

The Hot Spot Shift and Trend of Stem Education Research in the Context of Digital Education Transformation - Based on the Citespace Visualization Analysis

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Abstract: With the development of the information age, it is increasingly urgent to accelerate the promotion of Stem education. This article is based on the Stem educational literature and Web of Science core collection database in CiteSpace information visualization software, and compares the research trends and hotspots at home and abroad. The results show that the current popularity of Stem education research abroad continues to rise, and the domestic research shows a trend of rising first and then declining. There are obvious differences in domestic and foreign research hotspots, which mainly focus on education, teachers, Stem curriculum and other contents, while the domestic focus is on maker education, curriculum reform, schools and other aspects.

Keywords: Model; Prevention; Project based Learning; Maker Education; Stem Education

1. Research Methods and Data Sources

1.1 Study Method

This study was visualized by bibliometric methods with the help of CiteSpace software developed by Dr. Michael Chaomei Chen, Drexel University, USA. Through the author, keywords, keywords time eline and a series of visual function, map the Stem education research in the field of knowledge, the knowledge structure of the research field, application rule and distribution of visual network map, for researchers clarify the field knowledge source, important turning point, research direction and future research trend [1]. Knowledge graph is a kind of graph that shows the development process and structure relationship of scientific knowledge. People can rely on the help of the knowledge graph, which can look through the various fields and

structures of the human knowledge department, construct a complex knowledge network, and predict the development trend of science and technology and knowledge frontier. It is not only a visual knowledge graph, but also a serialized knowledge pedigree, showing the complex relationship of network, interaction, crossover, evolution or derivative between knowledge elements and knowledge groups.

1.2 Data Source

The data of this study are from Web of Science database and CNKI database. In order to improve the analysis quality of the literature, the WOS core journal database was selected to collect the literature of the CNKI and the academic journals of CNKI. Search strategy: the subject word "Stem education" was searched in the database in WOS, and finally got 15,779 related documents, and the search time span was 2012-2022. In CNKI, "Stem education" is used as the search term, and the search time span is also default, and screened in all literature to remove conference notices, advertisements, etc. Finally, 1,846 valid data were selected.

2. Study the Spatial and Temporal Distribution

2.1 Distribution of Literature Numbers

In a period of time, the number of academic literature published in a certain research field can reflect the research situation and development trend in this field, represent the development level of academic research in this field to a certain extent, and at the same time timely reflect the interactive relationship between social development and this field. The trends in the number of published literature over time can reflect the trends in the field from a macroscopic perspective [2]. Statistics on the number of Stem education research publications

from WOS database and cnKI database respectively, it can be seen that:

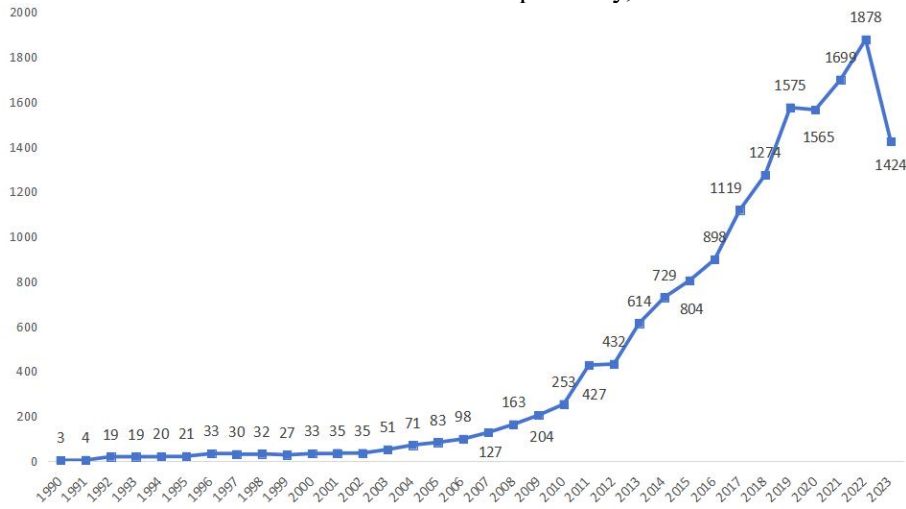


Figure 1. Annual Distribution of the International Stem Educational Research Literature

