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Mathematics anxiety in mathematics education: a bibliometrics analysis

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ABSTRACT

This research is based on a bibliometric analysis of publications on math anxiety. It aims to analyze the distribution of the results of publications on math anxiety in the last ten years based on research trends and topics, reputable journals, influential authors, institutions, and productive countries. Scopus was used as a data collection database and was analyzed using the VOSviewer and Biblioshiny tools. The workflow carried out in this research consists of research design, data collection, data analysis, data visualization, and data interpretation. Three hundred twenty-one articles published from 2013 to 2023 were retrieved and read carefully. The results of the analysis show that many research studies on mathematics anxiety have been carried out in mathematics education, and this theme influences mathematics learning. The Journal Frontiers in Psychology is at the top, and the University of Barcelona is the most influential institution. The United States has significant relevance in this field. The results of this research also provide researchers with insight into the extent to which this field has been studied, and they can explore various alternatives to this major based on research trends and influential articles.

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1. INTRODUCTION

Mathematics anxiety has received significant attention for research, considering that this theme has contributed impacts to mathematics education. Mathematics anxiety is a widespread problem throughout the world and affects all age groups [1]. It is true that many students lack interest in mathematics, are not aware of their mathematics skills, and consider mathematics to be a complex and challenging subject that causes anxiety [2]. Some research encompassing elementary school to tertiary level have been conducted, for example, elementary school [3]–[6], middle school [7]–[9], and higher education [10]–[15].

Mathematics anxiety can be experienced by children and adults, which can result in a high level of avoidance of learning mathematics or anything related to mathematical contexts [16], [17]. It is one of the predictors of mathematics learning achievement [18]. It can be an obstacle for someone in learning mathematics because mathematics anxiety is a feeling of tension and panic experienced by someone who faces mathematical problems [14]. Additional study indicates that individuals experiencing math anxiety have heightened activity in brain areas associated with negative emotions and reduced activity in brain regions associated with mathematical cognition [19].

Mathematics anxiety is a distinct type of anxiety illness that leads to a reluctance to engage in learning and practicing mathematics [20]. Mathematics anxiety is generally defined as feelings of tension, worry, or fear that interferes with mathematics performance [21]. Someone who experiences fear when dealing with numerical information is called mathematics anxiety [22]. If math anxiety is not handled well, it can be worrying for students. Students whos have excessive mathematics anxiety and are unable to control it can disrupt the mathematics learning system in the classroom. Students cannot maintain their focus and always feel afraid when studying mathematics. Therefore, there is a need for more in-depth research regarding this matter. By keeping this in mind, it is hoped that someone can organize and manage their mathematics anxiety well to place their anxiety proportionally when studying mathematics. How students can control and manage their mathematics anxiety so that it does not interfere with the students' mathematics learning process.

Mathematics anxiety is closely related to other variables: strategy [23], [24], calculation skills [25], mathematics achievement [26], [27], gender [28], [29], pedagogic action [30], math performance [31], [32], problem-solving [33], and technology [34]. Thus, the scope of this research has expanded to various other research fields, and the analysis of this study uses bibliometrics. Research using bibliometric analysis has been widely carried out, as bibliometric studies have been very prominent for decades due to their advanced contributions in introducing many areas of interest [35]. The main function of bibliometrics is to reveal developments and changes in any field and examine the conceptual, social, and intellectual structure of scientific publications in that field [36].

This bibliometric analysis research on mathematics anxiety aims to describe and discover the latest trends, topics, and characteristics of scientometrics in this collection of literature, which provides a general overview of scientific literature and insight into the future direction of mathematics anxiety in mathematics education. In this paper, three research questions are examined:

- What are the prevailing study subjects and emerging trends identified by word analysis of titles, abstracts, and keywords related to "mathematics anxiety" in the literature on mathematics education?
- What are the most important journal sources and the most influential authors on mathematics anxiety in the mathematics education literature?
- Which international collaborations between countries and institutions impact mathematics anxiety most in mathematics education literature?

2. METHOD

2.1. Study design

The scientific mapping workflow method used in this research consists of research design, data collection, data analysis, data visualization, and data interpretation [37]. Furthermore, the analysis method used in this research is bibliometric analysis. Bibliometrics is a statistical method for measuring and assessing increasing trends in a particular study area [38], [39]. This goal is achieved by assessing relevant patterns of excellence and emerging research areas [40]. This research used a bibliometric analysis method design using the VOSviewer and Biblioshiny applications. This design was utilized to identify research related to the theme of mathematics anxiety from various aspects. Publications related to mathematics anxiety were taken from the Scopus database.

2.2. Data collection

The data collection process went through several stages: data collection, filtering, transformation, and data cleaning. Article data were collected through the Scopus database because its coverage is wider than that of other databases [41]. We searched for articles related to the theme published from 2013 to 2023 (excluding books, seminar papers, proceedings, and so on). We wanted to see how mathematics anxiety had developed in the last ten years to produce up-to-date data based on articles in Scopus-indexed journals. In searching for articles, we used the phrase “mathematics anxiety” as the keyword and did not select the keyword “anxiety” since our research only focused on mathematics anxiety rather than anxiety in other areas.

2.2.1. Data filtering

After the data were collected, we filtered the data according to the objectives of this research. Some of the data that we filtered were title, abstract, and keywords as quality criteria. We also filter the publication year of the articles (2013-2023), subject areas (social science, psychology, mathematics, computer science), keywords (mathematics, anxiety, mathematics anxiety, math anxiety, test anxiety), language (English), limited to all open access, and articles that were not directly related to the objectives of this research.

2.2.2. Data transformation

The search results were saved in CSV and RIS formats to include important information regarding citations, bibliographic and abstract information, and keywords. The storage system was in two forms; this was done for article analysis using bibliometrics (VOSviewer and Biblioshiny). We did this because several analyses were not sufficient using VOSviewer alone, so we decided to use Biblioshiny as well to support the completeness of the analysis.

