Measurement Analysis and Evaluation of Twenty-Five Years of Chinese Mathematics Textbooks: Visual Analysis Based on CiteSpace Knowledge Graph (1999–2024)

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Abstract: At present, textbooks based on core literacy have become the inevitable demands of China's curriculum reform, and the literacy of textbook goal construction is the key to the implementation of core literacy requirements, which is a huge challenge for textbook compilers. In this paper, we use the visual metrology of the CiteSpace knowledge graph to analyze Chinese mathematics textbooks (1999–2024), hoping to guide the future direction of Chinese mathematics textbook research.

Keyword: Visualization; Mathematics textbooks; Future outlook; Keywords clustering; Time zone

1. Introduction

Education is the foundation of social modernization construction and a key representation of a comprehensive national strength. Education plays a crucial role in facing challenges [1]. Mathematics education is an important part of the modern school education system, and mathematics textbooks have become important reading materials for personal mathematics enlightenment and the main carrier for mastering mathematics. In recent years, the research of mathematics textbooks has attracted more and more attention in the international mathematics education community. "Diving into strengthening basic science research and giving more tilt to key basic disciplines such as mathematics and physics" [2]. Since the beginning of the new century, evidence-based textbook research has attracted the attention of scholars at home and abroad, but the path and method of how to construct high-quality mathematics textbooks through evidence-based research are not clear. "As an important foundation for all sciences, mathematical sciences have played a key, even decisive role in many important fields" [3]. The content of 21st-century learning has to always adapt to any changes that might happen in the industrial era [4]. In this paper, the visual econometric analysis of the CiteSpace knowledge graph is used to analyze the research of mathematics textbooks in China from 1999 to 2024. According to the results of the

map, the inter-annual changes of the authors' institutions and authors, as well as the number of publications, were analyzed. It shows the latest theoretical achievements and practical experience of domestic mathematics textbook research and brings thoughts to Chinese mathematics educators.

2. Methods

CiteSpace visual quantitative analysis is a widely used research tool in the field of bibliometrics. It can quantitatively analyze the literature collections of specific topics and form a basic understanding of the development status, hot spot evolution, and future trends of this research field with the help of a visual knowledge map. In this paper, CiteSpace software version 6.3.R1 and the database CSSCI (China Social Science Index), which is highly recognized by China National Knowledge Infrastructure (CNKI), were selected as the literature retrieval source, and the retrieval logic of "theme = mathematics textbook" was adopted to eliminate invalid information such as meeting push, column introduction, news announcement, periodical catalog, and new book recommendation. Finally, a total of 335 journal articles were obtained.

3. Results

3.1. The annual trend of issuing documents

The interannual change in the number of published articles can reflect the research enthusiasm of a specific topic at a specific time, and show the development direction of the research topic as a whole. According to the annual statistics of periodical papers in the CNKI database, the annual statistical table of published papers on the research of mathematics textbooks in China is shown in **Figure 1**. Based on the figure, the overall research results of mathematics textbooks in China showed a fluctuating trend, and the annual published papers reached a peak in 2015.
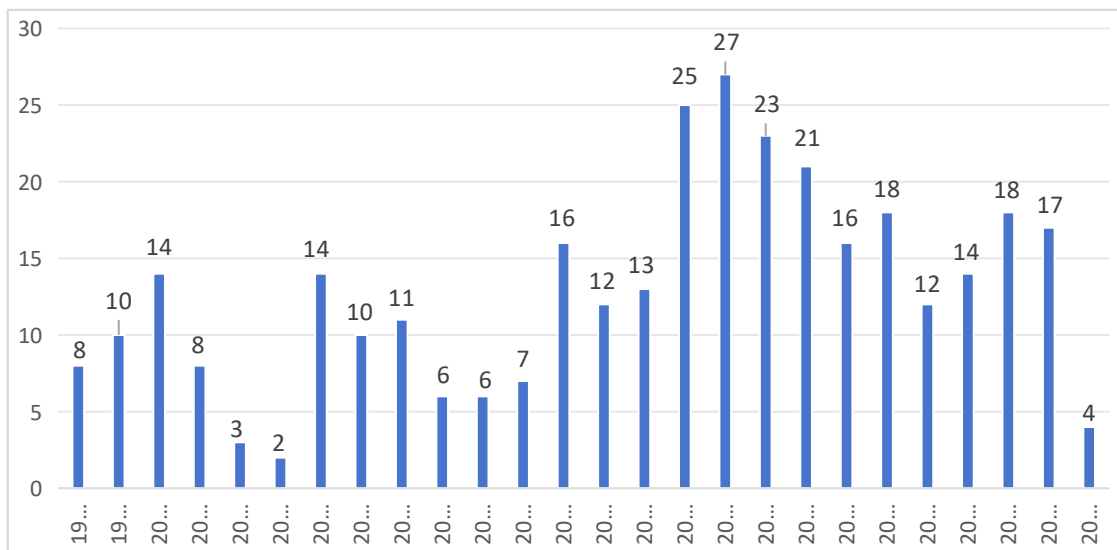

