

Knowledge Mapping of Math Anxiety: A Visual and Bibliometric Analysis

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Abstract: The purpose of this paper is to excavate and organize the developmental lineage and overall research framework in the field of mathematics anxiety research in China and other countries, to provide references for innovations and breakthroughs in mathematics anxiety, and then to promote the development of more effective interventions and educational strategies to assist individuals in overcoming mathematics anxiety, to enhance their mathematics learning. CiteSpace was used to analyze the mathematical anxiety literature in two databases, China Knowledge and Web of Science, in terms of the number of papers published, country/region distribution, topic knowledge mapping, and other dimensions, as well as to uncover the characteristics of mathematics research. The number of publications in the field as a whole is increasing, with the United States, the United Kingdom, and China dominating the field. In this sector, the United States occupies the central position and is the leader. "Mathematics Academic Achievement", "Mathematics Achievement", "Reliability", "Gender Differences", and "Higher Education" are the hottest research topics in this field. Mathematical anxiety remains a research hotspot in China and other nations, and scholars from all nations can collaborate with scholars and research teams from diverse cultures and backgrounds to expand the horizons of research, jointly advance research progress, and facilitate knowledge sharing and disciplinary growth.

Keywords: Mathematical Anxiety; Bibliometrics; Knowledge Graph; CiteSpace; VOSviewer.

1. Introduction

With the independence of mathematics from the traditional classification of natural sciences and the extensive application of mathematical ideas and methods in the study of humanities and social sciences, mathematics has become a quantitative and modeling link between natural sciences and social sciences (Huang Qin-an, 2001). Diverse academic disciplines are prospering as the world places a greater emphasis on education. Mathematics is one of the foundational subjects, and it has evolved into a scientific instrument that the majority of individuals wish to master. Nonetheless, the phenomenon of "math anxiety" has become prevalent in the learning process.

Mathematics anxiety is the negative emotional experience of tension and worry that people experience when solving mathematical problems and performing activities related to numbers in everyday life and academic settings (Richards and Suinn, 1972), accompanied by low self-confidence, fear of failure, and negative mental stereotypes about learning mathematics (Bandalos et al., 1995). This is a particular form of subject anxiety (Wang Feng-kui, LUO Zeng-ru, 2002).

The relationship between math anxiety and math performance has been the subject of most studies (Zhao Ji-chao et al., 2001). The "cognitive attention interference" model proposed by Mandler et al. has had a significant impact on the study of math anxiety (Mandler and Sarason, 1952), as it uses the important concept of "interference" to illustrate the relationship between anxiety and performance, i.e., the relationship between worry, some thoughts unrelated to the task, negative self-focus, low self-esteem, and other cognitions that can distract attention from the task and reduce the efficiency of the performance. The relationship between anxiety and performance is exemplified by the crucial concept of "interference," i.e., worry, task-irrelevant thinking, negative self-centeredness, low self-esteem, and other perceptions that distract from task learning and reduce the

efficiency of the activity, which can result in a decline in academic performance (Zhou Zhong-jin, 2013). On the other hand, anxiety hurts a person's working memory, cognitive strategies, and mental resources, which reduces the level of learning engagement (Pekrun et al., 2002). Using path analysis techniques, Pajares and Miller analyzed the effects of math anxiety, math self-efficacy, and math self-concept on the math performance of 350 college students in 1994. The study revealed a significant negative correlation between math anxiety and math achievement (Pajares and Miller, 1994), and this negative correlation was found in both Eastern and Western cultures (Ho et al., 2000), demonstrating its stable presence across cultures. However, researchers such as Skemp, who hold an anxiety arousal perspective, suggest that a certain level of math anxiety contributes to achievement, with a moderate level of anxiety arousal being optimal, and that math anxiety leads to a decline in achievement (Backhouse, 1986) once the appropriate threshold is exceeded. Moreover, according to the findings of some researchers, there is an interaction between math anxiety and math achievement, such that high math anxiety is associated with low math achievement, and low math achievement in turn leads to math anxiety (Omoniyi Israel and Peter Olubunmi, 2014; Huang Da-qing, 2006). Hsiu-Zu Ho et al. discovered that Chinese students with high math scores also experienced variable levels of math anxiety (Ho et al., 2000).

Byrd Pamala Gulley summarized three categories of math anxiety causes: personality-related, context-related, and related to the individual's past environment. Researchers in China and other countries have conducted extensive research on the causes of math anxiety. Individual triggers include mathematical confidence, the need for approbation, the need for successful experiences, and attitudes toward mathematics. Contextual causes include how mathematics is taught, the teacher's demeanor, classroom culture, school climate, test anxiety, and so forth. Contextual factors include socioeconomic status, parental factors, and socialization of

gender (Wang Feng-kui, LUO Zeng-ru, 2002). On the other hand, Norwood argues that math anxiety stems from parents' and teachers' negative attitudes toward math, low self-evaluations, and a one-sided approach to practicing math content that is not understood to address the problem (Gao Yongjin, 2009). Some Chinese researchers have also discovered that the teacher-student relationship negatively predicts students' learning anxiety (Liu Cai-xia, 2011), and that anxiety has a significant negative impact on math learning (ZHI Yang, 2014). However, a greater interest in acquiring mathematics can effectively reduce students' math anxiety (Wang Feng-kui, 2002). Both the teacher-student relationship and interest in mathematics learning can be influenced by self-efficacy; therefore, enhancing students' self-efficacy can further reduce their mathematics apprehension, which has a positive effect on their mathematics academic performance (He Sheng-qing, Qi Chun-xia, 2018).

There is currently no systematic and exhaustive compilation of the development history of mathematics anxiety research in China and other nations, nor is there a discussion of the similarities and differences between the research conducted in each nation. Therefore, in this paper, we will conduct a bibliometric analysis of 984 articles on mathematics anxiety from 2000 to the present using Citespace and VOSviewer, to determine the history of the development of the research on mathematics anxiety in each country, and then compare and analyze the characteristics of the research in each country to provide references for the future development of the research related to mathematics anxiety and puberty.

