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Research Progress on Digital Competency of Teachers at Home and Abroad based on Knowledge Mapping

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Abstract: In order to deeply study the research hotspots and development trends in the field of teachers' digital competence at home and abroad, 227 and 623 relevant literatures included in the China Knowledge Network (CNKI) database and Web of Science Core Collection (WoS) between 2006 and 2024 were selected. Using CiteSpace 6.3.R1 bibliometric software, trends in the number of publications, collaborative networks among authors and institutions, keyword co-occurrences, cluster analysis, and emergent words were visualized and analyzed. It was found that the volume of articles on teachers' digital competence at home and abroad showed a fluctuating upward trend; there was a close cooperative relationship between the authors of articles and institutions at home and abroad, and a more complete cooperative team was formed. Domestic research mainly focuses on the investigation of the status quo of teachers' digital competence, cultivation and enhancement, and the study of measurement model, while foreign research focuses more on the investigation, cultivation and enhancement, and assessment research of teachers' digital competence. Currently, the frontiers of domestic teacher digital competency research include vocational colleges and teacher development, while the frontiers of foreign research focus on online teaching and classroom practice.

Keywords: Knowledge Mapping; Teacher Digital Competence; CiteSpace; Visualization and Analysis.

1. Introduction

Since the European Union introduced "digital competence" in the Core Literacy for Lifelong Learning in 2006, the concept has rapidly become a global focus in the field of education, referring to the ability of individuals to use information technology proficiently in a wide range of social activities, demonstrating self-confidence, criticality and innovation. competence in all kinds of social activities, demonstrating confidence, criticality and innovation0 .It refers to the ability of individuals to skillfully utilize information technology in various social activities and demonstrate self-confidence, criticality and innovation. In particular, the development and enhancement of teachers' digital competence has attracted much attention as an important part of the education sector. The EU's subsequent framework details six core areas of digital competence for teachers: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and promoting digital competence for learners[2]. The framework is designed to be used as a basis for international assessments of teacher information literacy. It provides a reference framework for the international assessment of teachers' information literacy. China has also responded positively by releasing documents such as Digital Literacy for Teachers, which is dedicated to improving the educational and teaching competence of the teacher community in the digital era, emphasizing the important role of digital technology in optimizing teaching and promoting teachers' professional growth. The concept of teachers' digital competence has gradually evolved over time from expressions such as informatization teaching ability and digital literacy, and although the terminology has not been completely unified, the core focuses on teachers' comprehensive ability in the digital environment. Therefore, the above mentioned concepts and terms are unified into the research vision and named "digital competence" in a general way.

Based on this, in order to deeply understand the current situation and development trend of teachers' digital competence, this study extensively collects and analyzes high-quality literature both at home and abroad, including the core databases of Web of Science (hereinafter referred to as WoS) and the related resources in the core of Peking University and CSSCI databases in CNKI. Through visual analysis methods, we intuitively present an overview of the research in this field, compare the similarities and differences between domestic and international research, and summarize the main experiences and directions of the research. It aims to provide reference for further research and enhancement of digital competence of teachers in China.

2. Data Sources and Research Methodology

2.1. Data Sources

In the course of the study, in order to ensure the authority and broad representativeness of the literature, two major databases, China Knowledge Network (CNKI) in Chinese and WoS in English, were selected as the main data sources. On the CNKI platform, advanced screening strategies were used to focus on journal articles, specifically limiting the literature sources to the Peking University Core and CSSCI, with "teachers' digital competence" or "teachers' digital literacy" or "teachers' digital competence" or "teachers' digital competence" or "teachers' digital competence" or "teachers' digital competence" or "teachers' digital competence" or "teachers' digital competence" as the main data sources. The search was conducted with the keywords "teachers' digital competence" or "teachers' digital literacy" or "teachers' informatization teaching ability", and the timeframe was up to July 2024. After rigorous screening, non-directly related research materials were excluded, and 227 high-quality and valid documents were finally identified.

Foreign data were collected from the WoS core collection database. In view of the fact that "digital competence" is often translated as "digital competence" in the international context,

and "teacher" corresponds to "teacher" or "educator", the search topic was set as "digital competence" in order to collect all the relevant literature comprehensively and accurately. As "digital competence" is often translated as "digital competence" internationally, and "teacher" corresponds to "teacher" or "educator", in order to comprehensively and accurately collect all the related literature, the search topic is set as "digital competence of teacher" or "digital competence of teacher". In order to comprehensively and accurately collect all the relevant literature, the search topic was set as "digital competence of teacher" or "digital competence of educator", and the type of literature was limited to (Articles). Considering that the concept of "digital competence" originated from the 2006 EU report "Core Literacies for Lifelong Learning", the time span of the search was set from January 2006 to July 2024. After manually eliminating irrelevant and duplicated documents, 623 high-quality, closely related and valid documents were selected.

2.2. Research Methodology

CiteSpace 6.3.R1 (hereinafter referred to as CiteSpace) was used as the visualization tool in this study. The tool was developed by Professor Chaomei Chen and his research team based on Java language, which has the ability to convert the imported file data into visualization maps, and can reveal the features and patterns among the data and analyze the co-occurrence and clustering relationships among them[3] .The study is based on Java language. In this study, the retrieved data from domestic and international documents were imported into CiteSpace, and based on the research perspectives articulated in the content of the data analysis, the visualized knowledge maps were constructed respectively, in order to explore the research hotspots and cutting-edge trends in the field of teachers' digital competence at home and abroad.

3. Results

3.1. Analysis of Annual Volume of Publications

By analyzing the annual changes in the number of literature publications, we can clearly outline the evolution trajectory of the research topic in a specific academic field and deeply analyze the development path of the discipline. The annual literature data extracted by CiteSpace software is further processed in WPS software to draw an annual line graph of the number of publications, which visualizes the historical development of the research topic.

The national publication volume of teachers' digital competence shows 3 distinct stages of development and change (as shown in theFigure **1.** shown): (1) From 2006-2012, there was an overall slow growth trend. In this stage, with the popularization of the Internet and basic educational technologies and the introduction of the concept of teachers' digital competence, China began to pay attention to the initial practice and theoretical foundation of digital teaching. The number of articles published grew from 2 in 2006 to 10 in 2012. It is worth noting that in 2011, the number of articles was still 3, while in 2012 there was an inflection point and the number of articles grew to 10. The fundamental reason lies in the promotion of the policy, which is clearly pointed out in the "Outline of the National Medium- and Long-Term Education Reform and Development Plan (2010-2020)", "to enhance teachers' ability to utilize information technology, to update teaching concepts, to improve teaching methods, and to enhance the effectiveness of teaching"[4] . (2) It is fluctuating and upward from 2013 to 2020, with the number of articles published increasing from 4 in 2013 to 10 in 2020, which is closely related to the rapid development of technology, especially the wide application of mobile devices and cloud services, which provide more convenience and flexibility for teaching. (3) A rapid upward trend is observed from 2020 to 2024, as the shift in the domestic education model due to the epidemic thus contributing to the increased demand and attention of teachers to digital teaching and learning has driven the rapid progress of research in this field, with the number of articles published rising from 10 in 2020 to 40 in July 2024. In February 2023, the Ministry of Education (MOE) issued the "Digital Literacy for Teachers" education industry standard, which explicitly sets out the requirements for enhancing teachers' awareness, competence, and responsibility for using digital technologies to optimize, innovate, and transform educational activities[5]. The Ministry of Education issued the Education Industry Standard on Teachers' Digital Literacy. Given the high priority that the state attaches to the development of teachers' digital competence, it is expected that the amount of literature published in this research area will continue to show growth in the future.