2.2.3. Data cleaning

The data that have been stored were then verified for incomplete or incorrect data, and various inputs that did not conform to the research objectives were removed. At this stage, we also corrected some duplicate and inconsistent information so that the data produced at this stage had a minimum number of errors. For example, if there was the same journal, but the writing was different, then the journals were combined. Figure 1 is a flowchart of the data collection carried out.

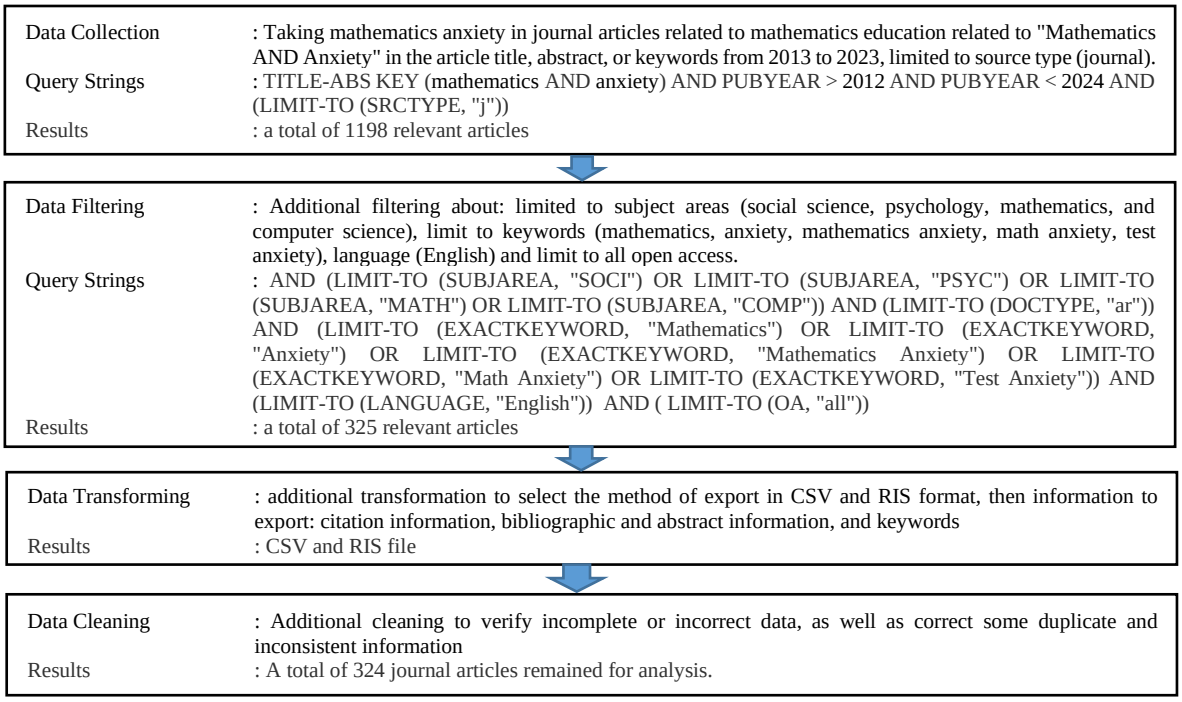


Figure 1. Data collection flowchart

2.3. Data analysis and visualization

Various techniques were used to describe information in publications. General information about the collection of publications had been summarized by year of publication, country, author, number of documents, and journals. Visualizations and overlays of mathematics anxiety were also displayed and analyzed. VOSviewer and Biblioshiny software collected, analyzed, and visualized bibliographic data using CSV and RIS formats.

3. RESULTS AND DISCUSSION

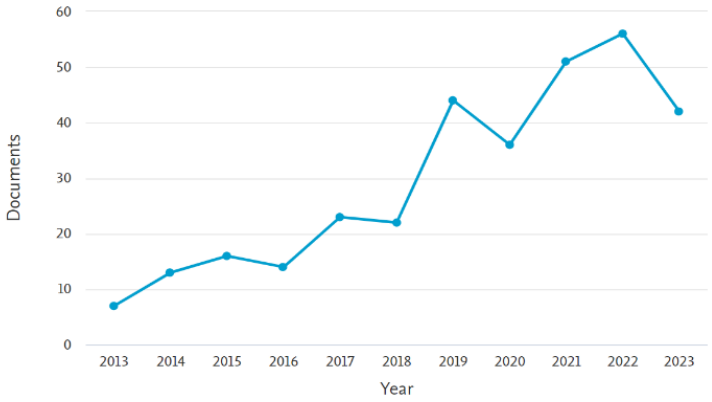
3.1. Results

3.1.1. General information and growth trends

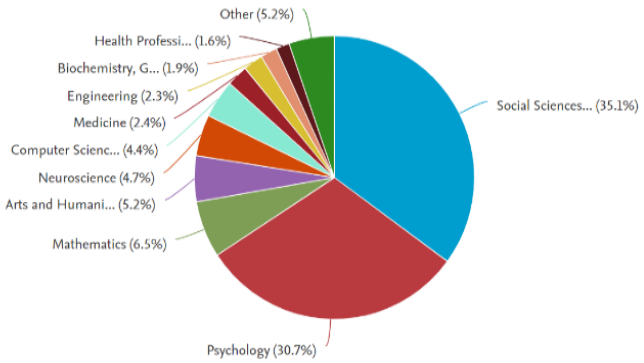
Mathematics anxiety has been developing for a long time and is starting to become a current research trend. This is because current researchers are examining not only cognitive aspects but also affective aspects that contribute to mathematics education. The development of the number of mathematics anxiety research from 2013-2023 can be shown in Figure 2.