2. Materials and Methods

2.1. Data Collection

Chinese studies in this study refer to the Chinese literature from CNKI. The search was conducted with "math anxiety" as the focus, and all research papers published between 2000 and the present were selected; 232 studies were included. Foreign language literature from the Web of Science (WOS) primary database was utilized to cite international research. The subject query for the search was "Math anxiety" or "Mathematics anxiety" or "Anxiety in Mathematics" or "Anxiety in math" or "Anxiety in mathematics." From January 1, 2000 to July 17, 2023, 948 studies pertaining to the topic of "math anxiety" were selected and included.

2.2. Data Analysis

Prof. Chen Chaomei's JAVA-based information visualization software, CiteSpace, can display the research progress, research orientation, and development trend of a particular field as a dynamic map. It is the most commonly used bibliometric analysis software (Chen, 2006). Various algorithms can be applied to the co-citation and co-occurrence metrics analysis of the literature in order to identify the main nodes of the literature collection, the patterns exhibited during the distribution time period, and to present a visual graph (Hu Xiaoling, Yuan Min, 2023). Nees Jan van Eck and others developed VOSviewer. It is used primarily for bibliometric network graph analysis (van Eck and Waltman, 2010). It is a bibliometric analysis software for mapping scientific knowledge in various domains of knowledge based on the principles of co-citation and co-citation of literature (LI Jie, WEI Ruibi, 2022).

Through CiteSpace, this study examines keyword co-occurrence, theme clustering, and institutional co-occurrence of research on mathematical anxiety in each country. VOSviewer was utilized to visualize and analyze the collaborating institutions, co-authors, etc., in order to precisely present the development history of the research under the theme and to conduct an in-depth comparison of the research in each country.

3. Results

3.1. Publication Trends

Analyzing the number and trend of literature publications can facilitate a swifter comprehension of the evolution of relevant research in a given field. The annual publication volume of CNKI and WOS-related topics over the past two decades was compiled and represented using Excel graphs. The bar graph depicts CNKI's annual publication statistics, while the line graph depicts WOS's annual publication statistics. Figure 1 illustrates the yearly publication trends of CNKI and WOS literature since the turn of the 21st century.

Relevant studies in China can be categorized into three distinct periods: 2000-2004 was the start-up period, with a maximum of six articles per year, while the number of articles in 2000 and 2001 was one, and the average annual number of reports was only three; 2005-2011 was the stabilization period, with an average yearly number of nearly eleven articles. Except for a minor dip around 2006, the number of articles has been relatively stable; the period from 2012 to 2018 was unstable, with an annual average of 14 pieces, with 2016 and 2018 reaching a peak of 18 articles and 2013 having the lowest number of articles, with only 4. From 2019 to the present, the average number of articles published yearly is less than ten. Only four pieces were in this category in 2019 and sixteen in 2020, but the overall trend is still downward.

Relevant research in other nations can be divided into three time periods: 2000-2008, a period of establishment with an average of six publications per year; 2009-2021, a period of sustained growth with an increase in annual publications from 11 in 2009 to 141 in 2021; Since the sample was collected in the middle of 2023, it is anticipated that the annual number of publications will be marginally lower than in 2022.

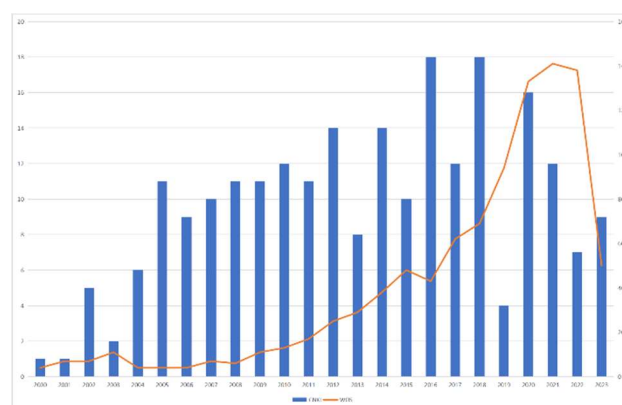


Fig. 1 The data for 2023 is not complete.

The rate of change in the quantity of publications differs from nation to nation. China quickly entered a seven-year stabilization phase after a start-up phase, an unstable phase since 2012, and a decline phase beginning in 2019. In contrast, other nations enter a period of sustained growth lasting thirteen years in 2021, following initial expansion. In the past

two decades, the global trend of research related to "math anxiety" has shown a continuous and rapid growth rate, indicating that researchers' focus on "math anxiety" has increased substantially. In contrast, published articles have decreased over the past two years.

3.2. Distribution of Journals

By analyzing the factors associated with publishing journals, it is possible to quickly identify the journals with the most influential research in the relevant field, thereby aiding

the reader in locating the source of high-quality articles and inferring, based on the types of journals included, the area on which the topic in question is centered. This study utilized an online bibliometric analysis platform to identify journals in mathematical anxiety with high publication volume and influence.

More than half of the top 10 English-language journals discovered through the search were located in Quarter 1, and the pertinent data is presented in Table 1. Frontiers in

Table 1. Top 10 national journals in terms of publications and corresponding IF (JCR 2020) and JCR quartile

Journal	Publications	IF(JCR2020)	JCR quartile
Frontiers in Psychology	77	3.8	Q1
Learning and Individual Differences	41	3.6	Q1
Contemporary Educational Psychology	24	10.3	Q1
Journal of Educational Psychology	19	4.9	Q1
Annals of The New York Academy of Sciences	18	5.2	Q1
Plos One	18	3.7	Q2
Psychological Reports	15	2.3	Q3
British Journal of Educational Psychology	14	3.7	Q1
Educational Psychology	13	3.2	Q2
Education Sciences	12	3	NA

Table 2. Top 10 national journals in terms of co-cited citations and the corresponding IF (JCR 2020) and JCR quartile

Co-Cited-Journal	Citations	IF(JCR2020)	JCR quartile
J Educ Psychol	1958	4.9	Q1
Front Psychol	1446	3.8	Q1
Learn Individ Differ	1424	3.6	Q1
J Res Math Educ	1227	2.8	Q2
Contemp Educ Psychol	936	10.3	Q1
Psychol Sci	853	8.2	Q1
Psychol Bull	704	22.4	Q1
J Couns Psychol	700	3.9	Q2
Child Dev	695	4.6	Q1
J Pers Soc Psychol	662	7.6	Q1

Psychology had the most articles, nearly one-third of the journal articles, and the second-most co-citations. Learning and Individual Differences and the Journal of Educational Psychology are also in the top four in terms of publications

and co-citations, indicating that these three journals are widely regarded as a hub for high-quality research in the field. In addition, the top 5 journals based on the number of pertinent articles are all located in Quarter 1. The British Journal of Educational Psychology has only 14 relevant articles. It is also situated in Quarter 1, making these six journals high-quality journals on "math anxiety." J Res Math Educ (Journal for Research in Mathematics Education) has the fourth-highest number of citations and is only in Q2.