According to Figure 1, the trend of international publications in the field of Stem education research is on the rise rapidly. Among them, from 1990 to 2002, the annual number of publications was relatively stable, with a relatively small number of articles, and the average number of publications was about 30, indicating that during this period, international scholars on Stem education research was in the initial stage, the number of researchers and mutual cooperation were small, and relevant theories need to be formed. From 2003 to 2009, the number of documents published by Stem education was in a steady upward trend, but the

rising rate was not obvious. The largest number of documents in this stage was 204 in 2009, indicating that the research on Stem education was deepening, and the number of scholars increased. Since 2010, the number of documents published by Stem Education has increased rapidly, and the number of documents has made a qualitative leap from before, reaching a peak in 1,974 articles in 2022. It shows that at this time, scholars' attention to the research field of Stem education has increased significantly. Many scholars enter this field for research, and scholars' interest in research is increasing, and mutual cooperation is very frequent.

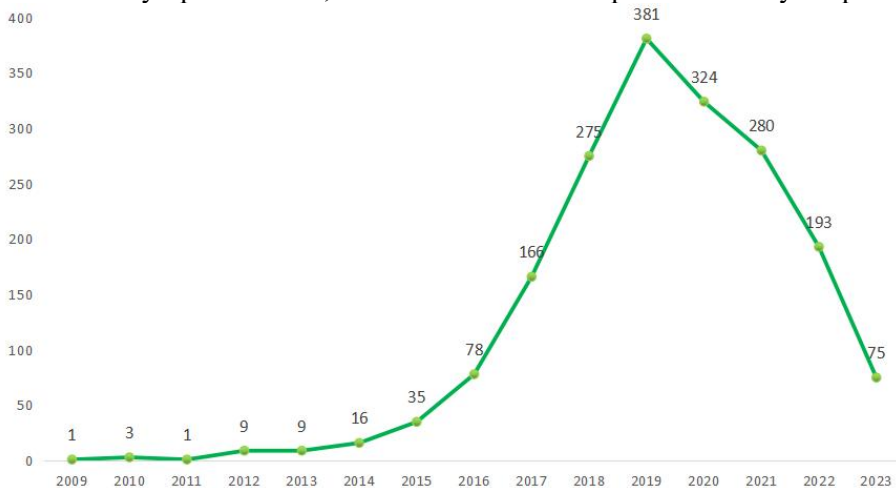


Figure 2. Annual Distribution Of Domestic STEM Education Research Literature

According to Figure 2, compared with international studies, the number of domestic studies on Stem education is relatively small and started late, which was conducted in 2009. On the whole, the post trend is divided into three stages.(1) In 2009-2013. During this period, the number of Stem education research literature

published by domestic scholars was relatively small, with the annual number of publications ranging between 1 and 9. In the first three years, the number of publications was 3 or less, and the range of change was small. It shows that in this time, domestic scholars are in the initial and exploratory stage of Stem education research,

and have little cooperation with each other.(2) In 2014-2019. At this stage, the number of studies in the field of Stem education increased rapidly, from 16 in 2014 to 381 in 2019, indicating that the research on Stem education in this stage increased significantly, and the research popularity increased significantly; the research contents include Stem education concept [3], Stem education practice [4], etc.(3) In 2020-2023. At this stage, the number of research articles was in a state of decline, but the decline was relatively small, and the average annual number of research articles was more than 100, indicating that Stem education research is still a hot content widely concerned by the academic circles.