Figure 1. Number of papers published

3.2. The distribution of research power

3.2.1. Analysis of research institutions and their groups

From the perspective of subject construction, the evaluation of the development of a subject in a school can be analyzed by studying two variables: the number of papers published and the subject evaluation carried out by

the Ministry of Education. On the one hand, the number of articles published by the institution directly reflects the research contribution of the institution in the field of educational sociology. On the other hand, the subject evaluation reflects the research and education quality of this institution. Therefore, the combination of quantity and quality can completely reflect the main research institutions in the field of educational sociology in China. What authoritative institutions and core units exist in the research of mathematics textbooks in China? In order to make accurate statistics, this paper adopted Price's law to count the research results published in the core institutions, and the corresponding formulas are as follows: $N \approx 0.749 \times \sqrt{N_{max}}$, where the letter N means the minimum number of papers published by the core author unit, while N_{max} means the number of papers published by the author unit with the highest output.

According to the statistics of HowNet, there were 297 institutions that participated in the research of mathematics textbooks in China from 1999 to 2024, among which 13 articles were published by the School of Mathematics and Statistics of Southwest University (**Table 1**), that is, $N_{max} = 13$, which $N \approx 2.7$ can be obtained by substituting into the formula, and the integer is 3. Combined with the calculation results, the following conclusions can be drawn: research institutions that publish three or more articles can be defined as core research institutions, and the statistical results are shown in **Table 1**.

Table 1. List of core author affiliations

Serial number	Number	Year	Organization
1	13	2012	School of Mathematics and Statistics Southwest University
2	11	2014	School of Mathematical Sciences Beijing Normal University
3	11	2011	East China Normal University
4	10	2007	School of Mathematics and Statistics Northeast Normal University
5	9	2015	School of Mathematics and Statistics Central China Normal University
6	9	2018	School of Mathematical Sciences East China Normal University
7	7	2019	Teacher Education College of East China Normal University
8	7	2009	School of Teacher Education Zhejiang Normal University
9	5	1998	People's Education Press Primary School Mathematics Room
10	5	2012	School of Education Sciences Yangzhou University
11	5	2001	People's Education Press
12	4	2013	Education Department of Northeast Normal University
13	4	2015	Teacher Education College of Tianjin Normal University
14	4	2014	School of Education Northwest Normal University
15	4	2009	Beijing Normal University Publishing Group
16	4	2014	Institute of Curriculum and Teaching at Nanjing Normal University
17	4	2010	School of Education Sciences Nanjing Normal University
18	4	2011	Basic Education Research Center of Southwest University
19	4	2013	Education Department of Beijing Normal University
20	3	2010	College of Teacher Education Ningbo University
21	3	2016	School of Mathematics and Information Science Guangzhou University
22	3	2018	School of Mathematical Sciences, Guizhou Normal University

The statistical results show that there are 297 colleges and universities participating in the research of mathematics textbooks in China, among which 22 are core research institutions. As can be seen from the number of papers published by institutions, the School of Mathematics and Statistics of Southwest University (13 papers) is in an absolute leading position in the research field of mathematics textbooks in China. In addition, the School of Mathematical Sciences of Beijing Normal University (11 articles) and the Department of Mathematics of East China Normal University (11 articles) have also contributed a lot to the study of educational sociology in China (**Table 1**).