However, it is still one of the most prestigious journals for research on "math anxiety."

Table 3 displays the top ten Chinese literature journals. Journal of Mathematics Education has nearly half of the journal articles. It ranks first regarding the number of articles and the compound impact factor, making it an essential journal for studying "math anxiety." Even though Research on Electrified Education has only published one piece, its compound impact factor ranks first, indicating that the journal continues to exert substantial influence on "math anxiety." According to the included periodicals, "math anxiety" is one of the hottest topics in psychology and mathematics education in China and abroad.

Table 3. Top 10 journals in Chinese literature and compound impact factor

Journal	Publications	Compound Impact Factor
Journal of Mathematics Education	36	5.294
Psychological Development and Education	9	4.803
Journal of Psychological Science	8	2.381
<u>Acta Psychologica Sinica</u>	5	3.57
Educational Science Research	5	2.533
Advances in Psychological Science	3	3.316
Chinese Journal of Clinical Psychology	2	3.113
Journal of Southwest University	2	1.961
China Journal of Health Psychology	2	2.05
e-Education Research	1	7.02

Table 4. Top 10 institutions in terms of number of articles issued

WOS Institution	Publications	CNKI Institution	Publications
Univ Chicago (USA)	36	Beijing Normal University	26
Beijing Normal Univ (China)	22	Shandong Normal University	18
Univ Barcelona (Spain)	21	Southwest University	7
Univ Cambridge (UK)	18	<u>Qiannan Normal College for Nationalities</u>	6
Univ Oxford (UK)	17	Shanghai Normal University	5
Univ Padua (Italy)	16	South China Normal University	4
Univ <u>Tubingen</u> (Geman)	16	<u>Shenzhen University</u>	4
Univ Haifa (Palestine)	15	Guangdong AIB Polytechnic College	3
Univ Ottawa (Canada)	14	East China Normal University	3
Florida State Univ (USA)	13	Hebei University	3

3.3. Country/region and Institution Contributions

We can reflect the strength pattern, resource allocation, and scientific cooperation in related research disciplines by examining and analyzing the current status of issuing institutions and their corresponding countries. Citespace was used to analyze the co-occurrence of institutions and governments. Tables 4 and 5 display the top ten institutions and countries in terms of the number of articles published.

As shown in Table 4, these research institutions include many of the world's most prestigious universities, including Cambridge University, Oxford University, the University of Chicago, and Harvard University. This also suggests that research in mathematical anxiety has garnered the interest of scholars from numerous prestigious universities. The University of Chicago has the most foreign language publications, with 36 papers published. Its featured disciplines are sociology and mathematics and relevant research (Beilock et al., 2010; Maloney et al., 2015). Concentrates on the influence of teachers and parents on students' math anxiety. Beijing Normal University and the University of Barcelona came in second and third place, respectively, with the second and third highest number of papers. In addition, there is a slight variation in the number of articles posted by institutions from various nations.

Teachers training colleges and universities in China are primarily responsible for mathematics anxiety research. Beijing Normal University (BNU) has an advantage in the number of publications in both Chinese and foreign languages,

indicating that it enjoys a high level of research

power and disciplinary contribution and is a leader in math anxiety research. Beijing Normal University's research results are primarily focused on two themes, cognition of math anxiety and analysis of math anxiety, such as investigating the mechanism of math anxiety and other factors on math performance (He Sheng-qing, Qi Chun-xia, 2018), the relationship between math anxiety and math learning engagement (HONG Wei et al., 2018) and the cognitive orientation of math anxiety research (Chen Yinghe, Geng Liuna, 2002). It was one of the first institutions in China to conduct research on the status of mathematics anxiety among students at different stages (Gao Yongjin et al., 2009; Huang Da-qing et al., 2008), and is among the earliest institutions in China to conduct relevant research. Second, Shandong Normal University is also one of the leading institutions in mathematics anxiety; consequently,

most relevant studies in China are conducted at Beijing Normal University and Shandong Normal University. In contrast, other institutions have published fewer papers that are of the same caliber.

As shown in Table 5, the United States accounts for approximately 42% of the total literature, significantly more than any other nation, and two organizations rank among the top ten in terms of the number of publications. It is possible

to say that the United States' contribution to mathematical anxiety is substantially more significant than that of other nations and that it is the leader in this research field, occupying the position of mainstream discourse. The United Kingdom, China, and Germany follow.

Table 5. WOS Top 10 countries/regions in terms of number of publication

Rank	Countries	Documents
1	USA	377
2	England	96
3	China	73
4	Germany	71
5	Turkey	58
6	Spain	54
7	Canada	52
8	Australia	48
9	Italy	45
10	Mexico	24

In this study, a clustering graph of cooperative institutions is created for analysis using VOSviewer. The larger the area of nodes in the chart, the greater the number of articles published, and the connecting line represents the cooperation between institutions. As depicted in Figure 2, there are strong ties between the relevant United States organizations. In addition, the global research on "math anxiety" is not entirely independent, and there are international institutions that collaborate. For instance, the University of Chicago in the United States and the University of Tübingen in Germany collaborate effectively with other institutions. Specifically, the University of Tübingen and the University of Salzburg in Austria conducted an interdisciplinary study in medicine and psychology that demonstrated that similar to different types of anxiety, math anxiety also affects the deactivation of the default mode network (DMN) during math tasks (Pletzer et al., 2015), resulting in a decrease in processing efficiency. In addition, institutions with a more significant number of publications collaborate more closely than those with a lower number of publications.

3.4. Authors and Cocited Authors

One of the most significant indicators of a researcher's contribution to a particular research field is the number of publications and citations. A group of researchers who are the most influential in a specific related field can be identified rapidly through a statistical analysis of the authors of the literature. Cluster analysis of co-authors can identify the research group that investigates a related crucial point and the field's most prominent scholars and core research team. In this study, we utilized VOSviewer to conduct a cluster analysis of co-cited authors by connecting the two sides of co-cited authors with a line; the more significant the node area, the greater the number of citations. The denser the connecting cable is in the VOSviewer co-cited authors clustering analysis, the closer the cooperation of the research group, and the larger the node area, the greater the number of publications within

the group.