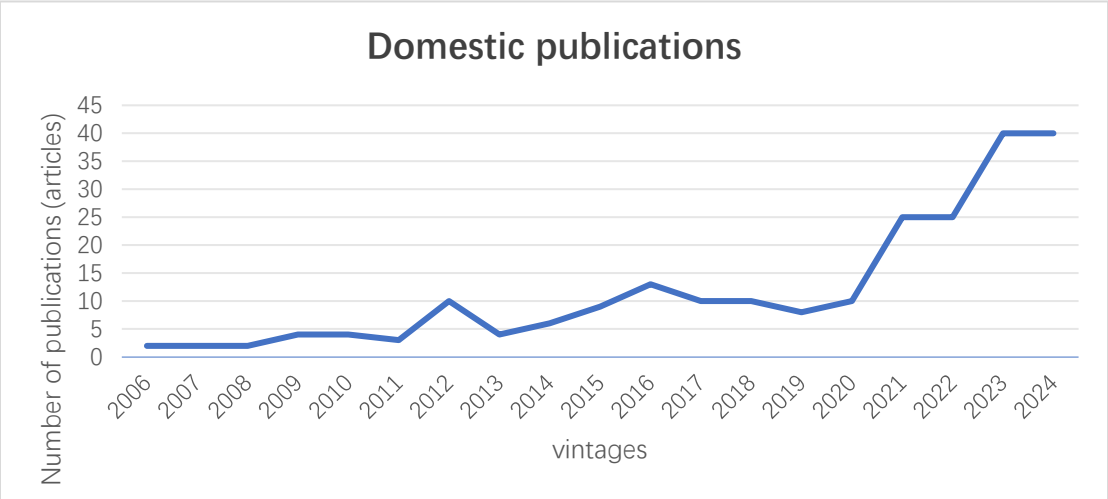

Figure 1. Digital Competency Postings for Teachers in the Country

From **Figure 2.** It can be seen that the volume of foreign digital competence publications also shows three stages of

development and change: (1) a slow fluctuating upward trend from 2008 to 2018, with the volume of publications growing from 1 in 2008 to 6 in 2018; (2) a straight-line upward trend from 2018 to 2019, with the volume of publications growing from 6 in 2018 to 40 in 2019; and (3) a rapid increase in the volume of research on digital competence during the the timeframe of 2019 to 2024 (note that the 2024 data is as of July, but has shown continued growth), the number of research publications on teacher digital competency has shown a rapid increase. Specifically, the number of publications has grown significantly from 40 in 2019 to 163 in 2023, a growth trajectory that clearly reflects the increasing activity and deepening of research activity in this area. Particularly noteworthy is the turning point in 2020, when the number of publications makes a dramatic leap from 40 to 85, which, as analyzed in the literature, highlights the strong interest of researchers in this topic as a result of the global epidemic that is driving the development of online teaching and learning, which, in turn, is placing new demands on the digital competence of teachers.

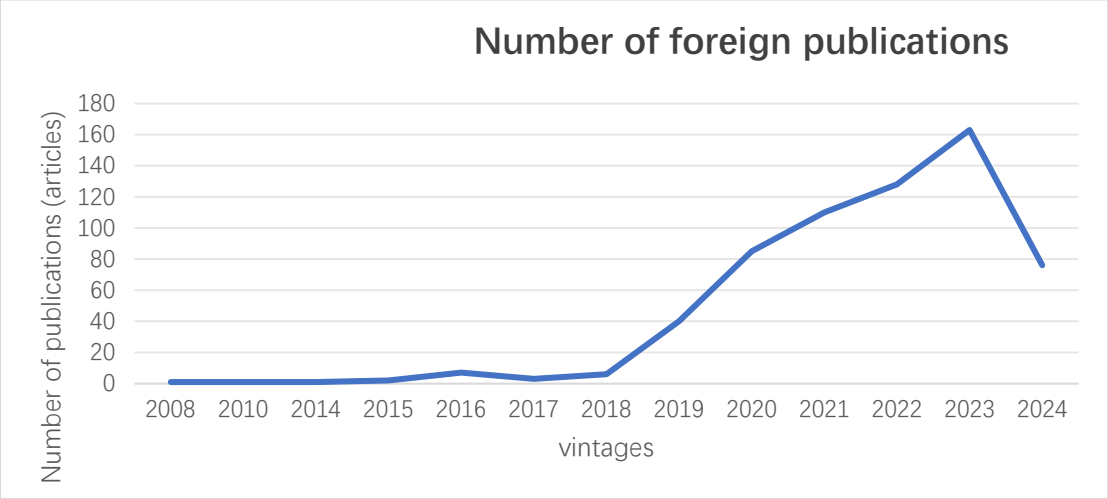

Figure 2. Digital Competency Postings by Foreign Teachers

3.2. Analysis of the Authors of Publications

Using the CiteSpace tool, a collaborative network of authors in the study of teachers' digital competence was constructed, and a table of the top 10 authors in terms of the number of publications was compiled to quantitatively analyze their contributions and influence. Specifically, the statistical results of domestic and foreign authors' posting volume (top 10) are displayed in Table 1 and the network mapping of domestic and foreign authors are presented respectively in**Figure 3.** and**Figure 4.** in Figures 3 and 4, respectively.