Generally, the main research institutions of mathematics textbooks in China are major normal universities (**Figure 2**). According to the relevant viewpoints of Price's Law, the formation of a group of high-yield authors on a subject needs to meet the corresponding preconditions, that is, the number of papers published by core research institutions accounts for about 50% of the total number of papers published. However, according to statistics, the number of papers published by the core institutions in the field of mathematics textbooks in China is 411, accounting for 37.46% of the total literature, which is still far from the core accreditation standard. From this, we can draw the following conclusions: during the twenty-five years from 1998 to 2024, the research of mathematics textbooks in China has not yet formed a core author group. By clustering the author units with the CiteSpace knowledge graph, we can get that the specific research directions of various institutions are different. Beijing Normal University focuses on #1 teaching material analysis, the reasoning is an activity of thinking that starts from a previously known statement of truth and deduces a new statement [5], developing students' mathematical reasoning skills is a goal of many curricula and an important part of the culture of the mathematics education research community [6]; Nanjing Normal University focuses on #6 Statistics and Probability, and East China Normal University focuses on #3 Question Raising and #4 Primary and Secondary Schools (**Figure 3**).
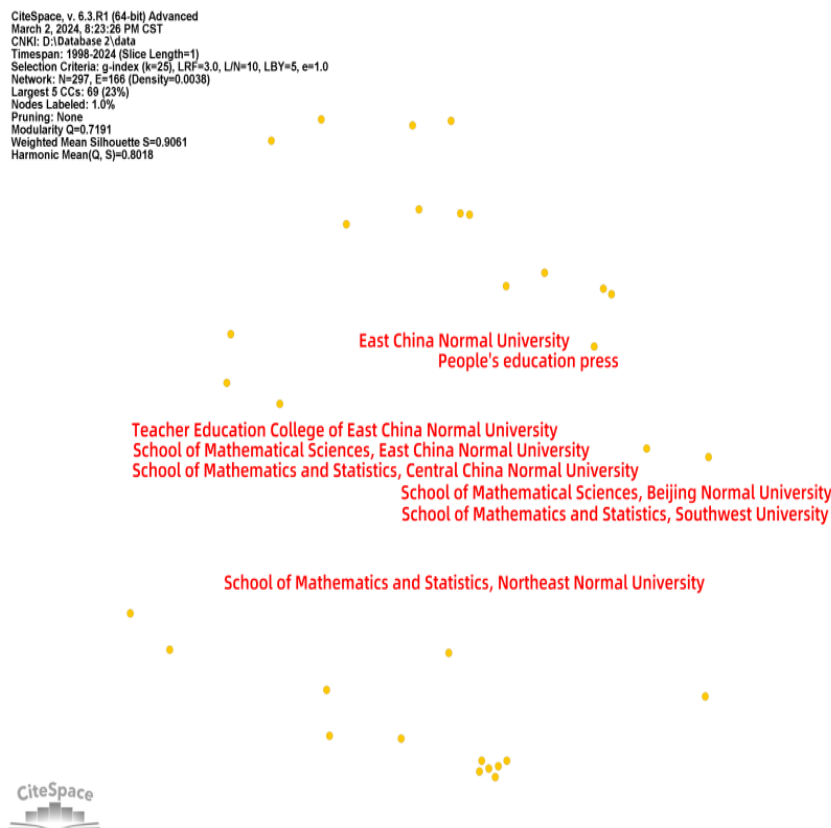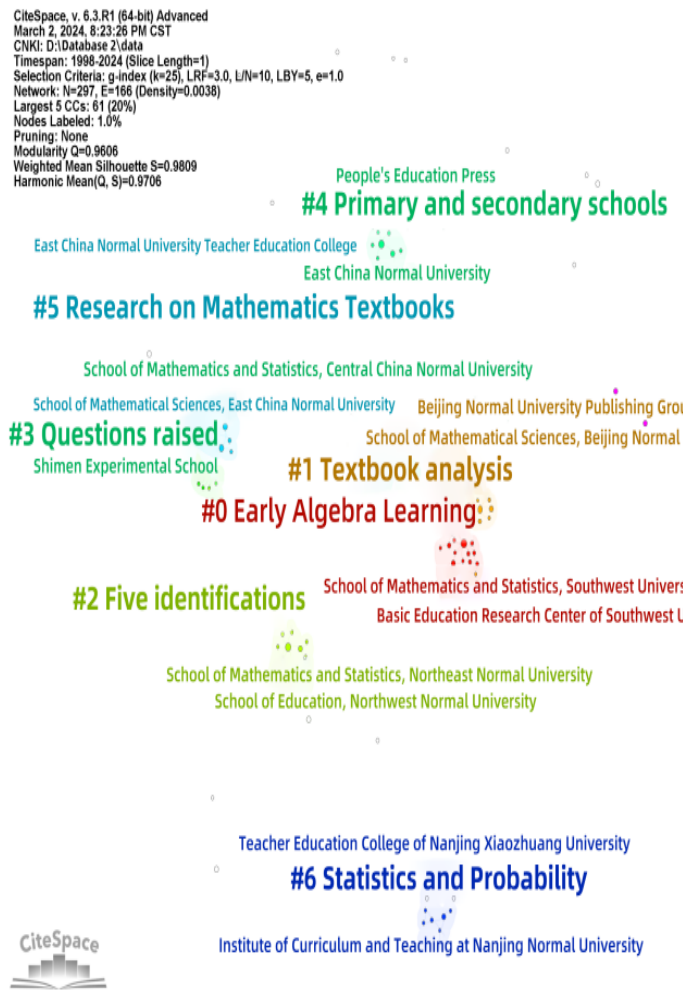