As shown in Table 6, six of the top ten authors in co-citation have more than 400 citations, with Ashcraft, Mh having the maximum number of sources with 1269. This demonstrates that Ashcraft Mh's research has a significant academic impact on "math anxiety," particularly in the study on working memory, math anxiety, and math performance, which has made significant contributions (Ashcraft and Kirk, 2001; Ashcraft and Krause, 2007) and is widely acknowledged by academic peers. Maloney, Ea, and Hembree, R are also well-known as leading authors in this discipline. In addition, Ma, X, the only scholar in China to rank among the top ten, identified a causal relationship between math apprehension and math performance (Ma and Xu, 2004). China's Ma X is one of the most influential researchers in his field on an international scale.

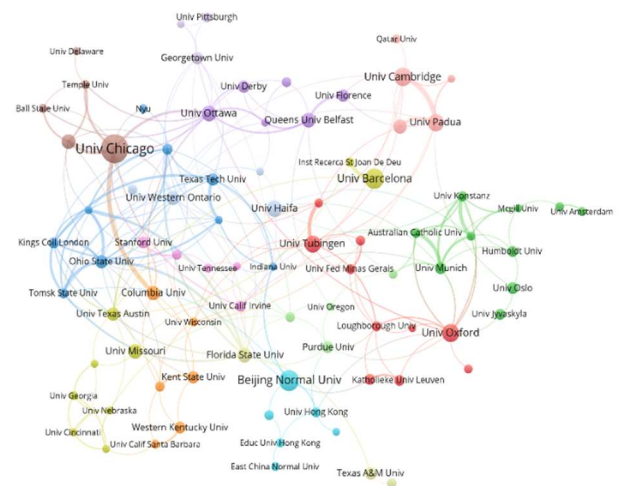


Fig. 2 Clustering of cooperative organizations

Table 6. WOS Top 10 authors in terms of the frequency of co-citations.

Author	co-citations
Ashcraft, Mh	1269
Maloney, Ea	538
Hembree, R	509
Ramirez, G	495
Beilock, Sl	479
Ma, X	446
Pekrun, R	375
Hopko, Dr	364
Richardson, Fc	349
Marsh, Hw	346