Table 1. Number of publications by domestic and foreign authors (top 10)

serial number	volume of publications	Name of domestic author		serial number	volume of publications	Name of foreign author
1	5	Yan Hanbing		1	21	Cabero-almenara, Julio
2	4	Wang Wei Jun (1935-1989), Chinese communist leader, a martyr of the Cultural Revolution		2	18	Palacios-rodriguez, Antonio
3	3	Tang Yuanbin		3	14	Guillen-gamez, Francisco D
4	3	Zheng Xudong (1930-), Chinese-American physicist, astronomer and mathematician		4	9	Llorente-cejudo, Carmen
5	3	Li Xiaodong (1965-), PRC film director		5	8	Barroso-osuna, Julio
6	3	Yang Lei		6	8	Ruiz-palmero, Julio
7	3	Han Seok Bin		7	7	Pozo sanchez, Santiago
8	3	Diao Junfeng (1936-), third governor of Hainan		8	7	Dias-trindade, Sara
9	3	Liu Qingtang		9	7	Lopez Belmonte, Jesus
10	3	Guo Shaoqing		10	5	Mendez, Vicente Gabarda

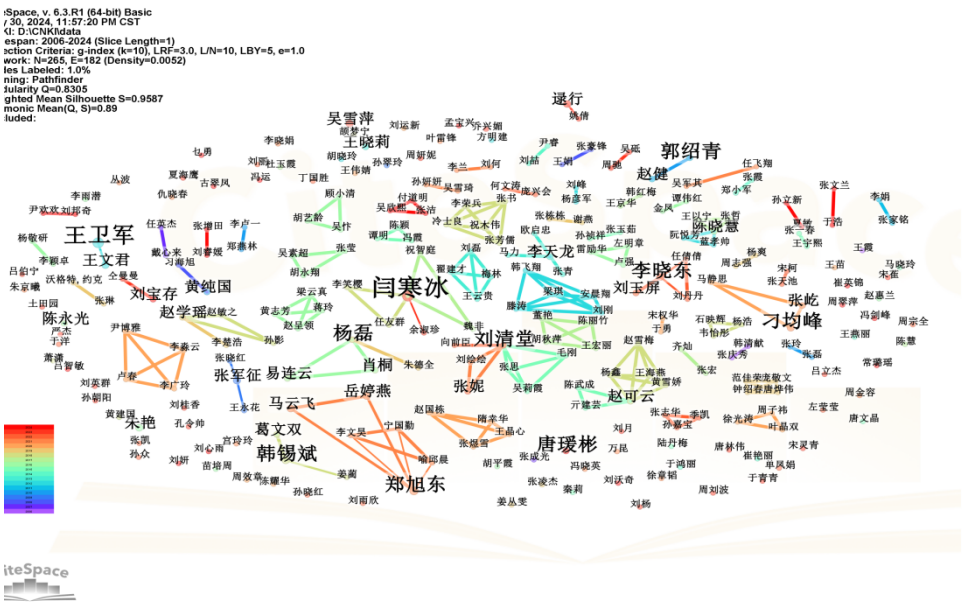

Figure 3. Network mapping of authors of domestic publications

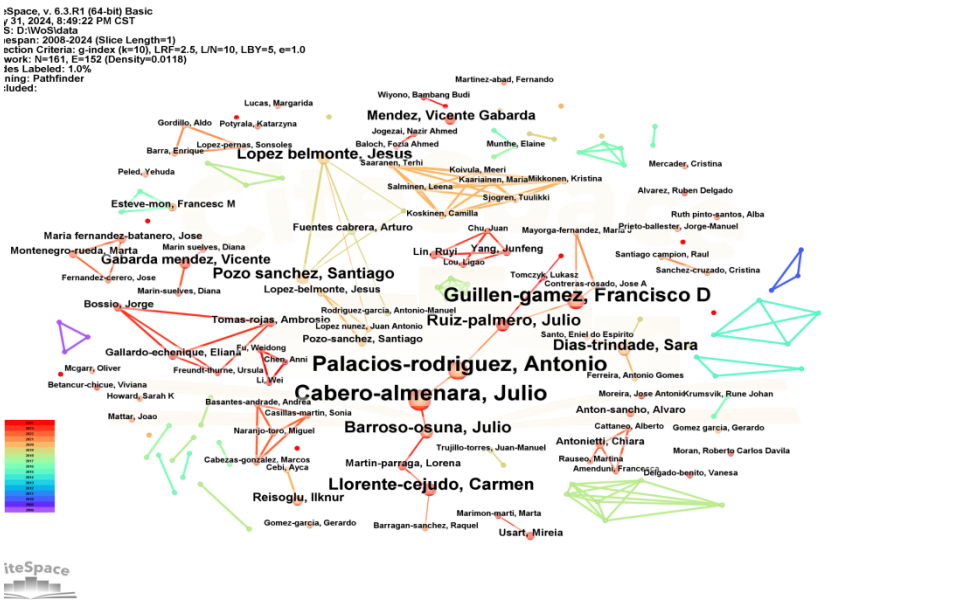

Figure 4. Network mapping of foreign authors

In the author cooperation network mapping, the connecting lines between nodes visualize the degree of cooperation between authors, with thick lines indicating close cooperation and thin lines reflecting looser cooperation. If two nodes are not connected to each other, it means that there is a lack of direct cooperation between the corresponding authors. The color variation of the connecting lines maps the duration of the collaboration, as shown in the color legend in the lower left corner, the gradient from red to purple represents the collaboration history from 2024 back to the starting year of the study. Meanwhile, the font size of an author's name is proportional to the number of their publications, with a larger font size representing a more significant contribution to the field, and vice versa, indicating a relatively small number of publications.

According to Table 1 The number of publications by domestic authors and**Figure 3.** network mapping of domestic authors who have published articles, the following conclusions can be drawn:(1) In terms of the number of articles published, Yan Hanbing is in the first place with five articles published, followed by Wang Weijun with four articles published. These two teachers appear to be particularly active in exploring teachers' digital competence, and their research results have a high impact in this field, so it can be said that they are an important force to promote the research on teachers' digital competence in China to move forward; (2) in terms of author collaboration, there are more collaborations between authors, mostly between two people, with more collaborating authors such as Zheng Xudong and Yan Hanbing; (3) in terms of author cooperation time, research cooperation teams appeared in the early stage, such as Huang Cunguo and Xi Haixu, Han Qingxian and Zhang Qingxiu.

By Table 1 Volume of publications by foreign authors and Figure 4. Mapping of the network of foreign authors who have published, the following conclusions can also be drawn: (1) in terms of the number of publications, the highest number of publications is by Cabero-almenara, Julio (21), followed

by Palacios-rodriguez, Antonio (18), two scholars who have demonstrated a great deal of interest in the area of digital competence of teachers ; (2) In terms of author collaborations, numerous research collaboration teams have been formed, such as those dominated by Pozosanchez, Santiago and Lopezbelmonte, Jesus. It is also worth mentioning that there is basically collaboration between authors with high publication volume, such asauthors Cabero-almenara, Julio, Palacios-rodriguez, Antonio, Guillen-gamez, FranciscoD; (3) In terms of the timing of author collaboration, in the early days, collaborative research teams began to appear in this field. And in recent years, such collaborative teams have emerged even more, and mostof them are in the form of multi-authored combinations. For example, the collaborative team of Bossio, Jorge and Gallardo-echenique, Eliana.