The analysis of the author cooperative network can show the academic status of some authors in the field of Stem education in academic journals. Meanwhile, the author cooperative network map can also clearly reflect the core author group of the research and the degree of cooperative relationship. Citespace Knowledge graph software can draw the source and author map of the research literature to view the importance indicators and network attributes of the author in the cooperative network. Therefore, this study set Note Types to Author, with the default time span and the time interval of 1 year. Based on this study, the knowledge map of major authors in the field of Stem education research at home and abroad was drawn (As shown in Figure 3 and Figure 4).

2.2. Author Collaborative Analysis



Figure 3. Cooperative Knowledge Map of Foreign Authors

Observe Figure 3, the author cooperation network, a total of 210 research authors, the attachment is 144, the author cooperation more close, generated nine research team, including MANUEL CASTRO and the author as the center of the largest research team, including nine authors, followed by the author of the YU WANG group, including four authors, and other cooperation team scale is smaller. From the perspective of the cooperation degree of the research authors, the degree of cooperation among the main authors is relatively high, and a strict and mature cooperation network has been formed locally in the relevant research field of Stem education.

Among the number of foreign authors published by them, the number of research authors in the field of Stem education is relatively average, with a small gap, and the largest number of articles is 15. The authors of 10 or more publications are PEDRO PLAZA, MANUEL

CASTRO, ALICIA GARCIAHOLGADO, GABRIELMIRO MUNTEAN and DANAM BARRY. The ALICIA GARCIAHOLGADO (Alicia Garcia, hall) as a salamanca university research scholars, in order to understand the college students of science, technology, engineering and mathematics higher education research, through the design questionnaire, the experimental quantitative design pilot in Spain, and draw the following conclusion: the view of STEM research is restricted by personal factors, such as motivation, education background, family and social influence, and social education must pay attention to the pursuit of higher education research decision component. Knowledge of the factors involved in the decisions helps the educational community to establish mechanisms to prevent lateral gender segregation [5]. And GABRIELMIRO MUNTEAN (Gabriel Miro Muntai), as a research scholar at Dublin City University,

mainly explores the application of gamification in the network delivery of science, technology, engineering and mathematics (STEM) disciplines. He proposed an innovative gamification framework, namely the NEWTON Enhanced Gamification Model (N-EGM), which was designed as part of the European Horizon 2020 project NEWTON. After the experiment, the proposed gamification solution proved effective in improving students' learning experience and participation, and also increased students' knowledge acquisition [6].

As can be seen from the knowledge map of domestic authors, A total of 86 study authors published more than two posts in Stem education, There are 44 lines between the authors, More communication between the authors, Cooperation is more frequent, A total of 13 research collaboration teams have emerged, But the cooperation team is small, Among them, the authors merlin and Lei Xueying are the research centers, A total of five research scholars were covered, Together, they studied how project-based STEM teaching promotes the cultivation of college students' innovative ability in a mobile learning environment, On the basis of sorting out the key elements such as the STEM teaching philosophy, Designed the project-based STEM teaching model framework in the mobile learning environment, And test the effectiveness of students' innovation ability training. The study found that the STEM-PBL teaching activities supported by mobile learning technology effectively improved the level of students' innovation ability, and students' learning participation significantly improved [7]. With Ding Jie scale of the research team in the second, including four scholars, the team analyzed the nearly ten years STEAM education teachers, found that STEM teacher training research mainly focus on training policy, training strategy, professional ability training and promotion, training practice case on four aspects, such as [8]. The rest of the research collaboration are small teams, consisting of two or three researchers.

In terms of the number of articles published by authors in China, the top five authors are Qin Jian, Zhang Yuting, Shao Mengqiu, Song Yi, Zhao Huichen, etc., and the number of articles is more than 10. Among them, Qin Jian from Shaanxi Normal University has the largest node and the largest number of articles, totaling 21 articles, and published them for the first time in