In Figure 2(a), it can be seen that the growth of mathematics anxiety research is growing every year. In 2013, 7 documents were published, and 13 in 2014. However, in 2016 there were 14 documents (a decrease

from 16 documents in the previous year). In 2017, 23 documents were published and the number continued to increase until 2019 (44 documents), but in 2020 it experienced a decline (36 documents). The following year, 2021, until now, there has been an increase in the amount of research on mathematics anxiety. Based on this graph, the highest published mathematics anxiety research was conducted in 2022 (56 documents). Mathematics anxiety is not only studied in the field of mathematics education, but many other fields also study this theme. This can be seen in Figure 2(b), which shows that the field of social sciences (35.1%) is the field that carries out the most studies on mathematics anxiety, followed by the fields of psychology (30.7%), mathematics (6.5%), arts and humanities (5.2%), neuroscience (4.4%), computer science (4.4%), and health professions (1.6%).



(a)



(b)

Figure 2. Document of mathematics anxiety by (a) year and (b) subject area

Figure 3 is a network visualization of mathematical anxiety mapping, and the image consists of seven clusters with 53 items. The first cluster is marked in red and consists of 10 items: cognitive, high school student, individual, math performance, math problem, mathematical achievement, mathematical performance, primary school student, task, and working memory. Cluster two consists of 10 items marked in green: anxiety level, attitude, belief, education, mathematics education, mathematics teacher, secondary education, self-confidence, student, and teacher. Cluster three is marked in blue and consists of 10 items: arithmetic achievement, gender difference, individual difference, mathematics anxiety, mathematics performance, primary school child, reasons, skill, metacognitive monitoring, and arithmetic skill. Cluster four consists of 8 items marked in yellow: academic achievement, mathematical problem, mathematics achievement, mathematics self-efficacy, middle school student, motivation, self-efficacy, and understanding. The purple color is cluster five, which consists of 7 items: academic performance, achievement, achievement emotion, emotions, perceptions, secondary school, and secondary school students. Cluster six, marked in cyan, consists of 6 items: ability, science, sex difference, spatial anxiety, technology, and test performance. The last cluster is marked in orange: mathematics motivation and students' perception. In this picture, you can see how mathematics anxiety is connected to other variables in mathematics education.

Figure 4 shown overlay visualization and connection of mathematics anxiety. In Figure 4 overlay visualizes mathematics anxiety from 2018 to 2021, marked in dark blue to yellow. The darker color indicates

that the variable was published in 2018, while the gradually lighter color at the variable point indicates the latest publication years. In the picture, it can be seen that mathematics anxiety has been widely publicized starting around 2019 and continues to grow to this day. Based on Figure 4, mathematics anxiety has many connections with other variables, including gender differences, mathematical problems, understanding, abilities, skills, teachers, motivation, beliefs, self-efficacy, high school students, and individual differences. This picture shows that mathematics anxiety is connected with not only psychological aspects (emotion, belief, motivation, self-efficacy, and gender) but also cognitive aspects (skills, abilities, understanding, mathematical problems, and metacognitive monitoring). Even though aspects of technology and education are connected to mathematics anxiety, the aspects of the subject studied are widely studied at the level of high school and secondary school students and mathematics teachers.