3.3. Analysis of Issuing Bodies

Launch CiteSpace, select the "Institution" node to generate a network map of domestic and international organizations, and export the corresponding frequency data to create a table. The details of the top 10 domestic and international research institutions in terms of the number of articles published are shown in Table 2. The network diagrams of domestic and foreign research institutions are shown in Table 2.**Figure 5.** and figure 6.

Table 2. Number of articles issued by domestic and foreign issuing organizations (top 10)

serial number	volume of publications	Name of domestic organization		serial number	volume of publications	Name of foreign organization
1	6	Department of Educational Information Technology, East China Normal University		1	44	University of Sevilla
2	5	School of Educational Technology, Northwest Normal University		2	35	University of Granada
3	5	Tsinghua University Graduate School of Education		3	26	Universidad de Malaga
4	5	Central China Normal University (CCNU)		4	21	Ministry of Education & Science of Ukraine
5	5	School of Educational Information Technology, Central China Normal University		5	19	University of Salamanca
6	4	College of Open Education, East China Normal University		6	18	University of Valencia
7	4	School of Educational Technology and Communication, Northwest Normal University		7	15	Universitat Rovira i Virgili
8	4	East China Normal University (ECNU)		8	13	Universidad de Extremadura
9	4	Teacher Education Research Center, Beijing Normal University		9	13	Universidad Internacional de Valencia VIU
10	4	East China Normal University		10	12	Universidad de Cordoba

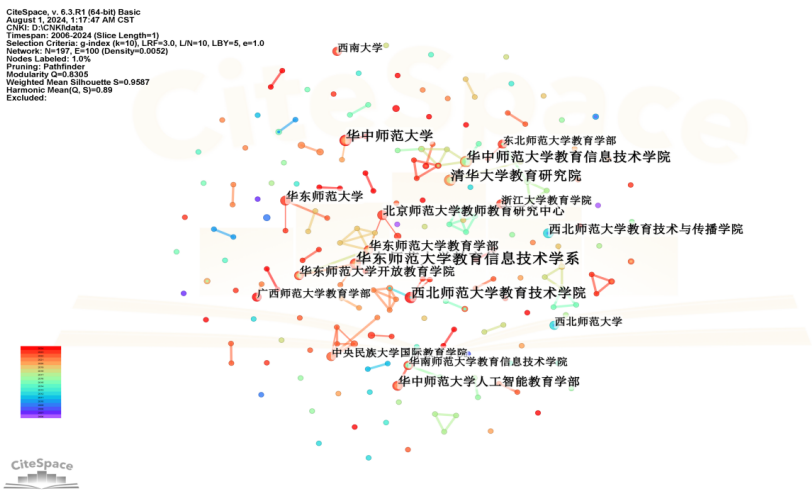

Figure 5. Mapping of the network of national author organizations

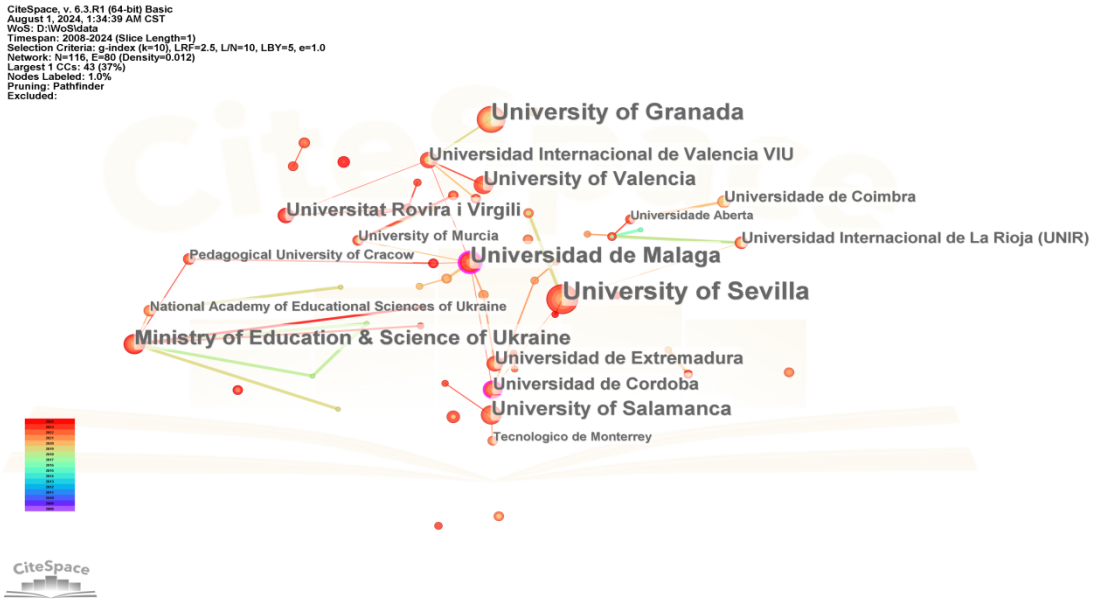

Figure 6. Network mapping of foreign sending organizations

In network mapping, the font size of an organization's name directly reflects the frequency of its messages, with larger fonts indicating more frequent messages. The thickness of the connecting lines between institutions maps the closeness of collaboration, with thick lines indicating frequent collaboration and thin lines vice versa. The timing of the collaboration can be interpreted by the color gradient (red to purple) of the legend in the lower left corner of the atlas, which represents the year of the institution's initial communication back from 2024.

By Table 2 Volume of articles issued by foreign issuing organizations and **Figure 5.** network mapping of domestic issuing institutions, it can be seen that the Department of Educational Information Technology of East China Normal University topped the list with 6 articles, highlighting its leading position in the research of teachers' digital competence, especially focusing on the investigation and assessment of teachers' digital competence. They are followed by the School of Educational Technology of Northwest Normal University (5 articles) and the Institute of Educational Research of Tsinghua University (5 articles). The analysis shows that the main issuing institutions of China's teacher digital competency research are highly concentrated in major universities and their different colleges, demonstrating the concentrated contribution of universities in this field, reflecting the interdisciplinary and diversified research posture, and helping to promote the integration of resources and innovation. **Figure 5.** The text in the upper right corner shows that the network density of the issuing institutions is 0.0052 (Density=0.0052), revealing the existence of certain cooperative links among the issuing institutions. Among them, East China Normal University (ECNU), Teacher Education Research Center of Beijing Normal University (BNU), and Department of Educational Information Technology of East China Normal University (ECNU) are the main collaborating institutions, and their collaborative activities are mainly concentrated after 2015.

By Table 2 Volume of articles issued by foreign issuing organizations and

Figure **6.** The network mapping of foreign publishing institutions shows that University of Sevilla tops the list with 44 articles, highlighting its scientific research advantage, followed by University of Granada (35 articles) and Universidad de Malaga (26 articles), which are also dominated by colleges and universities. Collaboration between foreign institutions is equally strong, with a high density of networks. Institutions such as Universidad de Malaga have a long history of collaboration, while University of Sevilla and others have been active in recent years and have notable post-2020 collaborations.

