institutions analysed are grouped into two independent clusters,

many of them have joint publications. These results are of great value for understanding the dynamics of such research and the importance of institutions in the advancement of knowledge, and suggest that close collaboration between pioneering universities exists to address the investigation of mathematics anxiety in Primary Education. It should be noted that most of the most important universities addressing this subject are located in the US, which is consistent with the results obtained in previous studies [40]. The central position of the US, along with other countries such as the UK, Italy, and Canada, on the map suggests that these countries stand out for their collaboration and connection in the scientific field. In this group, there is evidence of less close collaboration with Taiwan, which places it on the periphery of the map. Finally, the case of China stands out since its particular characteristics and its focus on research mean that despite its considerable scientific production and number of citations, its impact is not as high. These findings show the importance of international collaboration in the advancement of scientific knowledge [48].

Two clusters are found to be independent groups that represent authorship groups with different characteristics and relationships. First, there are prominent authors such as Susan C. Levine, who stands out for her high number of publications, and Sian L. Beilock, who is the most-cited author. In addition, the co-authorship data reveal a close relationship between these two authors, as well as between Erin A. Maloney and Gerardo Ramírez. The proximity of the nodes and the connections between them suggest that all these authors belong to the same research group. However, a weaker co-authorship relationship is also observed among Susan C. Levine, Maria Chiara Passolunghi, and Irene C. Mammarella, who belong to the second cluster.

In contrast, the growing trend in the production of publications related to mathematics anxiety in Primary Education in recent years suggests an increase in interest on the part of the scientific and academic community regarding the impact of mathematics anxiety on both academic performance and student well-being. The success and increase in the numbers of resources and methodological tools available to address mathematics anxiety in the classroom [49,50], as well as an interdisciplinary approach to the subject, are some of the factors that have encouraged research in this area.

The analysis of keywords can provide interesting insights into the structure and development of the field of research on mathematics anxiety in Primary Education. These results are relevant for understanding which thematic areas have received the most attention and which may be emerging or lacking in terms of development. The position of the keywords "gender-stereotype" and "perception" is noteworthy, as it makes them relevant and well-developed concepts in the field, that is, makes them motor keywords. This finding suggests the importance of understanding how gender stereotypes can influence mathematics anxiety and how the perception of oneself and others can affect the mathematical experience, as noted by Rossi et al. [23]. This line of inquiry can offer strategies to combat gender stereotypes in the classroom and enhance students' mathematical self-efficacy, particularly for girls who are often more vulnerable to the negative effects of these stereotypes [51,52]. Additionally, the inclusion of the keyword "perception" is related to how mathematics anxiety is generally measured through self-reports, and how this conceptualisation of perception might be linked to the typical measurement of mathematics anxiety through surveys. Conversely, it is worth highlighting the keywords "meta-analysis", "mothers/fathers", "students", "skills", and "mathematical self-efficacy", which show strong centrality but low density. This finding indicates that these keywords are topics of general interest in the field but have not yet been extensively researched or developed, suggesting that these are areas in which more research is needed to deepen our understanding of mathematics anxiety.

Our analysis of the co-occurrence network reveals three different clusters, each corresponding to specific subject areas within the set of keywords analysed. These clusters provide valuable information on the semantic structure of the investigated area based on the relationships among the keywords. The first cluster is related mainly to psychological and motivational aspects of performance in mathematics. The second cluster addresses

cognitive processes and individual differences, while the third cluster is more focused on educational aspects related to teaching and learning in Primary Education.

Key concepts such as "academic performance", "motivation", and "individual differences" are identified as affecting mathematics anxiety, in agreement with the results of Wang et al. [53]. In addition, there is a growing interest in the relationship between "motivation" and mathematics anxiety. These results provide a solid foundation for future research and the development of effective interventions in this field.

Furthermore, educators and policymakers can apply these findings practically by designing curricula and learning environments to alleviate math anxiety's risk factors. Techniques such as reducing pressure and stress during math assessments and fostering supportive classroom environments can promote a positive attitude toward mathematics [54].

Despite the valuable findings obtained in this study, it is important to recognise some limitations that may have influenced the interpretation of the results. Although our methodological search strategy aimed to capture a broad range of relevant studies, the potential omission of studies using alternative terminology such as "elementary school" could be a limitation of this study. Additionally, as the focus was solely on Web of Science (WoS), the selection of databases for the literature search may have introduced potential biases. While WoS is widely used and recognised, excluding other databases like Scopus or PubMed may have omitted relevant studies published in different contexts. Moreover, while our main focus was to measure production trends in research on math anxiety at the Primary Education level, it is important to state that our analysis is primarily centred on the quantitative evolution of scientific production. Although the temporal evolution of keywords was considered, with motivation emerging as the most prominent term in recent publications, this methodology might have overlooked certain qualitative or more detailed content aspects. Despite these limitations, the results of this study offer significant insights into research on math anxiety at the Primary Education level and highlight key areas for future research in this field.

5. Conclusions

The distribution of journals related to mathematics anxiety in Primary Education with the highest number of citations is concentrated mainly among three publishers (Elsevier, Wiley-Blackwell, and Taylor and Francis). The study of this distribution yields a classification that includes the following two clusters: one cluster that is more focused on psychology and another cluster that is more related to learning.

Regarding geographic location, a certain structure is observed since the institutions of the most important cluster, in addition to including some of the largest and most recognised universities worldwide, such as the University of Chicago, Columbia University, or University of Florida, are located mainly in the US, with some exceptions, such as the University of Haifa in Israel and the University of Tomsk in Russia. In contrast, the institutions in the minority cluster, though they are also prestigious universities, are smaller or have less international recognition than the previous universities [55]. Additionally, these universities exhibit a more dispersed geographical distribution, with representation spanning across various countries such as the UK, Italy, the US, China, and Finland. This diversity in geographical locations suggests a broader global presence among the institutions in the minority cluster, potentially indicating a more inclusive and internationally collaborative research landscape.

Moreover, there is growing interest on the part of the scientific community in the mathematics anxiety experienced by the youngest students—those in Primary Education. This finding points to an emerging trend that reflects the importance of addressing this phenomenon beginning in the early educational stages.

The study of the co-occurrence or joint appearance of the keywords used in the 360 publications included in the bibliometric analysis of mathematics anxiety in Primary Education highlights the interest of the scientific community in understanding how factors

such as gender stereotypes or the perception of mathematics among students can influence the appearance and development of this phenomenon.

Finally, the predominance of women among the authors who investigate mathematics anxiety in Primary Education is very noteworthy. This finding is influenced by aspects ranging from historical representation in related fields to the multidisciplinary nature of the subject, and even to differences in sensitivity to the emotional and social experiences of students [56]. In any case, this aspect indicates a promising direction for future research in the field, highlighting the importance of considering social and emotional aspects in the teaching and learning of mathematics in Primary Education.

Author Contributions: Conceptualisation, A.S., N.A. and A.A.; formal analysis and investigation, A.S.; methodology and validation, A.S. and N.A.; writing—original draft, A.S., N.A. and A.A.; funding, A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the projects GIU21/029 (University of the Basque Country, UPV/EHU) and PES17/39 (University of the Basque Country, UPV/EHU).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author/s.

Acknowledgments: The authors acknowledge the assistance of T. Villarroel.

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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