Figure 2. Author's organization

Figure 3. Author's institutional cluster diagram

3.2.2. Core author analysis

The so-called core authors refer to the group of authors who have a certain degree of influence and leadership in the research field and have published a certain standard. Analysis of core authors can help identify the leading groups in the field of research and provide a target reference for subsequent researchers. Therefore, in order to clearly and accurately present the core authors in the field of educational social research, Price's law was used to determine the core authors of the subject field, that is, $M \approx 0.749 \times \sqrt{N_{max}}$. In the formula, the letter M indicates the minimum number of articles published by the core authors, and the number of articles published by the authors with the most articles is indicated by N_{max}. According to the statistics conducted on the CNKI platform, during the period from 1999 to 2024, Naiqing Song published the largest number of papers on the sociology of education, with 13 papers (**Table 2**), and $N_{max} = 13$, and the result was $M \approx 2.7$ after the formula was substituted for calculation, and the whole number was 3 research results.

Therefore, the following conclusions are drawn: the number of papers published in the field of Chinese mathematics textbooks can be defined as core authors, as shown in **Table 2**. As can be seen from **Table 2**, Naiqing Song and Weizhong Zhang are the leading researchers in the field of mathematics textbooks in China. In addition, Naiqing Song, Weizhong Zhang, Ningzhong Shi, Dianshun Hu, Yiming Cao, Yunming Song, Xiaoqin Wang, Fanzhe Kong, Shihu Lu, and Jiucheng Liu are among the top 10 researchers in the field of educational sociology in China, as shown in **Figure 4**. According to statistics, there are 26 core authors (i.e.,

authors with more than 3 papers) in the field of mathematics textbooks in China, with a total of 123 papers, accounting for 36.71% of all research literature. Using the CiteSpace knowledge graph to cluster the authors, it can be obtained that the specific research directions of different authors also vary. Beijing Normal University focuses on "Textbook Analysis," Nanjing Normal University focuses on "Statistics and Probability," and East China Normal University focuses on "Problem Formulation" and "Research on Primary and Secondary School Textbooks" (**Table 2**).