2009. Together with Zhang Yuting and Shao Mengqiu, also from Shaanxi Normal University, they believed that STEM teachers play a vital role in STEM talent training, and explored the STEM teacher ability improvement model [9]. In addition, these three scholars also studied the relationship between STEM education and maker education in curriculum practice, and proposed that the example of "designing and making aircraft" can help front-line primary and secondary school teachers clarify the connection and difference between maker education and STEM education, so as to provide reference for curriculum practice [10]. Song Yi from Nanjing Normal University has published 17 articles. The main direction of his research is to of foreign Stem education projects. For example, the Canadian STEM Education program "scientist in Residence" review [11], Maryland STEM Practice Standard review [12], etc. As a research scholar of Henan University, the author Zhao Huichen believes that self-evaluation plays an important role in STEM education in primary and secondary schools. The self-evaluation subject formulates the self-evaluation standard of STEM education, chooses the self-evaluation method, improves the self-evaluation content, and then affects the environment of the development of STEM education [13].

3 Study Topic Analysis

3.1 Keyword Co-Occurrence Network

Keywords are representative words to describe the core content of the article. The higher the frequency, the higher the research heat. The high-frequency keywords can reflect the hot issues in the research field. Common word analysis is to reflect the strength of correlation between keywords through the co-occurrence of vocabulary pairs or noun phrases in statistical literature, and then determine the research hotspots, composition and paradigms of the disciplines or fields represented by these words, and analyze the development process and structural evolution of disciplines horizontally and vertically. Therefore, in the Citespace visualization software, the method of keyword co-occurrence network is mainly used to generate the keyword co-occurrence network knowledge map of Stem education research, so as to explore the hot content in the field of Stem education at home and abroad.

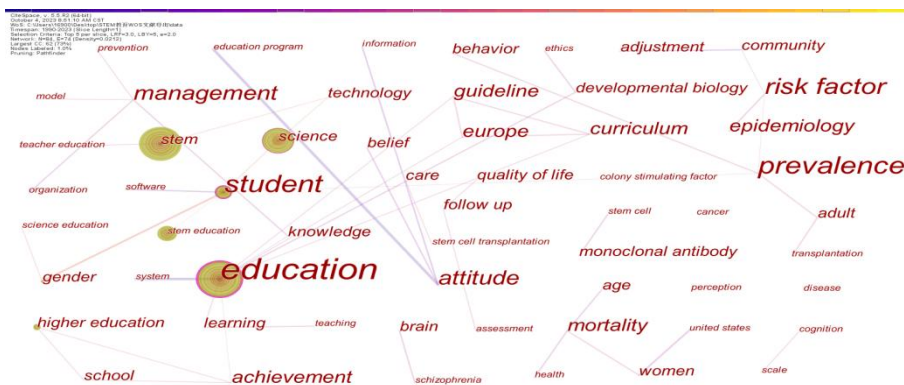


Figure 4. A Graph of the Network Knowledge Graph for the Co-Occurrence of International Keywords

As can be seen from the hot spots of international keywords, the research mainly focuses on the following aspects: ① The main keyword education is the most prominent in the nodes in the map, with the most frequency, 2823 times. At the same time, the purple circle of the nodes is more obvious, and the intermediary centrality is high, 0.11, which is closely related to other keywords. Education is essential to the vision of sustainability, and STEM education can essentially achieve the sustainable development goals, which can not only improve students' academic performance, but also improve real problem-solving skills. Furthermore, STEM can educate individuals on their interest in STEM subsubjects and the pursuit of STEM careers in [14].

② Keywords about Stem curriculum include science, mathematics, science education, engineering education, curriculum, etc. Developing Stem curriculum is crucial for the overall development of students. For example, Ata-Akturk A developed an education curriculum and tested two early childhood education teachers, five preschool children and five parents. The findings validate the eight key design principles of the curriculum and show that the curriculum contributes to children's knowledge, skills, feelings, and tendencies towards STEM [15].

③ Key words about teachers, such as teacher, school, teaching, education program, etc. Teaching in the context of STEM education requires mathematics teachers to effectively select, design and implement appropriate tasks in the classroom, and the important role of teachers and tasks as STEM educational tools requires the effective design and implementation of STEM tasks and STEM teacher education plan [16].