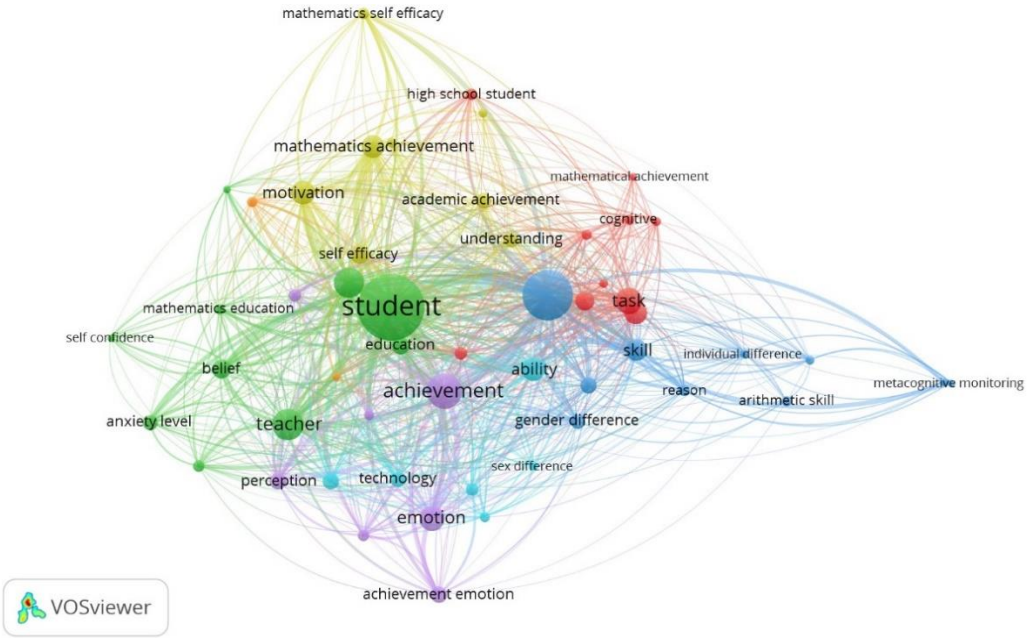


Figure 3. Network visualization of mathematics anxiety

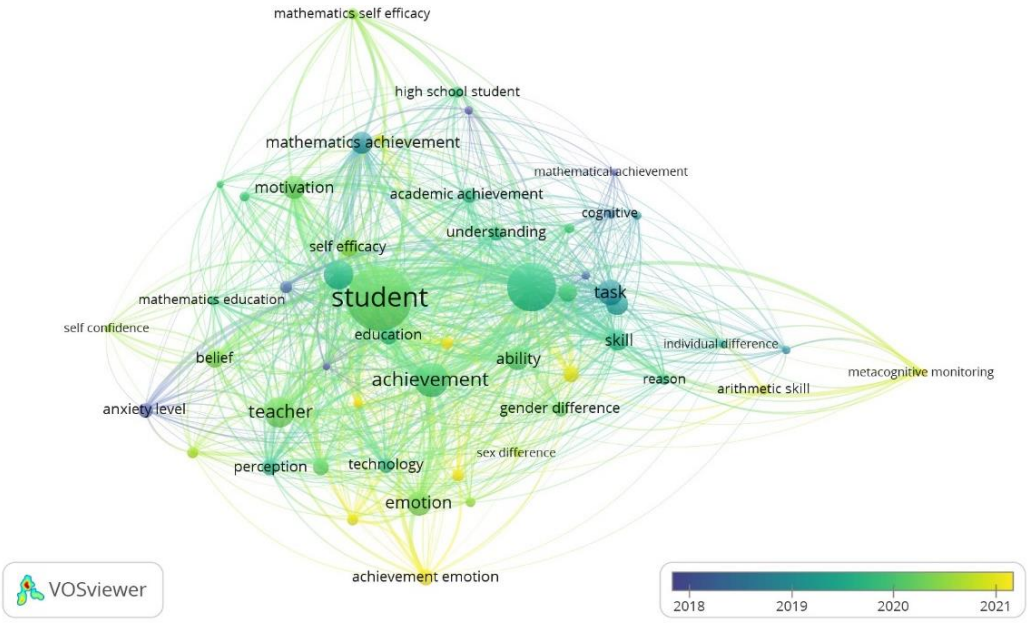


Figure 4. Mathematics anxiety on overlay visualization and connections

Figure 5 is a thematic evolution divided into three periods, namely 2013 to 2019, 2020 to 2021, and 2022 to 2023. In the first period, it appears that there are four major themes that researchers are interested in researching, namely math anxiety, mathematics anxiety, general anxiety, and effort. However, in the second period (2020–2021), research continues to develop and many new themes emerge in the study, but the theme of mathematics anxiety remains the most popular. Other widely studied themes include motivation, test anxiety, primary school, arithmetic, gender, primary school children, and mathematics achievement. Math anxiety has developed a study by linking other variables such as arithmetic, gender, and math anxiety itself.

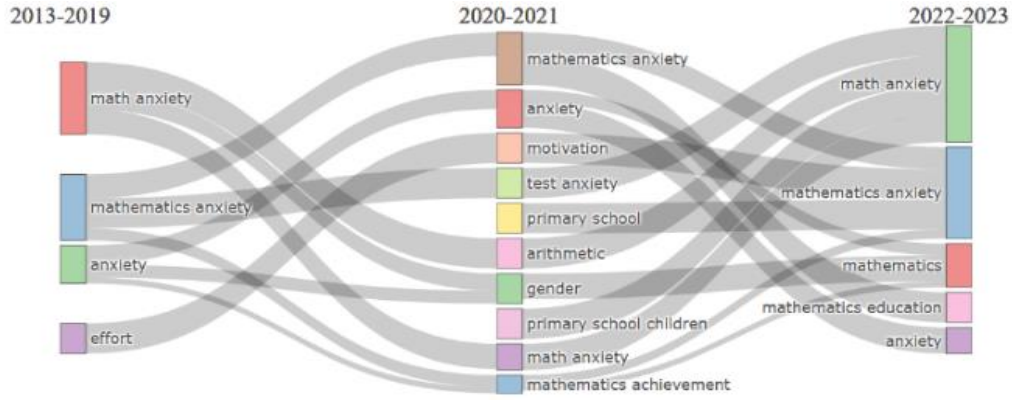


Figure 5. Thematic evolution

Mathematics anxiety develops with other variables, including test anxiety and mathematics achievement, while anxiety develops into gender and mathematics achievement. Effort develops with another theme, namely motivation. In the third period (2022–2023), there are five major themes of interest: math anxiety, mathematics anxiety, mathematics, mathematics education, and anxiety. However, the themes of math anxiety and mathematics anxiety remain the themes that most researchers are interested in. In this period, math anxiety is associated with other variables, such as test anxiety, arithmetic, and primary school children. Mathematics anxiety is associated with the variable's motivation, primary school, and mathematics achievement, while mathematics is associated with the variable's anxiety, gender, and mathematics achievement. Mathematics education is associated with mathematics anxiety, and anxiety is associated with the anxiety variable itself.

3.1.2. Contribution by journals

Based on Scopus data, it can be seen that 168 journals publish the theme of mathematics anxiety. However, what is analyzed in this research are the top ten journals that research this theme the most, which are journals indexed in the Scopus database. The journal data can be seen in Table 1. Table 1 show list of journals that publish research about mathematics anxiety in the Q1-Q3 quartile range. There are five journals in Q1, including the British Journal of Educational Psychology (SJR 1.39), Journal of Educational Psychology (SJR 2.51), CBE Life Sciences Education (SJR 1.57), Sustainability (SJR 0.66), Cognitive Research: Principles and Implications (SJR 1.00). There are four journals in Q2, including Frontiers in Psychology (SJR 0.89), European Journal of Contemporary Education (SJR 0.39), Eurasia Journal of Mathematics, Science and Technology Education (SJR 0.51), and Education Sciences (SJR 0.61). Meanwhile, there is only one journal in Q3, namely the European Journal of Educational Research (SJR 0.34).

Figure 6 shows the top five journals that published much research on mathematics anxiety from 2015 to 2023. Based on this data, Frontiers in Psychology is the most popular journal that publishes the most research on mathematics anxiety, with 39 documents. It can be seen that every year, the number of publications in this journal always increases, except in 2020 and 2022 when there was a decrease in the number of publications in both periods. The Journal of Educational Psychology has eight documents. Every year, except 2023 with no document showing research on mathematics anxiety, it publishes research on mathematics anxiety.