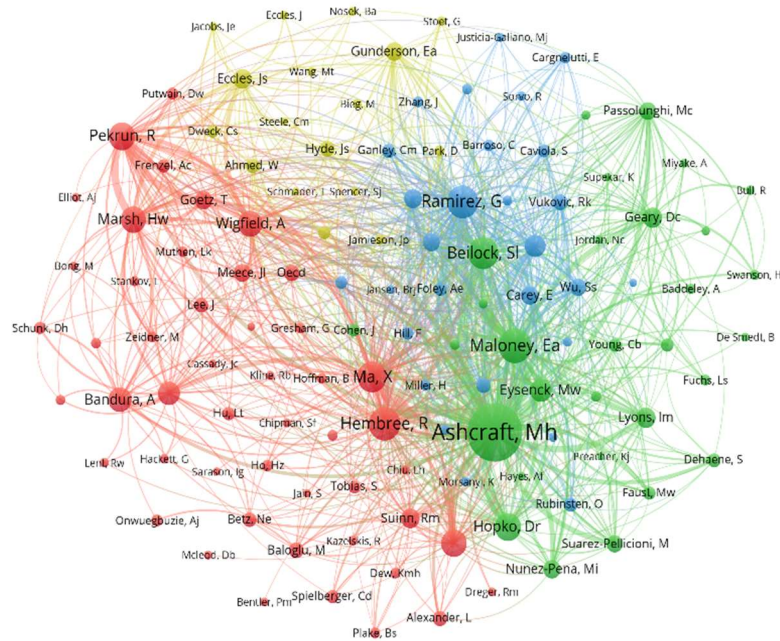


Fig. 3 WOS literature co-cited authors cluster analysis

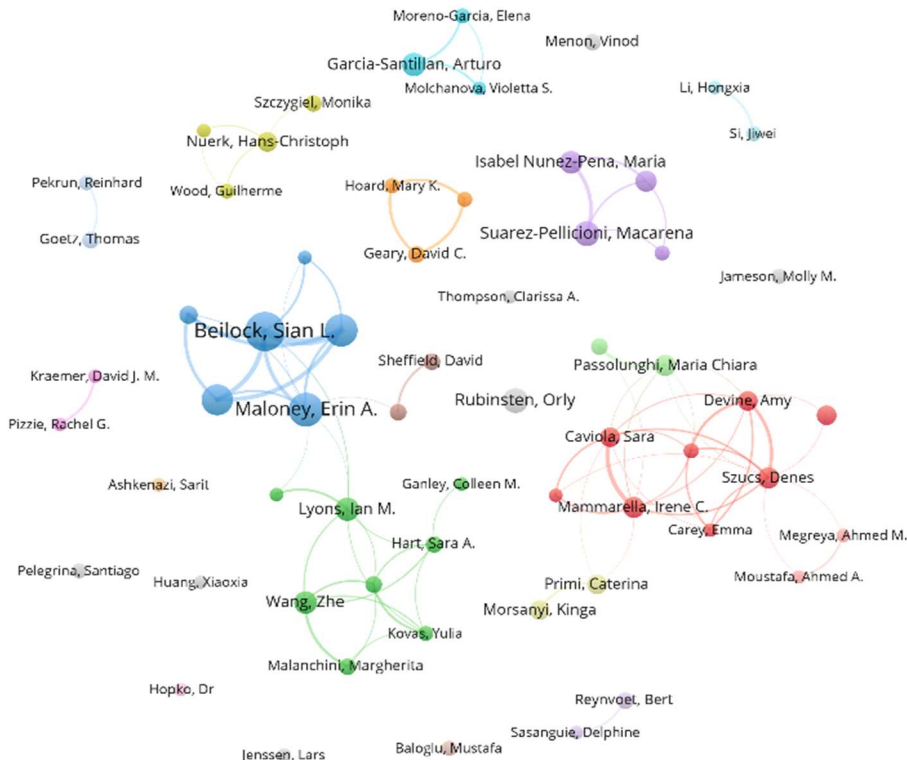


Fig. 4 WOS co-author cluster diagram

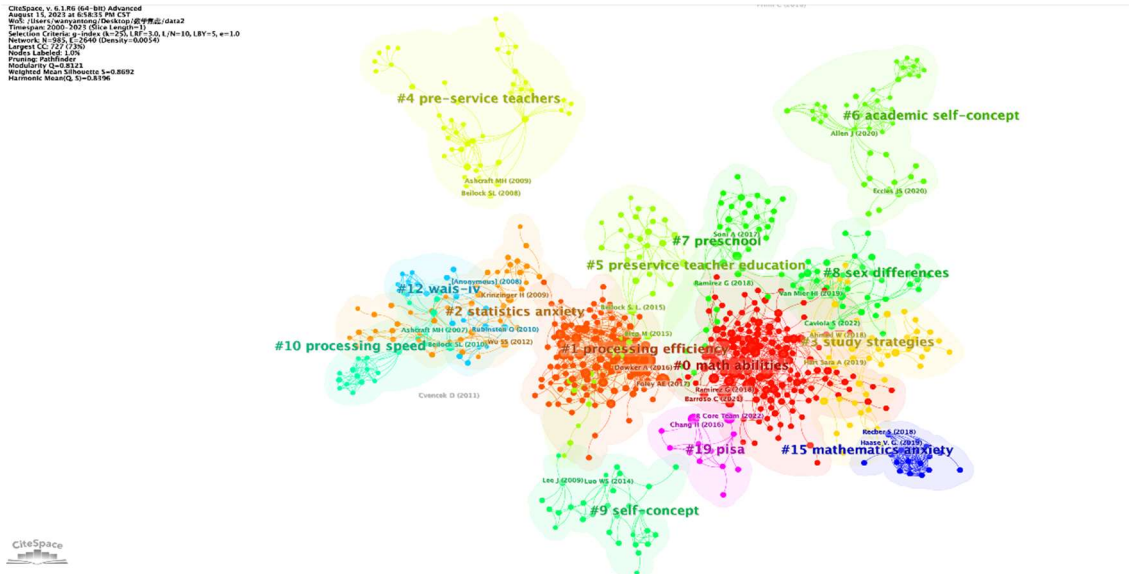
Based on the authors' collaboration proximity, VOSviewer was used to divide this study into four primary network blocks of varying colors (Figure 3). The scholarly collaboration in this field is more concentrated, forming extremely close and extensive ties. The network with authors such as Ashcraft, Mh, Ma, X, and Hembree, R as the relative center is the largest and most active, indicating that their collaboration with other authors is the largest and most active. In contrast, authors in the yellow network region, such as Wang, Mt et al. (Wang, 2012), who conducted a longitudinal examination of the links between math education and career interests and classroom environments, motivational beliefs, etc., collaborated with authors from other network regions to a lesser extent.

Si Jiwei, Zhao Xiaomei, and Xu Yanli from Shandong Normal University comprise the largest team of authors in Chinese literature, as depicted in Figure 5. The team investigated the relationship between parental education, elementary school children, and "math anxiety." It confirmed the differential role of parental involvement in the development of children's math anxiety (SI Jiwei et al., 2022). As depicted in Figure 4, the largest social network is the one led by Beilock, Sian L., and Maloney, Erin A. at the University of Chicago, which has contributed significantly to elucidating math anxiety's causes and preventive measures (Maloney, 2012). This is followed by the social network created by Wang Zhe of Virginia Tech, Ian Lyons et al. of the

University of Chicago, Mammarella, Irene C of the University of Padua, and Denes Szucs et al. of Cambridge. The other academic groups have fewer publications and fewer author connections. By comparing Figures 4 and 5, it is easy to determine that the number of independent researchers in China is significantly greater than in other countries and that the cooperation and communication among scholars in China is far less extensive and intimate than in other countries.

3.5. Highly Cited Reference Analysis

Citespace was utilized to analyze the mapping of reference clustering for foreign language literature. The clustering outcomes are depicted in Figure 6. The entire graph accumulates literature published from 2000 to 2023, with 985 nodes and 2640 connecting lines, Q value=0.8121>0.3, S value=0.8692>0.7, indicating that this clustering structure is significant. The results are trustworthy (Chen et al., 2010).