3.4. Analysis of Research Hotspots

3.4.1. Keyword Co-occurrence Analysis

Keyword co-occurrence analysis is the core step of literature research, aiming to analyze the distribution of hot topics in the research field and the future development trend of the discipline. Using CiteSpace software, we set the year as the time slicing unit and selected "keyword" as the node type to construct the co-occurrence network map of keywords at home and abroad. Further, the top 10 keywords with the highest frequency of occurrence were filtered and exported to form a table (Table 3) for clear presentation. These high-frequency keywords not only reflect the current research hotspots, but also provide clues for predicting the dynamics of the discipline. The keyword co-occurrence network mapping between domestic and foreign countries (**Figure 7.** vs. **Figure 8.**) Visualize the research focus and association structure in their respective fields, which provides strong support for in-depth analysis and comparison of domestic and foreign research trends.

Through in-depth analysis of the domestic keyword co-occurrence network mapping and frequency table, it was found that the field of teachers' digital competence covered a total of 202 keywords (N=202), between which there existed 252 connecting lines (E=252), forming a tightly interconnected network with a network density of 0.0124 (Density= 0.0124).

This network structure indicates that the keywords are more closely interconnected, reflecting the diversity and intertwined nature of the research topics. In the graphical presentation, the scale of the keyword nodes intuitively reflects the frequency of their appearance, and a higher

frequency represents a higher degree of research fervor in the field.

Table 3. Frequency table of domestic and foreign high-frequency keywords (top 10)

Domestic Keyword Frequency Chart					Foreign Keyword Frequency Chart			
serial number	frequency	centrality	byword		serial number	frequency	centrality	byword
1	41	0.32	digital literacy		1	256	0.59	digital competence
2	19	0.59	principals		2	112	0.06	ict
3	11	0.04	teaching ability		3	111	0.02	education
4	10	0.22	vocational school		4	109	0.19	teacher training
5	9	0.49	Higher Education Teachers		5	107	0	higher education
6	9	0.17	Teacher training		6	95	0.11	technology
7	9	0.06	information technology		7	70	0.09	students
8	7	0.46	informatization (the Information Age analog of industrialization)		8	55	0.53	information
9	7	0.24	information literacy		9	53	0.07	digitalliteracy
10	6	0.13	development strategy		10	48	0	competence

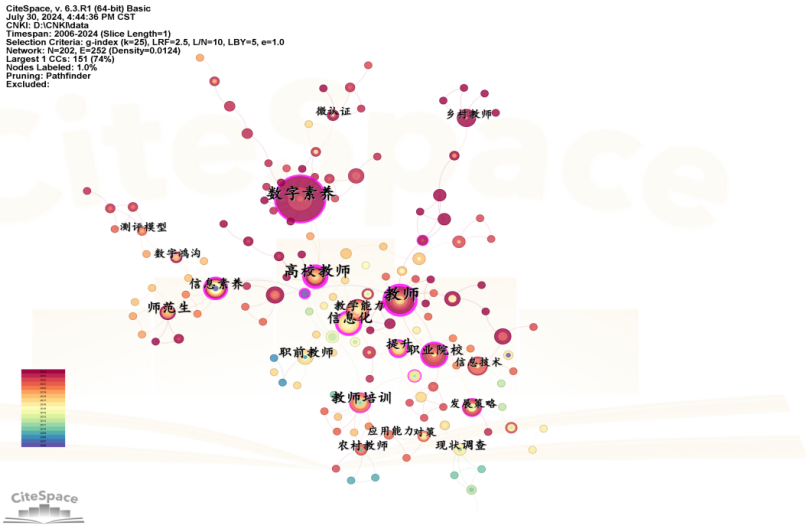

Figure 7. Domestic keyword co-occurrence network mapping

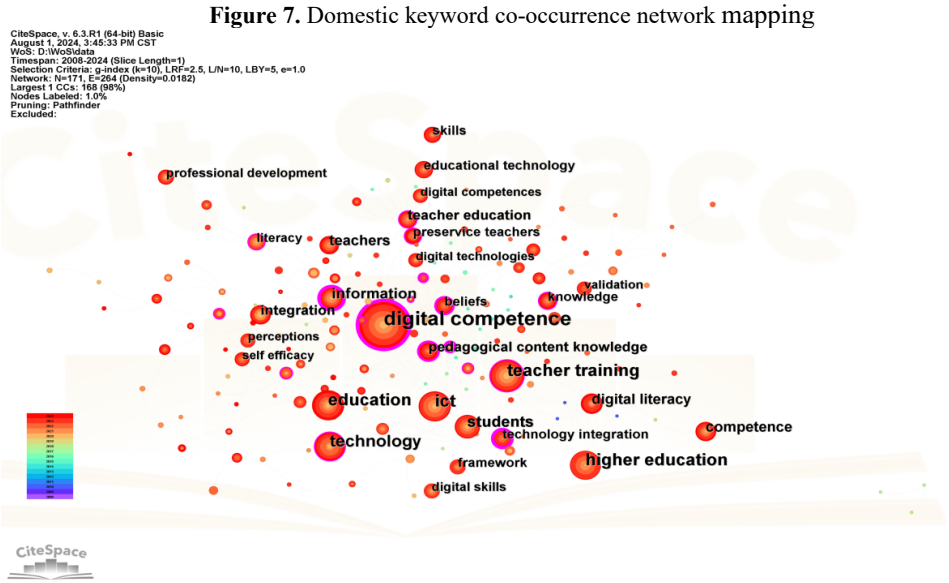

Figure 8. Keyword co-occurrence network mapping in foreign countries

Specifically, keywords such as digital literacy, college teachers, teachers, vocational colleges and universities, teaching ability, and information technology have become hot research topics in China due to their high frequency of occurrence. Further analyzing Table 3 data, it is found that "digital literacy" occupies an important position with a frequency of 41 times and a centrality of 0.32, while "teacher" highlights its central position with a frequency of 19 times and a centrality of 0.59, and "vocational institutions" and "higher education institutions" and "teaching ability" are the most important keywords in domestic research. Meanwhile, "vocational schools" and "college teachers" also become the focus of research with higher frequency and centrality respectively, and these data together reveal the main direction of the research on teachers' digital competence in China.

On the contrary, the keyword co-occurrence network in the field of teachers' digital competence also demonstrated a high degree of correlation, containing 171 keywords (N=171) and 264 connecting lines (E=264), with a network density of 0.0182 (Density=0.0182), which indicates that foreign research in this field also presents a tight keyword linkage network. Among the high-frequency and highly researched keywords, digital competence, ict, education, and teacher training are particularly prominent. By analyzing the **Table 3** Through in-depth analysis of the frequency and centrality of keywords in China and abroad, we find that the keywords "digital competence", "teacher training" and "technology" are particularly prominent in the network of high-frequency and highly researched keywords. technology" have a centrality of more than 0.1, which further confirms their importance in foreign research on digital competence and reveals the research hotspots and trends in this field.