Table 2. Authors of core publications

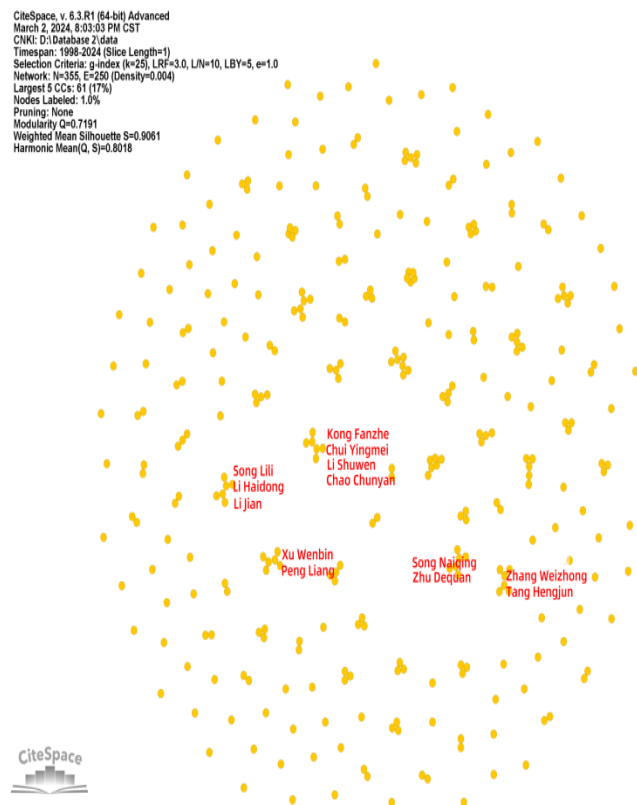| Number	Quantity	Author
1	13	Naiqing Song
2	9	Weizhong Zhang
3	8	Ningzhong Shi
4	6	Dianshun Hu
5	6	Yiming Cao
6	6	Yunming Song
7	5	Xiaoqin Wang
8	5	Fanzhe Kong
9	5	Shihu Lv
10	5	Jiucheng Liu
11	4	Jianpan Wang
12	4	Xingyun Li
13	4	Binyan Xu
14	4	Wenbin Xu

Figure 4. Author of the article

Using the CiteSpace knowledge graph to cluster authors, the specific directions of different authors are also different. Naiqing Song and Yunming Song focused on #0 Elementary Mathematics, Shihu Lv focused on #1 high-quality resource sharing course, and Ningzhong Shi focused on #2 induction, as shown in Figure 5.

Figure 5. Cluster diagram of authors

3.3. Research results and content analysis

The extraction and condensation of the main content of the paper is the keyword, and the keyword can best present the main academic views and ideas of the author's article. Tracking keywords can well grasp the development path and development status of relevant literature research objects. "Node Types": Keyword is clicked to get a clear visualization result, and the knowledge graph of the co-occurrence of the main keywords obtained is shown in **Figure 6**.
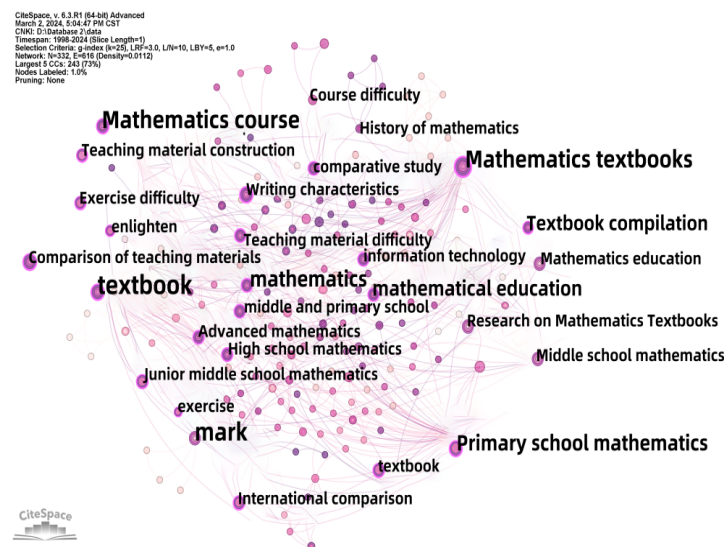