Top 25 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2000 - 2023
Beilock SL, 2010, P NATL ACAD SCI USA, V107, P1860, DOI 10.1073/pnas.0910967107, DOI	2010	13.92	2010	2015	█
Ashcraft MH, 2009, J PSYCHOEDUC ASSESS, V27, P197, DOI 10.1177/0734282908330580, DOI	2009	11.04	2010	2014	█
Maloney EA, 2011, Q J EXP PSYCHOL, V64, P10, DOI 10.1080/17470218.2010.533278, DOI	2011	15.98	2012	2016	█
Maloney EA, 2010, COGNITION, V114, P293, DOI 10.1016/j.cognition.2009.09.013, DOI	2010	13.04	2012	2015	█
Young CB, 2012, PSYCHOL SCI, V23, P492, DOI 10.1177/0956797611429134, DOI	2012	19.87	2013	2017	█
Vukovic RK, 2013, CONTEMP EDUC PSYCHOL, V38, P1, DOI 10.1016/j.cedpsych.2012.09.001, DOI	2013	14.03	2013	2018	█
Ramirez G, 2013, J COGN DEV, V14, P187, DOI 10.1080/15248372.2012.664593, DOI	2013	26.35	2014	2018	█
Devine A, 2012, BEHAV BRAIN FUNCT, V8, P0, DOI 10.1186/1744-9081-8-33, DOI	2012	19.34	2014	2017	█
Maloney EA, 2012, TRENDS COGN SCI, V16, P404, DOI 10.1016/j.tics.2012.06.008, DOI	2012	19.34	2014	2017	█
Lyons IM, 2012, CEREB CORTEX, V22, P2102, DOI 10.1093/cercor/bhr289, DOI	2012	15.25	2014	2017	█
Lyons IM, 2012, PLOS ONE, V7, P0, DOI 10.1371/journal.pone.0048076, DOI	2012	13.72	2014	2017	█
Goetz T, 2013, PSYCHOL SCI, V24, P2079, DOI 10.1177/0956797613486989, DOI	2013	12.66	2014	2018	█
Wu SS, 2012, FRONT PSYCHOL, V3, P0, DOI 10.3389/fpsyg.2012.00162, DOI	2012	10.66	2014	2017	█
Wang Z, 2014, J CHILD PSYCHOL PSYC, V55, P1056, DOI 10.1111/jcpp.12224, DOI	2014	12.72	2015	2019	█
Park D, 2014, J EXP PSYCHOL-APPL, V20, P103, DOI 10.1037/xap0000013, DOI	2014	12.32	2015	2019	█
Maloney EA, 2015, PSYCHOL SCI, V26, P1480, DOI 10.1177/0956797615592630, DOI	2015	13.01	2016	2020	█
Carey E, 2016, FRONT PSYCHOL, V6, P0, DOI 10.3389/fpsyg.2015.01987, DOI	2016	14.92	2017	2021	█
Ramirez G, 2016, J EXP CHILD PSYCHOL, V141, P83, DOI 10.1016/j.jecp.2015.07.014, DOI	2016	14.21	2017	2021	█
Beilock S. L., 2015, POL INS BEH BRAIN SC, V0, PP4, DOI 10.1177/2372732215601438, DOI	2015	11.24	2017	2020	█
Dowker A, 2016, FRONT PSYCHOL, V7, P0, DOI 10.3389/fpsyg.2016.00508, DOI	2016	26.67	2018	2021	█
Hill F, 2016, LEARN INDIVID DIFFER, V48, P45, DOI 10.1016/j.lindif.2016.02.006, DOI	2016	13.67	2018	2021	█
Suarez-Pellicioni M, 2016, COGN AFFECT BEHAV NE, V16, P3, DOI 10.3758/s13415-015-0370-7, DOI	2016	10.72	2018	2020	█
Ramirez G, 2018, EDUC PSYCHOL-US, V53, P145, DOI 10.1080/00461520.2018.1447384, DOI	2018	16.87	2020	2023	█
Namkung JM, 2019, REV EDUC RES, V89, P459, DOI 10.3102/0034654319843494, DOI	2019	13.34	2020	2023	█
Zhang J, 2019, FRONT PSYCHOL, V10, P0, DOI 10.3389/fpsyg.2019.01613, DOI	2019	18.92	2021	2023	█

Fig. 5 A prominent figure in the cited literature

Based on the cluster location analysis, the 19 research clusters can be divided into two distinct categories. It is the cluster characterized by a close relationship between inheritance and derivation. It is also the primary focus of "math anxiety" research. This category includes clusters of keywords such as #0 (mathematical skills), #1 (processing efficiency), #3 (study strategies), #7 (preschool), #8 (gender disparities), and #15 (mathematics anxiety). This cluster addresses the relationship between students' education, capacities, and arithmetic anxiety.

This group consists of keywords such as #10 processing speed, #12 wais-iv, #6 academic self-concept, and #19 pisa, which are relatively independent of the main study but contain a certain quantity of research. For instance, Lambert K. et al. demonstrated that number-processing speed and

visuospatial ability had a much more significant influence on math performance than IQ (Lambert and Spinath, 2018). In contrast, Stoet G. et al. found that gender differences in math and reading scores were inversely proportional (Stoet and Geary, 2013).

Literature emergence maps can illustrate changes in research locations over time to identify possible trends and cutting-edge research. The articles with the highest citation burst strength are "Math Anxiety, Working Memory, and Math Achievement in Early Elementary School" (Ramirez et al., 2013) (strength=26.35) by Ramirez G and "Mathematics Anxiety: What Have We Learned in 60 Years?" by Dowker A (strength=26.67) published in 2016 (Dowker et al., 2016). This indicates that the topics were at the forefront of researchers' minds and were widely known during their

respective periods.

This indicates that the topics were at the forefront of researchers' minds and were widely known during their respective periods. "Female teachers' math anxiety affects girls' math achievement" by Beilock, SL (Beilock et al., 2010) and "The language of mathematics: examining the impact of language on children's mathematical development" by Vukovic, RK in 2013 (Vukovic and Lesaux, 2013) both spanned 15 years in terms of the duration of their emergence. This indicates that the literature mentioned above has been the research focus for an extended period and has laid the foundation for the field's long-term growth.

3.6. Keyword Analysis

Keywords are highly refined and generalized expressions of research papers, which are the external manifestation of research themes; analyzing keywords facilitates the rapid comprehension of papers' central ideas and research themes (Sun Jiajia, Li Yajing, 2022). The frequency of keywords in a particular research field correlates closely with its level of interest. By analyzing the keywords of a specific area, it is possible to comprehend the research hotspots of the field, as well as to evaluate the updating speed of the field's research content and the vitality of disciplinary research (Ouyang et al., 2018). By accumulating keywords from CNKI and WOS, tabulating them, and analyzing them with VOSviewer clustering, we can visualize the major research themes in "math anxiety."

According to the word frequency and clustering maps of keywords in Table 7 and Figure 8, the core keywords of international research on math anxiety include "math anxiety," "mathematics," "anxiety," and "working memory," among others, with "math anxiety" being the most researched. The majority of research on math anxiety focuses on working memory (Ashcraft and Kirk, 2001), gender disparities

(Beilock et al., 2010; Devine et al., 2012), and self-efficacy (Pajares and Graham, 1999). However, keywords such as "numeracy" appeared less frequently, which may be attributable to the pedagogical emphasis of the mathematics curriculum in countries such as the United Kingdom and the United States, considering each country's cultural context. The National Council of Teachers of Mathematics (NCTM) encourages the use of calculators by students at all times and levels. Teachers should also become more proficient in "using and helping students use technology and other tools for mathematical investigations" (Tarr et al., 2000). In countries such as the United Kingdom and the United States, the emphasis is placed more on the comprehension and application of mathematical concepts than on pure computational skills; consequently, less emphasis is placed on critical terms such as numeracy in mathematical anxiety.