3.4.2. Keyword Clustering Analysis

Based on the co-occurrence network graph, Log-likelihood ratio (LLR) algorithm is applied to categorize closely related keywords, and then form different research clusters. In-depth analysis of the structural characteristics of these clusters, the core nodes, and the tightness of the association between them can be used to observe the core areas and development directions of the research subject from a macroscopic point of view.

For the clustering analysis of domestic keywords, the corresponding network mapping was constructed, as shown in **Figure 9.** shown.

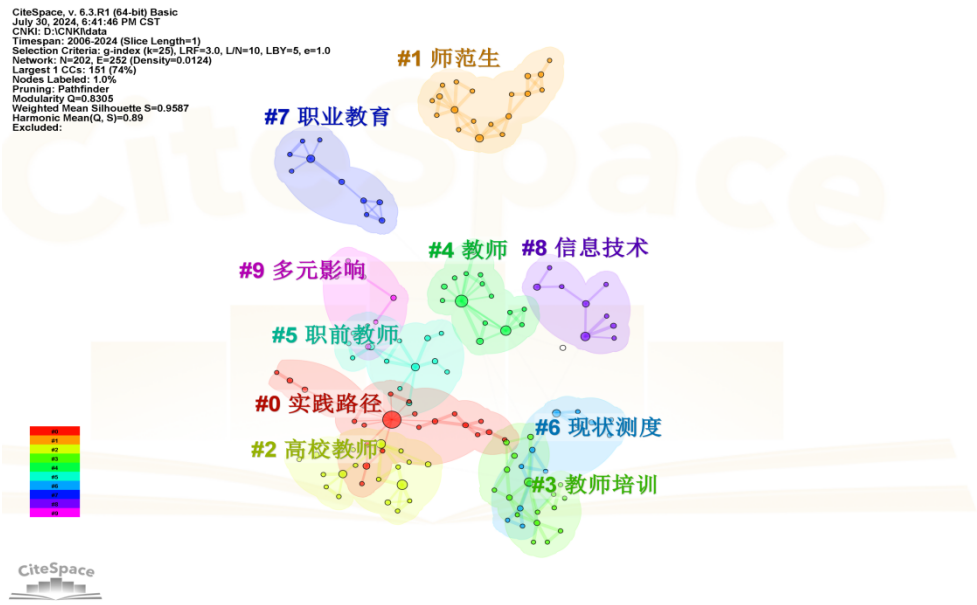

Figure 9. Domestic keyword clustering network mapping

In the academic field, a Q value of more than 0.3 indicates significant clustering and an S value of more than 0.7 indicates high clustering confidence. **Figure 9.** In the upper right text, it shows that the Q value is 0.8305 and the S value is 0.9587, which both satisfy the conditions. Therefore, the results of domestic keyword clustering analysis are credible. The results of clustering analysis of domestic keywords by**Figure 9.** it can be seen that there are 10 clusters formed, which are #0 practice path, #1 teacher trainee, #2 college teacher, #3 teacher training, #4 teacher, #5 pre-service teacher, #6 status quo measurement, #7 pre-service education, #8 information technology, and #9 multiple influences. Organizing and summarizing the clusters, the research hotspots can be classified into the following 3 areas.

(1) Research on the current status of teachers' digital competence. This research hotspot mainly contains the keywords #1 teacher trainees, #2 college teachers, #5 pre-service teachers, #6 status quo measurement, and #7 vocational education. The hotspot has three sub-themes: the investigation of digital competence of teachers in different regions of China, at different educational levels, and in different teacher specialties. However, studies on each sub-theme may overlap. From different regions, Song Quanhua, Yu Yong (2020)[6] and Li, Tianlong, and Ma Li (2013)[7] investigated the current status of information technology literacy of college teachers in some colleges and universities in the western region of China and Xi'an region, respectively. From different educational levels, Zheng Yanlin,Li Luyi (2010)[8] , Zhang Shu, Leng Shiliang, Li Rongbing, et al. (2018)[9] and Li Yuqian (2016)[10] investigated the informatization teaching ability of teachers in primary and secondary schools, higher vocational schools, and universities in China, respectively. From different teacher specialties, Wang Jinghua,Han Hongmei (2017)[11]

investigated the current status of informatization teaching ability of English teachers in colleges and universities.

(2) Research on the development and enhancement of teachers' digital competence. This research hotspot mainly contains keywords such as #0 practice path and #3 teacher training. In the cultivation and enhancement of teachers' digital competence, scholars have proposed customized cultivation models for teachers at different educational levels, such as primary and secondary schools, teacher trainees, pre-service teachers, vocational education teachers, and college teachers. For example, Zhang Qingxiu, Han Qingxian (2006)[12] and Sun Cuiling (2009)[13] proposed targeted training methods through specific cases. Zhang Lin, York Vogt (2019)[14] By drawing on the experience of the Netherlands, it is proposed that the success of the model of integrating disciplines to cultivate teacher trainees' informationized teaching competence relies on integrating the strengths of the three levels of disciplinary teacher educators, the management of disciplines, and the management of the teacher education colleges. Ou, Qizhong, Zhang, Qing (2013)[15] , Zhao Koyun, Qi Jianyun, Chen Wucheng (2015)[16] and Zeng Guoquan, Wang Guangqiang, Song (2023)[17] proposed a cultivation path of informatization teaching ability for primary and secondary school teachers. Zhou, Cuiping, Tao, Mengzhu, Cao, Yan, et al. (2024)[18] Based on the empirical study of community education teachers in S city, the improvement strategy of digital literacy of community education teachers is proposed.

(3) Research on the measurement model of teachers' digital competence. This research hotspot mainly contains keywords such as #4 teachers, #8 information technology, and #9 multiple influences. Yang, Shuang, Zhou (2019)[19] A digital literacy evaluation index system for college teachers was constructed, covering five dimensions of digital technology application, digital information management, digital content creation, digital community construction, and digital security ability, totaling 18 specific digital literacy evaluation indexes. Yang, Lei, Zhu, Dequan (2019)[20] After clarifying the meaning and composition of informatization learning power, we developed an assessment tool - "Teachers' Informatization Learning Power Assessment Questionnaire" and constructed the corresponding teachers' informatization learning power assessment model. Wang Xiaojun, Zhao Wenping (2024)[21] Based on the literature research, the interview data were analyzed in depth using the rooting theory, and the preliminary structural dimensions of digital literacy of teachers in vocational colleges and universities were constructed.

For the clustering analysis of foreign keywords, the corresponding network mapping was also constructed, as shown in **Figure 10.** shown.