As can be seen from the hot spots of keywords in domestic Stem education research, the research mainly focuses on the following aspects:

① The main search term stem education is the largest node, the largest number of occurrence, 845 times, and the observation centrality shows that the heart is also high, 0.47, which plays a pivotal role in the connection of other keywords. At present, STEM education, as a topic of great attention in the field of education, plays an important role in cultivating students' comprehensive literacy and improving their thinking and innovation ability [17].

② Keywords about maker education, including maker education, innovation, teaching innovation, innovation ability, maker courses and so on.

Maker education is a new education model, [18]. It is a type of education to cultivate young makers in the maker space, and it is a kind of engineering education [19] to cultivate students' comprehensive practical ability in the form of creation.

③ Keywords related to teaching reform include teaching mode, teaching reform, subject integration, curriculum reform and curriculum design, etc. In the new era of socialism with Chinese characteristics and the critical background, accelerating the STEAM education reform in China is not only the only way to cultivate comprehensive, innovative and application-oriented talents, but also a feasible path to enhance national competitiveness and education development to cope with their own crisis [20].

④ Related to the key to the school, including primary and secondary schools, kindergartens, primary school education, primary and secondary schools, in recent years, with the manufacturing technology, information

technology, computer technology and other modern technology in education, many primary and secondary schools in our country also carried out the robot, 3D printing, a guest and a series of STEAM activities, has obtained the certain effect [21]

From the perspective of the centrality index representing the promoting effect of nodes, the keyword prevalence has the highest mediation centrality, and the purple circle outside the node is the most obvious, and the centrality is 0.91, which is the most closely related to other keywords. Other high school mental keywords include poverty, care, view, risk, etc., the centrality is higher than 0.3, and is closely related to other keywords. In domestic research, the intermediary center of keyword project learning is the highest, with a centrality of 0.84, while the centrality higher than 0.6 also includes stem, stem, science education, science and technology museum, science and technology museum, etc., which constitute the core nodes of the network.

3.2 Keyword Time Evolution Analysis

The keyword timeline knowledge graph generated based on keyword clustering can better reveal the specific problems involved in the Stem research field and the evolution of the keywords covered. A cluster visualization analysis of the references for the relevant content was performed by selecting the node type as the cited reference in the Citespace visualization software. Later, the timeline knowledge graph is generated on the basis of clustering, which is a timeline axis view, the Y axis is the cluster name, and the X axis is the year of keyword appearance, which can show the time span and research progress of the keywords contained in each cluster. The time distribution of keywords at home and abroad, as shown in Figure 5.

As can be seen from Figure 5, a total of 8 clusters were generated in the international Stem education research keywords, which also represented 8 research directions. These 8 clusters were # 0 adjustment, # 1 general practitioner, # 2 surveillance, # 3 epilepsy, # 4 technology, # 5 stem education, # 6 motivation and # 7 strategy. In the knowledge graph where clusters appear, the module value Q size of clusters is correlated with the density of nodes, and since $Q=0.7629$, it shows that the network structure clustering of international Stem

Education Research cluster is effective and can be used for scientific cluster analysis. The average profile value S size can be used to measure the homogeneity of clusters, $S=0$, indicating high homogeneity and good division of different clusters..5333

From the perspective of the time distribution of international keywords, keywords first appeared in 1992. Including education, system and other keywords. Most of the keywords appeared before 2010. It shows that during this period, the research heat of foreign scholars on Stem education increased significantly, and the number of studies increased rapidly. The emerging keywords include alternative medicine, stem education, stem cell research, cognition, science education and others highly related to Stem education. After 2011, the number of keywords in international research decreased sharply, indicating that the research in the field of Stem education has gradually become mature in recent years, and the research content is constantly improved, such as professional development, college, engineering education, etc. At the same time, it is worth noting that the keyword motivation appeared in recent years may become the focus of future research.