Table 1. List of mathematics anxiety journals

No	Source	Publisher	N.C	Scopus quartile*	SJR 2022*
1	Frontiers in Psychology	Frontiers Media SA	55251	Q2	0.89
2	British Journal of Educational Psychology	Wiley-Blackwell	982	Q1	1.39
3	Journal of Educational Psychology	American Psychological Association	2136	Q1	2.51
4	European Journal of Contemporary Education	Academic Publishing House Researcher SRO	426	Q2	0.39
5	CBE Life Sciences Education	American Society for Cell Biology	1181	Q1	1.57
6	Eurasian Journal of Mathematics, Science and Technology Education	Modestum Ltd.	985	Q2	0.51
7	Education Sciences	MDPI AG	5313	Q2	0.61
8	Sustainability	MDPI AG	27397	Q1	0.66
9	Cognitive Research: Principles and Implications	Springer Open	739	Q1	1.00
10	European Journal of Educational Research	Eurasian Society of Educational Research	767	Q3	0.34

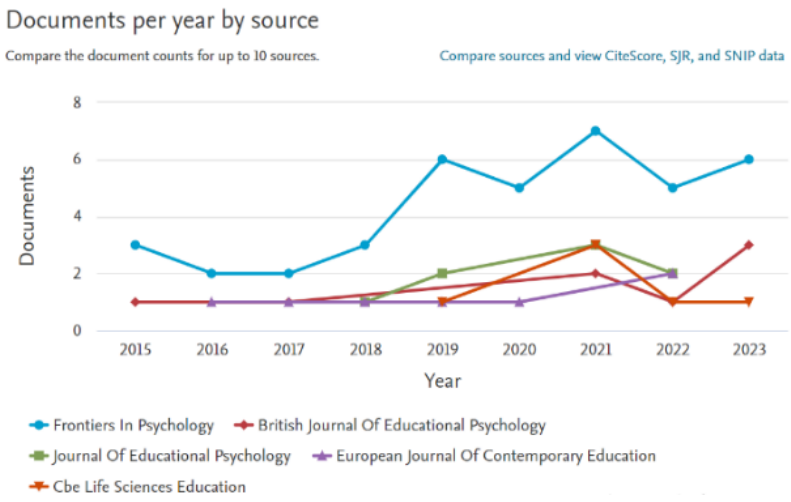


Figure 6. Documents per year by source

3.1.3. Contribution by author

Nine hundred seventy-eight authors from various countries have researched this theme. The rapid development of this research shows that this theme contributes well to mathematics education because mathematics anxiety can hinder a person's performance in mathematics. Table 2 lists the most productive authors who have studied this theme.

Table 2. The five most productive authors

Author	Country	NP	TC	H-Index	PY_start
Garcia-Santillan	Mexico	10	143	7	2015
Pekrun, Reinhard	United Kingdom	7	985	77	2013
Goetz, Thomas	Austria	7	917	55	2013
Nunez-Pena	Spain	9	187	19	2013
Caviola	United Kingdom	4	171	21	2016
Colome	Spain	6	32	12	2019

NP= number of publications, TC= total of citations, PY-start= publication year start

Table 2 shows the most productive authors in producing mathematics anxiety research based on country, number of publications, total of citations, h-index, and publication year start. Garcia-Santillan, from Mexico, started publication on this theme in 2015 with ten articles published, 143 citations, and an h-index of 7. Pekrun Reinhard is a writer from the United Kingdom who started publication on this theme in 2013 with 7 publications, a total of 985 citations, and an h-index of 77. Next on the list is Goetz Thomas from Austria, who

started publication in 2013 with 7 article publications, a total of 917 citations, and an h-index of 55. Nunez-Pena, a researcher from Spain, started publishing related to this theme in 2013 with 9 publications, a total of citations of 187, and an h-index of 19. Caviola from the United Kingdom started publication in 2016, with 4 publications, 171 citations, and an h-index of 21. Lastly, Colome, who is from Spain, started publication in 2019, with 6 publications, 32 citations, and an h-index of 12. Figure 7 shows the network between authors in studying the theme of mathematics anxiety. Authors are marked with nodes. The size of the nodes indicates the number of publications, and the lines show the relationship between authors. Collaboration between authors is not strong, with most authors collaborating with up to 3 to 5 authors.