Figure 6. Keyword co-occurrence diagram

As can be seen from **Figure 6**, 323 nodes (keywords) and 616 connections (co-occurrence relationships) are obtained. As can be seen from the figure, the different sizes of the keywords represent differences in the frequency of keyword co-occurrence, and the larger the keywords in the figure, the higher the frequency of co-occurrence. However, the visual knowledge graph cannot accurately feedback the frequency of keywords and the central ranking, but can only observe the research hotspots from the perspective of perceptual intuition. In order to improve the credibility and scientificity of the research, this paper adopts the following formula to accurately sort out the high-frequency keywords: $T = \frac{1}{2}[-1 + \sqrt{(1+8*I)}]$. In the formula, T represents the lowest frequency of high-frequency keywords, and I is used to represent the number of keywords. According to the data exported by CiteSpace, the keyword is I = 323, and substituting it into the formula, the result is T ≈ 24.92, and it is taken as 25 research results. Based on this, it is concluded that in the field of educational sociology research in China, keywords with a frequency of 25 times or more are defined as core keywords.

The Network Summary Table is clicked to obtain the detailed parameters of the keywords, and the co-occurrence frequency of the keywords can be obtained after sorting. Among them, there are only 3 keywords with a frequency greater than or equal to 25, which are mathematics textbooks (36), primary mathematics (28), and textbooks (25). It can be seen that after excluding words with too wide meanings, the core keyword of mathematics textbooks in China should be "primary school mathematics." In addition, the top 10 frequencies of keywords are listed in descending order, as shown in **Table 3**.

Combined with the co-occurrence chart and statistical table of keywords in Chinese mathematics textbook research, the keyword "primary school mathematics textbook" (with a frequency of 28, ranking second) with a high frequency reflects that the research hotspot of mathematics textbooks in China is still mathematics textbooks in the compulsory education stage.

Table 3. Keyword sorting

Number	Frequency	Centrality	Year	Keyword
1	36	0.38	2004	Mathematics textbooks
2	28	0.24	2005	Primary school mathematics
3	25	0.22	1998	teaching material
4	20	0.18	2004	Primary school mathematics textbooks
5	10	0.11	2007	Comparative research
6	9	0.06	2016	Textbook writing
7	8	0.07	2001	Mathematics courses
8	7	0.04	2001	higher mathematics
9	7	0.03	2006	Textbook construction
10	7	0.08	2009	Comparison of textbooks

In order to further study the contextual changes of the main keywords, the Timezone-View in the Layout of the Control Panel is clicked to get the time zone map of the keywords. A two-dimensional coordinate is established, all nodes are positioned in the horizontal axis of time, and the nodes are set in different time zones in the coordinates according to the time of their first occurrence, and go up with the nodes in the timeline one by one. In this way, a left-to-right, bottom-up evolution of knowledge in the sociology of education is presented (**Figure 7**). Among them, from 2005 to 2015, the most important keywords appeared, including primary school