In the domestic Stem education research, 8 clusters were also generated, which were specifically # 0 science education, # 1 stem concept, # 2 stem teacher, # 3 project learning, # 4 information technology, # 5 engineering design, # 6 education activity, and # 7 stem education concept. The module value of the cluster is $Q=7965$, indicating that the network structure studied in this field clusters well, and the average profile value is $S=0.5978$, indicating high homogeneity. The following study analyzes the keyword evolution of the key cluster.

From the perspective of the time distribution of keywords, the keywords of domestic research first appeared in 2010, including the main subject words, stem education, stem and project learning. In the following years, the number of keywords appeared less, including mathematics, innovation and so on. Most of the keywords appeared after 2015. It shows that during this period, the research heat of Stem education increased significantly, and the number of research increased rapidly. In the field of science education in Stem education, it has developed from science education standards to technology innovation and interdisciplinary education, the field of stem concept has developed from maker

education to education informatization and new engineering, and the field of project learning has developed from science literacy to popular science education. The recent hot spots mainly

include educational equity, visual analysis, teacher professional development, curriculum reform, localization, preschool stem education and so on.

Table 1. Keyword Frequency Statistics

Order Number	Keyword	Frequency	Centrality	Order Number	Keyword	Frequency	Centrality
1	Education	2823	0.11	1	Stem Education	845	0.47
2	Stem	2627	0.12	2	Stem	272	0.81
3	Science	2039	0.02	3	Maker Education	93	0.15
4	Stem Education	1367	0	4	Steam Education	92	0.56
5	Student	1276	0.17	5	America	86	0.09
6	Higher Education	921	0.12	6	Stem Educational Idea	71	0
7	Gender	872	0.05	7	Key Competence	57	0
8	Technology	835	0.07	8	Project-Based Learning	52	0.84
9	Mathematics	670	0	9	Model Of Instruction	49	0.11
10	Women	626	0.15	10	Stem Curriculum	42	0.29
11	Achievement	608	0.1	11	Science Education	35	0.69
12	Impact	523	0.06	12	Elementary And Secondary School	33	0.15
13	Performance	516	0	13	Instructional Design	33	0.13
14	Knowledge	487	0.05	14	Steam	33	0.72
15	Experience	410	0	15	Primary School Science	31	0
16	Attitude	318	0.22	16	Interdiscipline	29	0.32
17	Model	238	0.09	17	Stem Teacher	28	0.04
18	Motivation	149	0	18	Scientific Literacy	26	0.54
19	Perception	121	0	19	Artificial Intelligence	22	0.09
20	Teacher	105	0.04	20	Curriculum Design	20	0

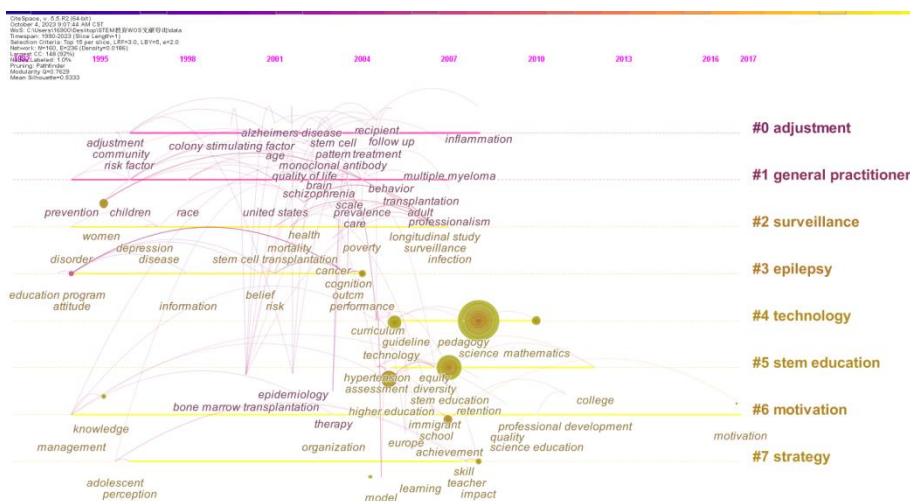


Figure 5. Time Distribution of International Keywords

3.3 Present Analysis of Key Words

Emergent words refer to the key terms that have a sudden increase in frequency in a short time or a significant increase in frequency. Through the

analysis of the sudden words, we can explore the development trend and frontier hotspots in the field of Stem at home and abroad. Draw the knowledge map of emerging words at home and abroad, as shown in Figure 6 and Figure 7:

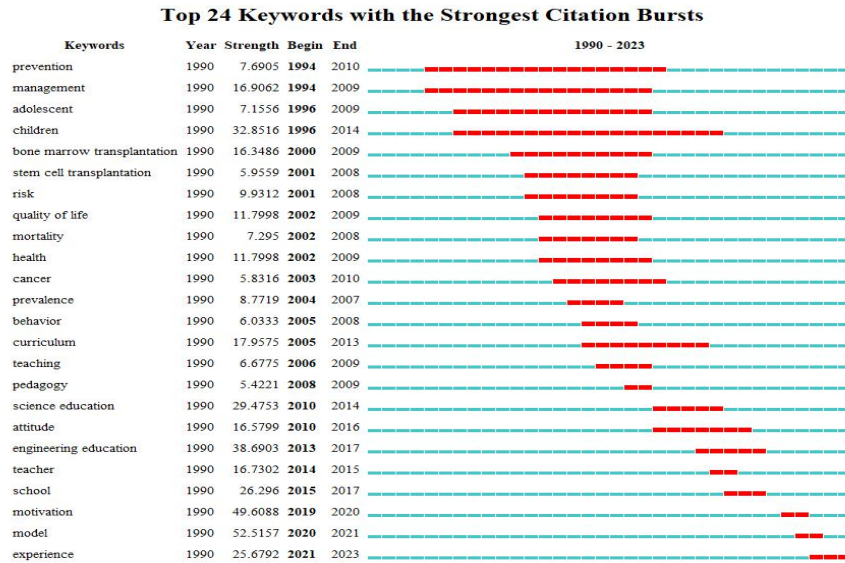


Figure 6. Knowledge Graph of International Keywords

Figure 6 shows the 24 keywords with the most reference surge in foreign countries from 1994 to 2023. The red part in the figure clearly shows the starting and ending time and the evolution process of the key words. In terms of duration, the emergent word children had the longest duration of 19 years with 1996-2014, followed by keyword prevention with 17 years and duration of 1994-2010. The emergent word management and adolescent also last longer, for 16 years and 14 years respectively. In terms of emergent intensity, the highest, up to 52.5157. Some studies have pointed out that modelling and modeling should be used as a means to

promote STEM literacy and transfer knowledge and skills between environments inside and outside STEM disciplines, and that modeling activities can be a meaningful way to achieve STEM education [22]. Next, the sudden word motivation, with an intensity of 49.6088. The third strongest word is engineering education and 38.6903, while the other words with higher intensity include children, scienceeducation, school, etc. The sudden word experience began to appear in 2021 and continues to date. It is still a hot topic of foreign Stem education research recently.