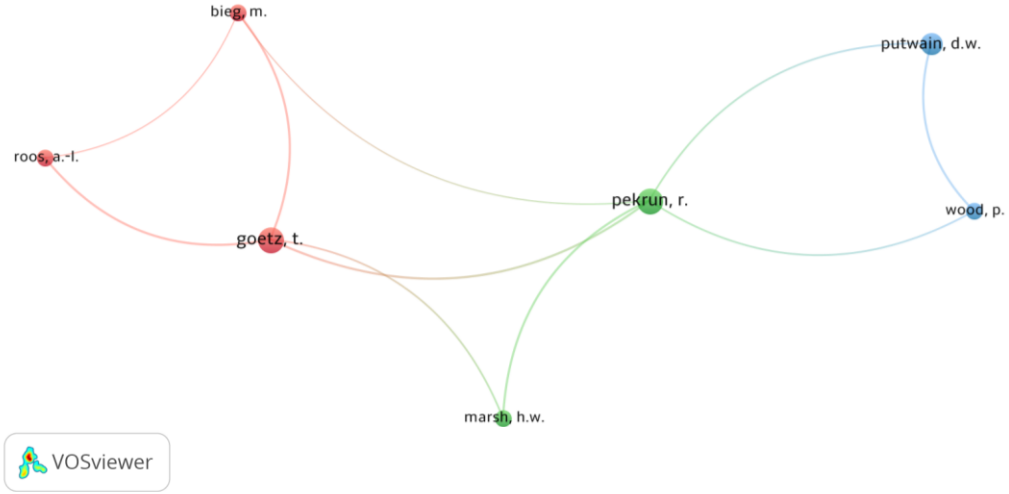


Figure 7. Visualization of the network between authors' distribution

3.1.4. Contribution by country

Mathematics anxiety has become a concern in various countries. Around 78 countries have contributed to mathematics anxiety research, which is increasingly in demand. When someone has excessive stress, it can have an impact on learning mathematics. Figure 8 shows the number of publications in the ten countries that publish the most on mathematics anxiety, including the United States with 62 documents, the United Kingdom with 48 documents, Germany with 32 documents, Spain with 31 documents, Turkey with 20 documents, Australia and Italy with 18 documents each. Canada, Indonesia, and Switzerland are next on the list with 14 documents each. The countries come from various continents.

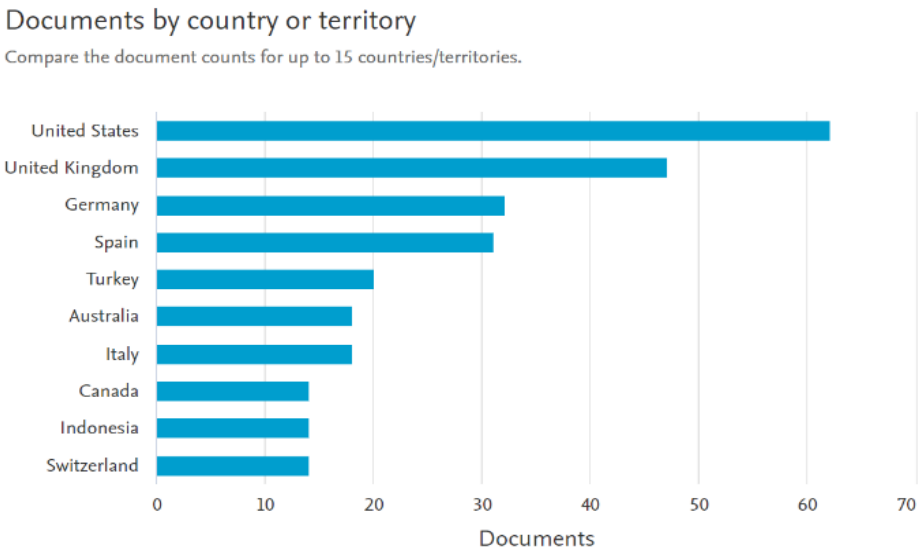
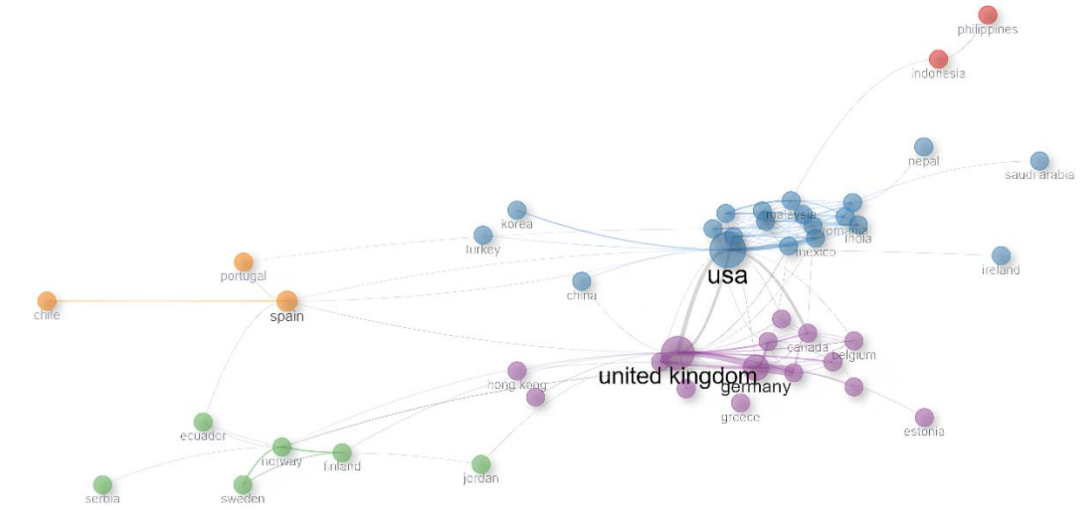


Figure 8. Documents by country

Figure 9 lists the ten countries with the most research related to this theme. In Figure 9(a) is a collaboration network between countries that publish on mathematics anxiety. It shows the network of countries that conduct research together. The United States collaborates with several countries, including Mexico, Pakistan, Malaysia, India, Turkey, Korea, Ireland, Spain, and others. The United Kingdom collaborates with other countries, including Germany, Canada, Japan, the United States, Spain, Finland, and Bangladesh. Spain collaborates with Chile, Portugal, Ecuador, and several other countries. Malaysia collaborates with Indonesia, India, Pakistan, and several other countries which also collaborate between countries, although more collaboration is needed than the United States and the United Kingdom. Figure 9(b) shows the corresponding author's countries that collaborate on publications. The green chart shows countries that only carry out single-country publications (SCP), including Turkey, Indonesia, and the Netherlands. Meanwhile, the United States, Spain, Germany, and the United Kingdom carry out SCP and multiple-country publications.