mathematics textbooks, compilation characteristics, international mathematics education, curriculum difficulty, etc.
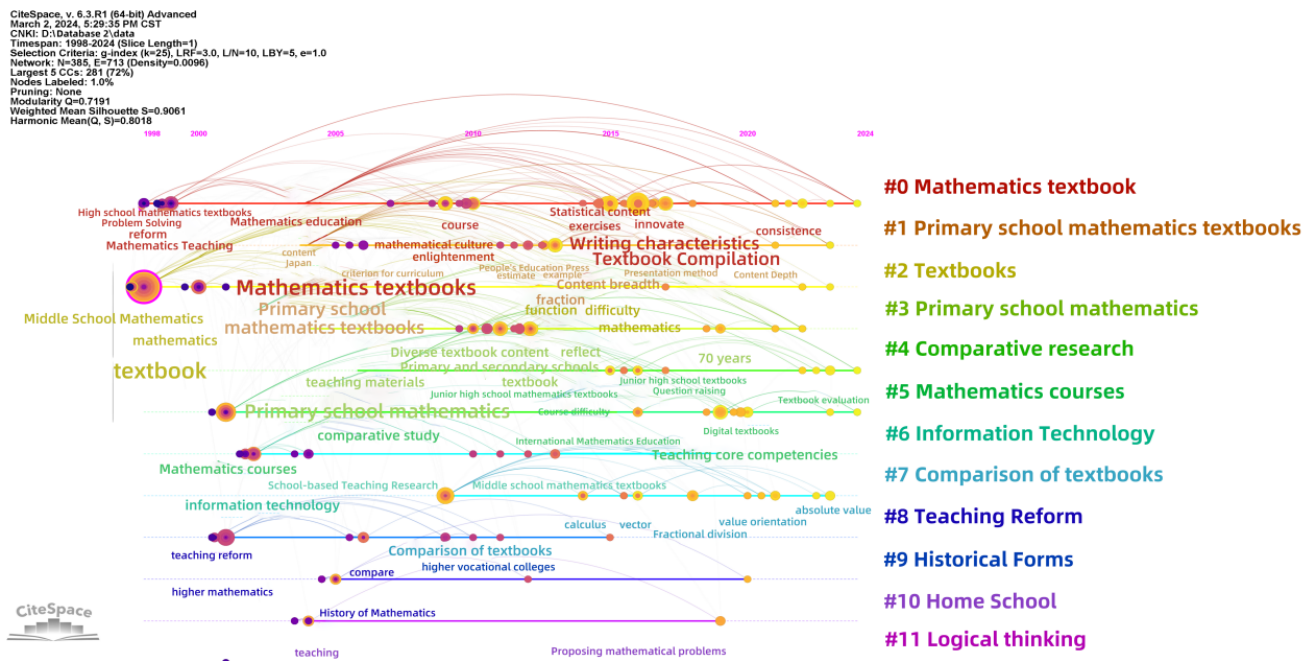

Figure 7. Time zone chart

3.4. Core keyword analysis

A cluster map of keywords can indicate different research topics in the field. In the process of clustering keywords, the similarity of nodes in the network is clearly reflected, which is of great help for us to detect and identify the representative knowledge subgroups of a certain research field, in other words, it is very conducive to exploring the hot topics in the research field. "Extract Cluster Keywords" is clicked, Use Keywords is selected, LSI, LLR, MI, and other clustering methods are selected to generate different clustering results, and finally LSI, LLR, and MI clustering results are selected, and the clustering map of the generated keywords is as follows (**Figure 8**).
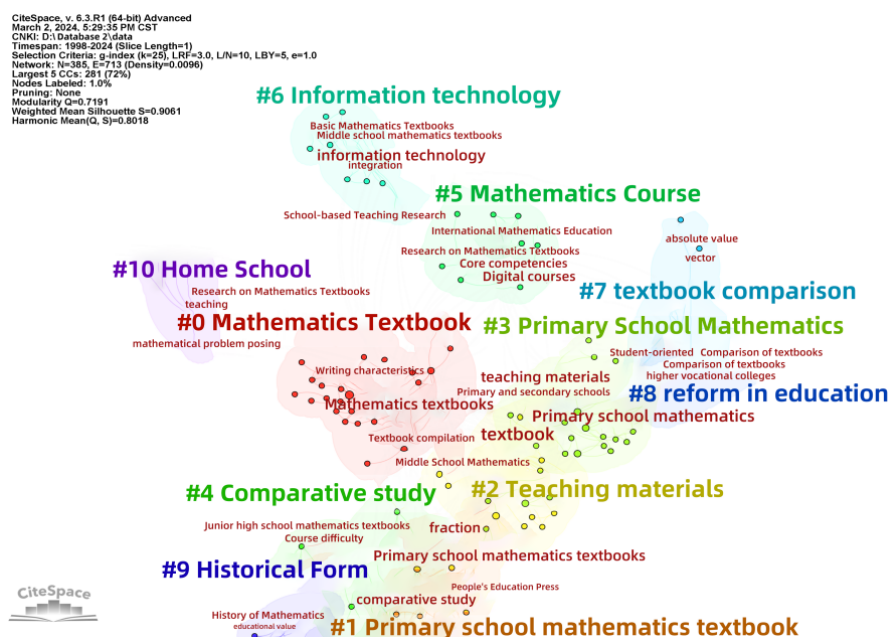