As shown in Table 8 and Figure 9, Chinese studies have paid less attention to the associations between gender, working memory, and math anxiety, and the corresponding search terms do not appear frequently. On the other hand, there is a significant amount of interest in the fields of math performance and math learning, which concentrates primarily on the keywords "math anxiety," "math performance," and "math learning." The perception of math anxiety (Chen Yinghe, Geng Liuna, 2002), math learning at various phases of development, and math achievement (HONG Wei et al., 2018; LUO Run-sheng et al., 2006) received more attention. Tian Bao et al., for instance, elaborated that test anxiety influences test performance through the mediating variable of test self-efficacy and suggested that test self-efficacy directly affects test performance and is a mediating variable of test anxiety influencing test performance (Tian Bao, Guo Dejun, 2004). In addition, keywords such as "motivation," "responses," and "accomplishments" play a significant role in bridging the divide between different subfields.

Table 7. Top 20 keywords in terms of frequency of occurrence (WOS)

Rank	Keyword	Occurrences	Rank	Keyword	Occurrences
1	math anxiety	457	11	adolescence	22
2	mathematics achievement	134	12	motivation	21
3	mathematics	94	13	arithmetic	20
4	anxiety	88	14	mathematics self-efficacy	20
5	working memory	60	15	academic achievement	19
6	self-efficacy	49	16	math attitudes	19
7	gender	41	17	self-concept	19
8	mathematics education	31	18	stem	19
9	gender differences	28	19	children	17
10	test anxiety	27	20	numeracy	17

Table 8. Top 20 keywords in terms of frequency of occurrence (CNKI)

Rank	Keyword	Occurrences	Rank	Keyword	Occurrences
1	math anxiety	146	11	countermeasures	7
2	math achievement	28	12	influencing factors	7
3	math learning	22	13	high school students	7
4	anxiety	19	14	academic achievement	6
5	math self-efficacy	14	15	learning motivation	6
6	math	13	16	children	5
7	advanced math	10	17	working memory	5
8	junior high school students	9	18	causes	5
9	learning anxiety	8	19	math teaching	5
10	middle school students	7	20	math self-concept	5

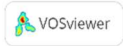
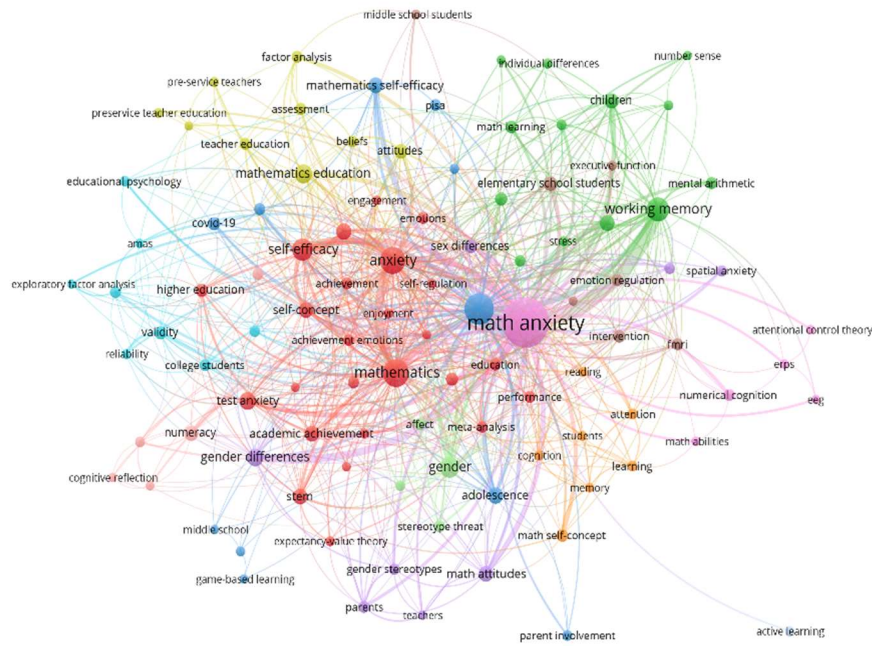


Fig. 6 Vosviewer foreign literature keyword clustering atlas

3.7. Research Hotspots and Frontiers

Based on a clustering analysis of keywords, this study displays the most prominent keywords in various years and colors using VOSviewer. The magnitude of the node

represents the frequency with which the keyword appears. In contrast, the color of the node indicates distinct periods of occurrence. The evolution of the research focus over time is demonstrated plainly.

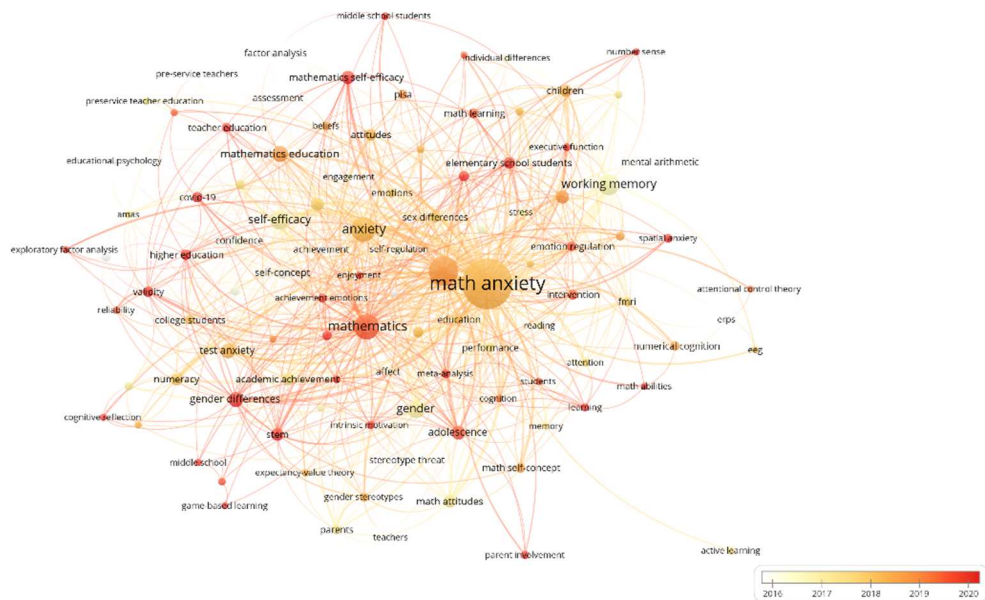


Fig. 7 The change of key words in overseas research

4. Discussion

4.1. General Information

Mathematics is fundamental to the fields of science, engineering, and technology. It provides the primary instruments for logical reasoning and problem-solving, laying a solid foundation for developing and applying other disciplines. Mathematics is indispensable for the support and application of the natural sciences, social sciences,

engineering, and technology. Moreover, mathematics anxiety is prevalent among students (Baloglu and Koçak, 2006; Ma and Xu, 2004; Rodarte-Luna and Sherry, 2008; XIONG Jianhua, 2008), which dampens their enthusiasm for learning mathematics and causes them to avoid math-related courses (Birgin et al., 2010).