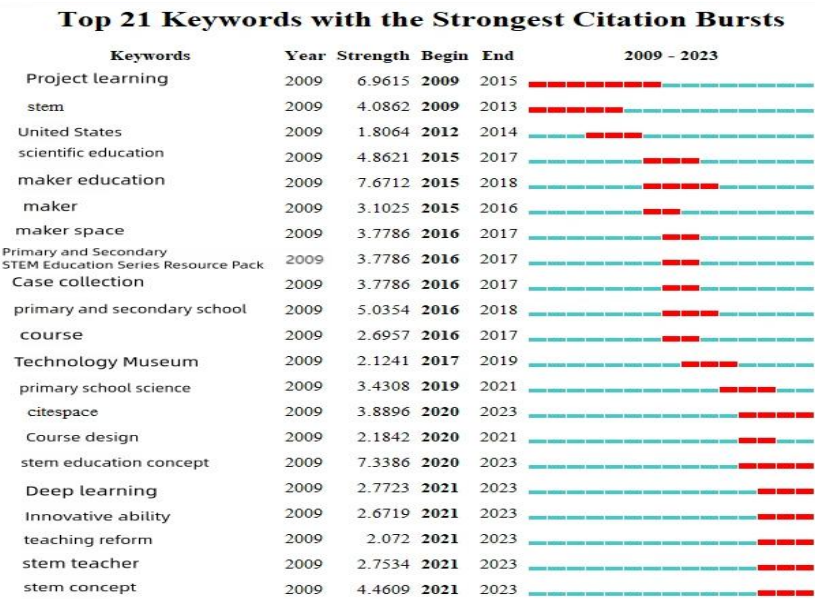


Figure 7. Domestic Keywords Appear Knowledge Map

According to Figure 4, there are 21 most cited keywords in the field of Stem education research in China. In terms of the duration of emergent

words, the duration of emergent word item learning was the longest, with 7 years, from 2009 to 2015. Project-based learning advocates

that teachers should design a series of experience and inquiry activities around real problems or challenges. Students need to use a variety of subject knowledge and skills to solve problems, and to express, communicate and display the final learning results [23]. The duration of Stem ranked second, with five years, from 2009 to 2013. The rest of the sudden term lasted for four years or less. From the perspective of sudden intensity, the intensity of sudden words in China is relatively low. The keyword with the highest intensity is maker education, with intensity of 7.6712, and the second place is stem education concept, with intensity of 7.3386. The rest of the sudden words with high intensity include project-based learning, science education, stem concept, etc. From the perspective of research trend, the research progress in recent years pays more attention to curriculum design, deep learning, innovation ability, stem education concept, tem teachers and other research contents.

4. Conclusion

This study is based on CiteSpace information visualization software, from the perspective of domestic and foreign, the WOS and CNKI database Stem education research literature data sorting and visual analysis, to explore the forefront of the Stem education research hotspot and evolution process, including the annual post, the author, research hotspot, etc., to provide reference for the future Stem education talent research in our country.

From the perspective of the research status, the number of foreign research publications showed a rapid increasing trend. Before 2010, the number of publications was relatively stable and relatively small. After 2010, the number of literature articles has increased rapidly. The number of domestic articles has experienced three stages of steady development, rapid growth, and slow decline. The number of foreign research authors in the field of Stem education is relatively large, relatively few in China and started late, but the cooperation between domestic and foreign authors are relatively close.

From the perspective of research hotspots, the research content and research focus of the two are different. The research direction of Stem education abroad mainly focuses on education, teachers and stem courses, and the frequency of education, stem, science, stem education and

student is high. The research subjects of Stem education in China mainly focus on maker education, teaching reform, schools and other aspects, and the keywords stem education, stem, maker education, Steam education and other aspects are more frequently used. From the perspective of research clustering and time evolution, the international community mainly revolves around 8 clusters such as # 0 adjustment, # 1 general practitioner and # 2 surveillance, and most of the clusters are closely related. In China, it mainly focuses on 8 clusters, such as # 0 science education, # 1 stem concept and # 2 stem teachers, and the cluster connection is also relatively close. The international research keywords first appeared in 1992, but most keywords appeared before 2010. Domestic research keywords first appeared in 2010, and most of the keywords appeared after 2015. From the perspective of sudden words, the gap between the number of sudden words at home and abroad is not large, but the intensity and duration of sudden words are significantly higher than that of domestic words. A total of 24 sudden words have appeared abroad, model has the highest occurrence intensity, prevention lasts the longest for 17 years, experience has the potential to become a research hotspot in international Stem education. A total of 21 sudden words appeared in China, among which the project learning was the highest intensity, and maker education lasted the longest for 7 years. Curriculum design, deep learning, innovation ability, stem education concept, stem teachers and so on are still the recent research hotspots of Stem education in China.

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