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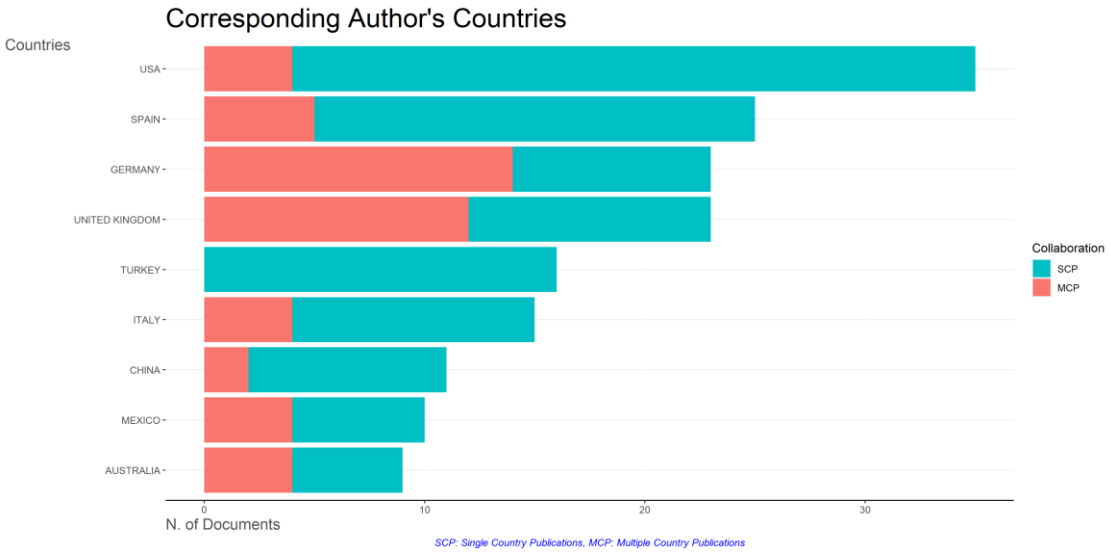

(b)

Figure 9. The countries of collaboration in (a) the network and (b) corresponding authors

3.1.5. Contribution by affiliate

Based on data obtained from Scopus, 160 different affiliates published on the theme of mathematics anxiety. Based on the analysis results, it was found that there were ten most relevant affiliates. This can be seen in Figure 10. The University of Barcelona is the most relevant affiliate regarding this research theme with as

many as 23 documents published from this affiliate. Furthermore, the University of California has nine documents, similar to the University of Oxford. A total of 8 documents are published from affiliates of Florida State University and the University of Padova, seven documents are published from affiliates of the University of Cambridge and the University of Munich, while six documents come from affiliates of Australian Catholic University, Dartmouth College, and Institut de Recerca Sant Joan de Deu.

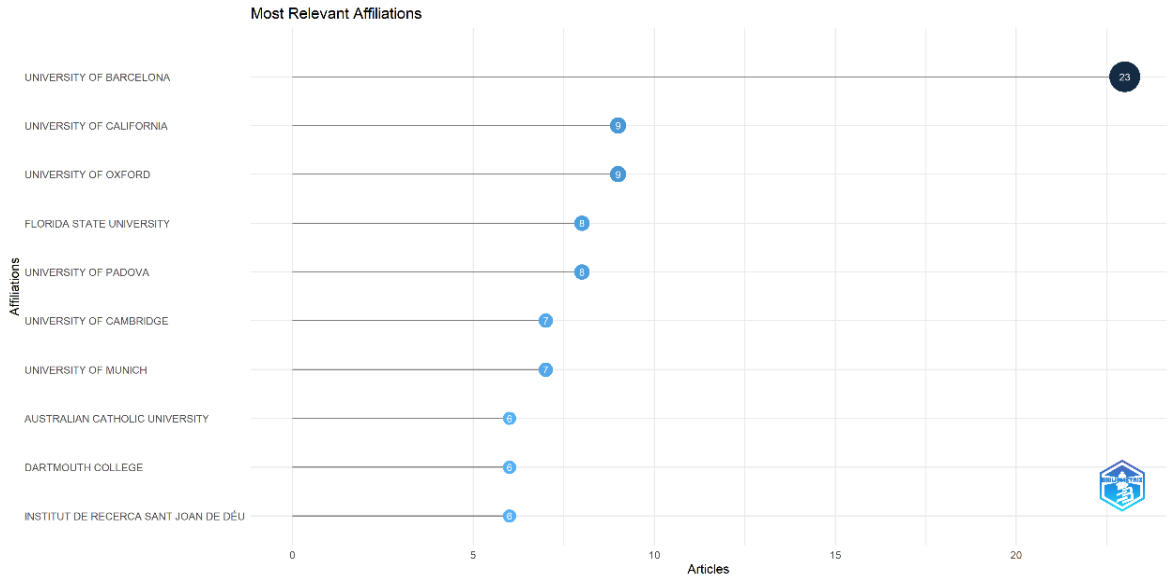

Figure 10. Most relevant affiliations

Figure 11 shows the production of the ten affiliates that published the most on mathematics anxiety from 2013 to 2023. The University of Barcelona, is the affiliate that published the most on this theme compared to other affiliates. In 2013, it published 1 article; in 2014, it had four documents, and every year, there were more and more publications coming out related to this theme (in 2019, there were 14 articles, and it continued to increase until 2023 when 23 articles were recorded). The University of California, it can be seen that in 2015 this affiliate published 1 article. It then annually increased until 2022, when there were 9 articles. However, in 2023, there were no publications related to this theme. The University of Oxford, had 2 articles in 2016, and every year the number of articles also increased until in 2023, when 9 published articles related to this theme were found. Next, the University of Padova showed that in 2017 it had 3 articles and annually increased up until 2023 with 8 articles recorded.