Since Richardson and Suinn conducted a groundbreaking study on math anxiety in 1972 and defined it as "a feeling of tension and anxiety that impedes number manipulation and mathematical problem-solving in a wide range of everyday

life and academic situations" (Richards and Suinn, 1972), several studies have been conducted on the subject. As a popular topic in psychology, math anxiety has garnered considerable international attention. The study of mathematics anxiety has significant practical significance, scholarly value, and positive effects on individuals and society.

Citespace and VOSviewer were used to conduct an econometric analysis of "math anxiety" from 2000 to the present. Keywords, institutional authors, and published mathematics anxiety literature were analyzed to determine the current status of research, research centers, and field development trends.

4.2. Analysis of Current Status

As depicted in Figure 1, worldwide research on "math anxiety" has exhibited a sustained and rapid increase over the past two decades, indicating that researchers' focus on the topic has increased substantially. In contrast, published articles have decreased over the past two years. The relative decline in the number of studies on "math anxiety" in China over the past two years may be attributable to new policies. The Opinions on Further Reducing the Burden of Homework for Students in Compulsory Education and the Burden of Out-of-School Training were published by China in 2021. This is the first time China has issued a specific policy on reducing the burden, and the development of fundamental education in China has entered the "post-load-reducing era" (FAN Yong-feng, 2021). Students have been deprived of the average growth of time and space for a long time due to the double pressure of homework and off-campus training. This policy can, to some extent, promote the healthy development of the social order of education and alleviate students' academic severe anxiety (MA Kai-jian et al., 2021). In contrast, since the 2019 outbreak of the new coronavirus, China and other countries have become more concerned about the epidemic's impact on academic anxiety (Alemany-Arrebola et al., 2020; Barbosa-Camacho et al., 2022; WANG Qiuyun et al., 2022). In the context of ever-changing times, the staged differences in the quantity of published research literature across nations reflect the shift in research fervor and content induced by constant changes in current events and politics, social culture, and educational ideas.

4.3. Limitation

China began its primary body of research comparatively late, and its research system still needs to mature, with more significant fluctuations in steady development than other nations. As the influence of math anxiety in education and psychology has gradually grown, more and more countries, institutions, authors, etc., have become involved in this field, with the United States, which is located in the middle of the area, conducting the most research, followed by the United Kingdom and China. The University of Chicago ranks first among WOS-related institutions with 36 publications. In comparison, Beijing Normal University ranks first among CNKI-related institutions with 22 and 26 publications, respectively. In addition, teacher training universities conduct most research on mathematical anxiety in China, but there is less cooperation between institutions.

On the other hand, the relevant institutions in the United States collaborate more closely and have established cooperative solid relationships. This suggests that the level of collaboration between Chinese academicians is significantly

lower than that of international. In China, a lack of academic cooperation can lead to limited sharing of knowledge and resources between research institutions, resulting in relative isolation of different research disciplines and a lack of interdisciplinary collaboration and exchange. In addition, it inhibits the genesis of innovation and new ideas, which impedes the advancement of academic research. Therefore, it is essential to actively promote academic cooperation and strengthen inter-institutional educational exchanges to advance the mathematical anxiety research field.

4.4. Research Hotspots and Frontiers

In terms of trending topics, new and diverse research on related issues is emerging. Internationally, there is a renewed emphasis on "gender differences," "self-efficacy," and "education." The interaction between arithmetic anxiety and sociocultural factors is given more consideration. Emerging research interest in mathematics anxiety in China focuses on "mathematics academic performance," "mathematics achievement," and "reliability." In recent decades, women's participation in science, technology, engineering, and mathematics (STEM) disciplines has been relatively low. This has resulted in a pervasive gender stereotype that math and science are male domains in which women are not competent or interested, at least compared to men. Men are perceived to be more likely to participate and excel in math and science (Nosek et al., 2002). To address this issue, governments, educational institutions, and research organizations have begun to prioritize gender equality and have made endeavors to encourage women to pursue careers in STEM. Several nations have created special scholarship and award mechanisms to encourage women to study and conduct research in mathematics. For instance, the German MINT Ph.D. fellowship program (Ph.D. fellowship program) establishes a funding program for female doctoral candidates in MINT (mathematics, information, natural sciences, and technology) disciplines and the UK Women in STEM Leadership Scholarship. This demonstrates the international emphasis on gender differences in mathematics. These incentives, which aim to break down gender barriers in mathematics, increase women's participation and achievement in mathematics, and promote gender equality and diversity, are of inspirational value for the alleviation of mathematical anxiety and may, therefore, serve as an emerging trend in the field of mathematical anxiety research. In a broader sense, the issue of gender equality in science is about the embodiment of universal values and ideas, such as upholding human rights, opposing discrimination, and equal treatment, within science (Gong Xu, 2010).

In contrast, China's interest in this field still needs to be improved. International research hotspots typically reflect the academic community's frontiers and trends. In gender differences, self-efficacy, and education, Chinese academics can collaborate with academics and research teams from other cultures and backgrounds. This will broaden the research scope, facilitate research advancement, and facilitate knowledge sharing and the growth of the discipline.

5. Conclusion

Mental health awareness and mental health literacy of the entire population are receiving more and more attention. The mental health level of students has been emphasized as the foundation for enhancing the mental health of the whole population (Pang Hongwei, 2023). There is a close

relationship between math anxiety and mental health issues, and prolonged anxiety can contribute to developing other psychological problems, such as depression and additional anxiety disorders. Therefore, enhancing further research and collaboration on math anxiety will aid in gaining a deeper understanding of the nature and mechanisms of math anxiety, as well as the current state of research in this field in various countries and the future trajectory of development. In addition to developing more effective interventions and educational strategies to assist individuals in overcoming math anxiety, this study will provide essential lessons for promoting the learning and development of mathematics among individuals.

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