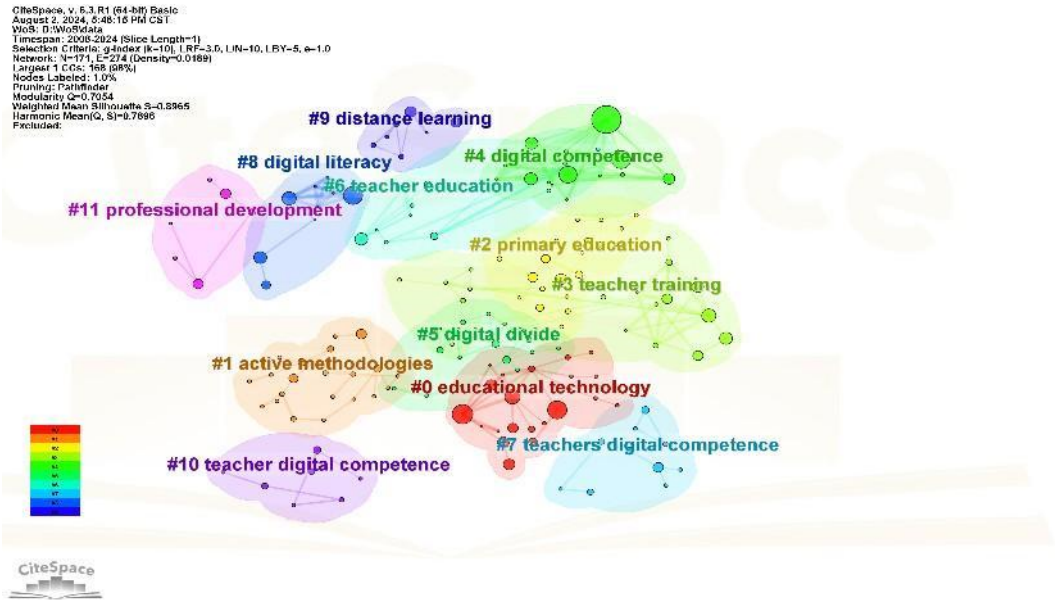

Figure 10. Network mapping of foreign keyword clustering

In**Figure 10.** the upper right corner can also be seen that the Q value reaches 0.7054 and is significantly higher than the benchmark of 0.3, while the S value is also as high as 0.8965, which is far beyond the standard of 0.7. These two points fully indicate that the results of the cluster analysis of foreign keywords also have a high degree of credibility. Figure 10 visualizes the results of the analysis, forming 12 clusters, each of which represents a different research field or direction. These are: #0 educational technology, #1 active methodologies, #2 primary education, #3 teacher training, #4 digital competence, #5 digital divide, #6 teacher education, and #7 teachers' digital teacher education, #7 teachers' digitalcompetence, #8 digital literacy, #9 distance learning, #10 teacher digital competence, #11 professional development. The clusters were organized and summarized to classify the research hotspots into the following 3 areas as well:.

(1) Research on the assessment of teachers' digital competence. This research hotspot mainly contains keywords such as #0 educational technology, #1 active methodologies, and #4 digital competence. Studies on the assessment of teachers' digital competence are mainly categorized into self-assessment and other-assessment. santo, ED; de Lima,TPP and Oliveira, AD (2021)[22] A generic self-assessment framework based on the digital competencies of teachers analyzes the digital competencies needed by teachers. Alarcón,R;Jiménez,ED and de Vicente-Yagüe,MI (2020)[23] A tool to assess the digital competence of educators was developed: the DIGIGLO questionnaire, which was validated as a valid and reliable instrument to assess the digital

competence of educators in the eight domains considered (the six domains covered by the European Framework for Digital Competence of Educators and the two new domains corresponding to the externalities of the digital competence of educators).

(2) Teachers' digital competence research study. This research hotspot mainly contains keywords such as #2 primary education, #5 digital divide, #7 teachers' digital competence, #8 digital literacy, #9 distance learning. McGarr, O and McDonagh, A (2021)[24] An online survey was used to explore the digital competence of recent entrants to a pre-service teacher education program at an Irish university.Bitemirova,S;Zholdasbekova,S;(...) ;Zhanbirshiyev,S (2023)[25] Translation and validation of the Digital Competence Scale for Undergraduates in Kazakhstan for the Diploma for Educators in Technical and Vocational Education and Training (TVET) and discovery of the current state of their digital competence. The results showed that participants reported a moderate digital competence score.

(3) Research on the training and development of teachers' digital competence. This research hotspot mainly contains keywords such as et #3 teacher training, #6 teacher education, #10 teacher digital competence, #11 professional development, etc. Lucas,M; Dorotea,N and Piedade,J (2021)[26]. Analyzed the contribution of three continuous professional development courses to the improvement of teachers' digital competence. The results showed that the contribution was positive, with increased proficiency in all competencies and competency areas explored during the sessions.Marimon-Martí,M;Valero,JAS and Fernández,MAP (2023)[27] pointed out the need to propose a series of indicators of expert judgment that are aligned with the TDC Common Framework and that could be used to develop guidelines for initial teacher training.