Figure 8. Keyword clustering

In the process of exploration, this paper carried out a cluster analysis of the keywords of all the literature related to mathematics textbooks, in order to explore and analyze the main content classification in this subject area. The S value of the Mean Silhouette index is 0.9061 (> 0.5), and the Modularity Q value is 0.7191 (> 0.3), indicating that the divided structure is significant and the clustering state is reasonable. There are 11 color blocks in the figure, representing 11 clusters, the label of each cluster is the keyword in the co-occurrence network, and the serial number of the cluster is #0~#10, the larger the number, the fewer keywords contained in the cluster. Collinear relationships are represented by the connections between nodes in the cluster, and the more connections between nodes, the higher the degree of co-occurrence between keywords in the field. In general, there are many connections between nodes in each cluster, which reflects the high degree of co-occurrence between keywords in this field. From **Figure 8**, we can see that the research on mathematics textbooks in China can be summarized into the following six themes: #1 primary school mathematics textbooks and #2 primary school mathematics focusing on primary school sections; #4 Comparative study and #7 textbook comparisons focusing on comparative perspectives; #5 Mathematics Course focusing on teaching, #6 information technology, and #8 teaching reform combining with the development of high and new technologies of the times, "as an important carrier of curriculum thought and content, teaching materials develop and change with the reform of curriculum" [7]; #9 historiography and #10 studying the historical development of mathematics and the macro environment that affects students' development. Homeschooling education is the most important thing in forming individuality, and on this basis, we hope to improve and cultivate students' core mathematical literacy through education [8].

4. Discussion

In this paper, quantitative analysis is carried out in combination with the research needs, and the analysis results are displayed in the form of data distribution and map. The research conclusions are summarized as follows:

The first point is that the research of mathematics textbooks in China needs to carry out in-depth discussions from the theoretical basis of textbook design in different countries, as well as the social, cultural, and institutional aspects, so as to gradually internationalize Chinese mathematics textbooks, "serving education, thriving academia, and accumulating culture" [9]. It can be seen from the keyword map and time zone map that the "comparative research" of Chinese mathematics textbooks is mostly aimed at the comparison of domestic textbooks, such as the emergence of keywords "70 years" and "review." Comparison of current international mathematics textbooks is still one of the most popular research interests [10]. It is only the first step to know what foreign teaching materials look like and what are different from domestic teaching materials. We should further understand why the processing or arrangement of specific topics in specific situations is more conducive to the teaching and learning of mathematics, or how to achieve the improvement and promotion of Chinese teaching materials [11]. Comparative research should not be confined to textbook texts but should seek beneficial experiences of foreign textbooks from multiple perspectives such as textbook development, use, evaluation, or digital resources to promote the internationalization of Chinese mathematics textbooks.

Secondly, quality is the lifeline of textbook compilation, and a significant feature of future textbook research is to pay attention to textbook evaluation. The Mathematics Curriculum Standards for Compulsory Education (2022 Edition) (hereinafter referred to as the New Curriculum Standards) points out that at the present stage of compulsory education, it is necessary to focus on inheriting the successful experience of China's curriculum construction, but also to draw on the international advanced education concepts, and further deepen the curriculum reform. Strengthening the comprehensiveness and practicability of the curriculum,

promoting the reform of parenting methods, and focusing on the development of students' core qualities are necessary actions [12]. As the main carrier of curriculum objectives, the textbook is the main tool and resource for teachers and students to carry out teaching and learning [13]. The development of teaching materials is always an important part of mathematics teaching materials research, but there is a huge gap between academic research and practice [14]. The "Overall Plan for Deepening the Reform of Educational Evaluation in the New Era" clearly proposes to improve the quality monitoring and evaluation mechanism of teaching materials. In the transformation of China's basic education from dual-base to three-dimensional goals and then to core literacy, the construction of teaching materials pays more and more attention to high-quality development, and the scientific, reasonable, and operable evaluation system of teaching materials is a powerful starting point for quality assurance. Thinking about issues such as high-quality textbooks, evaluation indicators, evaluation criteria, and reliability and validity of the evaluation system is helpful in clarifying the essence of the textbook and promoting the continuous optimization of the textbook. At present, the development of teaching materials based on core literacy has become the inevitable appeal of China's curriculum reform [15].

Disclosure statement

The author declares no conflict of interest.

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