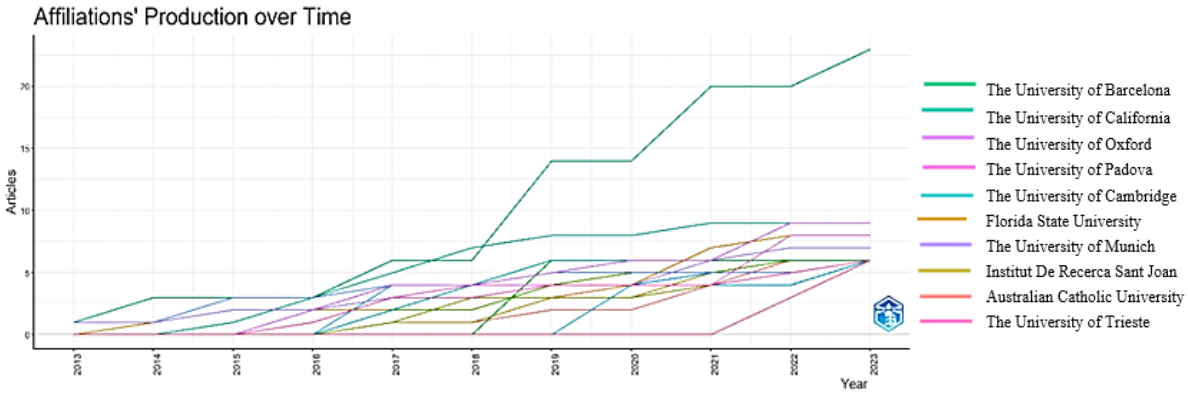

Figure 11. Affiliations' production over time

The University of Cambridge, in 2017, there were 2 articles related to the theme of mathematics anxiety, and every year it increased until 2020 with 6 documents recorded. Florida State University, in 2016, two articles were recorded, and each year it also increased until 2022 with 8 articles found. The University of Munich, in 2014, there was 1 article recorded, and this number continued to increase every year until, in 2023, there were seven articles published related to this theme. Institut De Recerca Sant Joan De Deu, in 2018, there was 1 article, and it always increased until 2022, with 6 articles published. Australian Catholic University, in 2018, there appeared to be 1 article, which then continued to increase yearly until 2022, with six articles. The University of Trieste, in 2016; there appeared to be 1 article related to this theme, and every year, there was an increase in publications until 2023, with 6 articles recorded.

3.2. Discussion

Bibliographic data from the Scopus database provides a general overview of mathematics anxiety research in the last ten years (2013–2023). The study of mathematics anxiety in the last ten years has experienced development and improvement. Based on Figure 2(a), it can be seen that the development of this research has increased every year in the number of publications, and this research is not only studied in the field of mathematics education but in other fields of science that are linked to mathematics anxiety as shown in Figure 2(b).

Based on network visualization as shown in Figure 3, this theme has connections with other themes. Research on this theme has been carried out by various researchers from various countries and affiliates, and they publish their research results in high-ranking Scopus journals such as Q1 and Q2. This research is interesting because this theme is a common problem among students from elementary school to university [42]–[44] and one factor that influences learning and mastery of mathematics is mathematics anxiety [45]–[48]. Research also shows that math anxiety affects not only students but also prospective teachers have an impact on anxiety [49].

This theme is one of the most relevant words with 93 occurrences and the theme of mathematics anxiety is seen as a high-demanded topic from 2013 to 2023. Based on Scopus data, 168 journals contribute to publishing the theme currently. The Frontiers in Psychology is the journal that publishes the most on this theme, with a total of 55,251 citations in the Q2 quartile and an SJR in 2022 of 0.89 as shown in Table 1. Based on Table 2, most journals are indexed in the Q1 and Q2 range, with one journal in the Q3 quartile.

974 authors have contributed to research and publications related to this theme. Garcia-Santillan is the author who has studied this theme the most, with a total of 10 publications and 143 total citations, followed by other authors as shown in Table 2. In the last ten years, research groups from the United States and Europe have collaboratively studied this theme. Countries that only carry out SCP include Turkey, Indonesia, and the Netherlands. Meanwhile, countries that carry out single-country and multiple-country publications are the United States, Spain, Germany, and the United Kingdom. The United States has conducted the most research and collaborative networks between countries on this theme, while Germany has been cited the most. Studies on mathematics anxiety have been conducted cross-culturally in European countries [50]. Furthermore, Foley *et al*. [51] state that countries with higher student math performance tend to have lower student math anxiety, though it should be noted that this varies across countries [52].

Based on data obtained from Scopus, 160 different affiliates published on the theme of mathematics anxiety. The University of Barcelona is the most relevant affiliate regarding this research theme with as many as 23 documents published from this affiliate. In 2013, this affiliate published 1 article and every year it published more and more publications related to this theme. In 2023, there were 23 articles recorded from this affiliate.

4. CONCLUSION

This study utilizes bibliographic data sourced from the Scopus database to ascertain the progression of publications on mathematics anxiety in mathematics education during the past decade. The main findings of this research are as follows: i) based on word analysis in the title, abstract, and keywords mathematics anxiety in mathematics education literature, it is stated that the theme of mathematics anxiety or math anxiety is the topic that has received the most research studies in the last ten years; ii) the Frontiers in Psychology is the journal that publishes the most on this theme, with a total of 55,251 citations in the Q2 quartile, and the SJR in 2022 is 0.89, and Garcia-Santillan is recorded as the author who has studied this theme the most with a total number of 10 publications with total citations of 143; iii) the United States is the country that has conducted the most research related to this and the collaborative network between countries. At the same time, Germany is the country that has been cited the most, and the University of Barcelona is the most relevant affiliate regarding this research theme. There are limitations to this research, in which only sources indexed in the Scopus database were used. The Biblioshiny program works in harmony with other databases, therefore

this program can be used in further research. This research only used "article" document type; new research can be carried out by selecting other, more diverse types of documents. Researchers can benefit from these studies by identifying key studies, prominent authors, or journals that use key concepts for their area of interest. They can publish their research in these journals.

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