3.5. Research Frontier Analysis

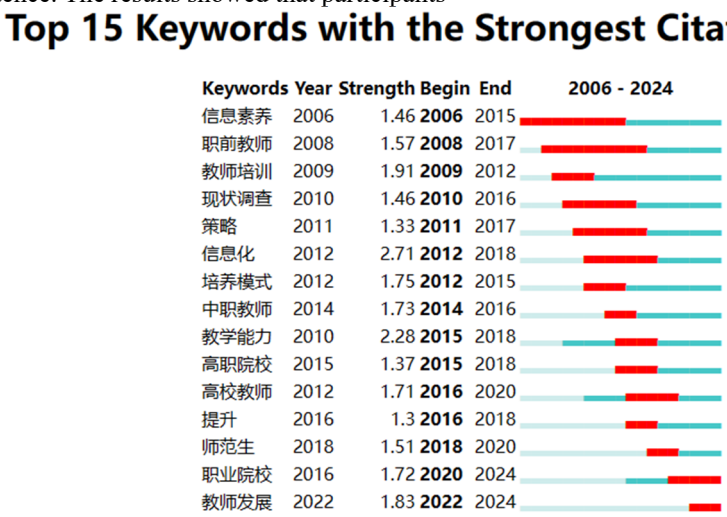

Figure 11. Domestic keyword emergence map

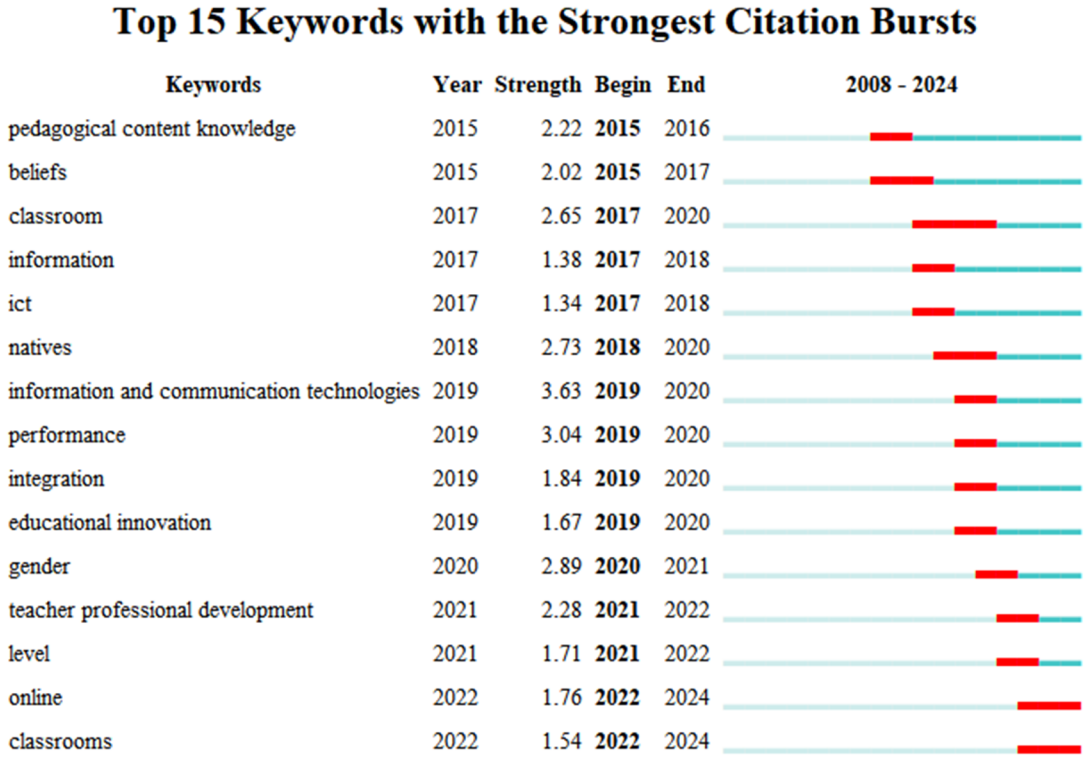

Figure 12. Keyword emergence map of foreign countries

The emergent words refer to keywords whose frequency of occurrence in the research field increases dramatically in a specific period of time, which can reveal the dynamics of the field. For the literature in the field of teachers' digital competence, a keyword emergence analysis was implemented, and two versions of the keyword emergence map at home and abroad were drawn accordingly. Among them, the domestic part of the emergence map is as follows **Figure 11.** and the one for the foreign part is shown in **Figure 12.** is shown. These charts effectively reveal the hotspot variation and trend development of this field in both domestic and foreign research.

In terms of the emergence of the keyword of digital competence for teachers in China, "information literacy" became the focus of attention as early as 2006, marking the beginning of a more in-depth exploration of the development of this competence for teachers in China's education sector. At that time, scholars and educators have focused on information literacy, from the definition, status quo survey to the evaluation system and other dimensions of a wide range of research, this stage can be regarded as the initial exploration of the development of digital competence of teachers. In recent years, the continued emergence of the keywords "vocational schools" and "teacher development" has revealed the new trends and frontiers of current research on teachers' digital competence. Since 2020 and 2022, these two keywords have been at the center of research, reflecting the education field's great concern for the growth and development of specific groups and individual teachers. An in-depth analysis of this phenomenon reveals multiple motivations behind it:(1) educational policies have promoted the digital competence of teachers in vocational colleges and universities, who play an indispensable leading role in the development and implementation of information curricula, as well as in educational and teaching activities; (2) students have turned to online learning during the epidemic, which has also raised the demand for teachers' digital teaching competence; (3) in the digital era, teachers' professional development has entered a new stage, and digital literacy has become a key element in shaping the modernity of teachers' subject literacy. In addition, in terms of frequency, the term "informatization" has the highest frequency (intensity: 2.71), making it the most influential academic frontier. There is a mutually reinforcing and interdependent relationship between digital technology and informatization. Informatization constitutes the basis for the development of digitization, while digitization is the advanced form of the development of informatization, and the two are not clearly differentiated in the research theme. At present, scholars in China have shown strong interest in research in the field of informatization.

The emergence of foreign keywords of teachers' digital competence, in terms of the emergence time, "pedagogical contentknowledge" "beliefs" has the earliest emergence time, starting in 2015, this period of time Scholars focused on research directions such as teachers' pedagogical content and beliefs about teachers' digital competence. The emergence of "online" and "classrooms" lasted from 2022 to the present, and it is the current research frontier in the field of digital competence of foreign teachers, which is mainly due to the impact of the epidemic that has changed the traditional teaching methods. The emergence of this research frontier is mainly due to the impact of the epidemic, which has changed the traditional way of teaching, and teachers are mainly teaching in online classrooms, which has led to an increase in the research on teachers' digital competence. In terms of the strength of emergence, "information and communication technologies" has the strongest emergence (Strength: 3.63), jumping to the forefront of the research, with a significant impact, and the use of ICTs by teachers to accomplish their teaching is the fundamental reason for this.

4. Conclusion

(1) From the data of Chinese and English papers published, scholars at home and abroad have gradually deepened their research on teachers' digital competence, and domestic and foreign researchers represented by Yan Hanbing and Cabero-almenara, Julio respectively have made the most in-depth research on the field of teachers' digital competence and contributed the most. The research institutions at home and abroad in this field are mainly dominated by the Department of Educational Information Technology of East China Normal University and the University of Sevilla. And there is close cooperation between domestic and international authors and institutions, forming a complete cooperation team.

(2) From the analysis of research hotspots and frontiers, the overall research trend in China focuses on the investigation of the current status of teachers' digital competence, cultivation and enhancement, and measurement modeling, while the foreign countries focus on the investigation, cultivation and enhancement, and assessment research of teachers' digital competence. At present, the research frontiers of digital competence of teachers in China are vocational colleges and universities and teacher development, while in foreign countries are online and classrooms, and information and communication technologies have become the most influential research frontiers. In the future, the development and enhancement of teachers' digital competence should be the main development direction of the field of teachers' digital competence, especially focusing on teachers in vocational colleges and universities.

(3) The data used in this study comes from the huge databases WoS and CNKI, so there may be some missing data after searching. Secondly the selected time span is from 2006-2024, the research scope is broader and only relatively important information is analyzed, which may lead to the analysis is not comprehensive enough, in the future, the author will continue to improve in the study of teachers' digital competence, and hope that it can provide thinking for the research field related to teachers' digital competence.

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