



The Current State of Digital Literacy Research in China: A Literature Review

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Abstract: The purpose of this study is to analyse the current research status, hotspots and development trends of teachers' digital literacy in China. The article uses Citespace to visualize and analyse 1,129 relevant Chinese literature published between 2007 and 2024 in China Knowledge Network CNKI. The study found that (1) the research on teachers' digital literacy in China started in 2007 while the number of studies has increased significantly in recent years as well as the research topics have become increasingly diversified. (2) The research hotspots mainly

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focus on the connotation of digital literacy, the necessity of cultivation, the relationship with rural revitalization, and the strategies for improving digital literacy in higher education and basic education stages. Based on the research results, this paper puts forward suggestions with a view to providing valuable references and lessons for the development of the enhancement of teachers' digital literacy in China.

Keywords: digital literacy, teachers, literacy review, research progress

1. Introduction

In today's fast-changing digital technology, digital literacy has jumped up to become a key element in measuring individual competence and social progress.

Gilster (1990) designed the concept of digital literacy in the book *Digital Literacy*. Israeli scholar Eshet-Alkalai (1994) summarized that the main content of digital literacy contains five aspects: picture-image literacy, recreation literacy, branching literacy, information literacy, and social-emotional literacy. With the popularization of the Internet of Things and Artificial Intelligence and the rapid progress of digital technology, digital literacy not only affects individual learning and work efficiency, but also largely determines the economic competitiveness and social progress of a country and region. The global digital literacy framework contains seven digital competency domains and twenty-six specific competencies (Zhang & Sheng, 2019). The education system has an important responsibility in developing digital literacy. China's education system is in a critical period of digital transformation, and there is an urgent need to accelerate the process of improving teachers' digital literacy.

The Central Committee for Cybersecurity and Informatization issued (2021) the *Outline of Action for Enhancing Digital Literacy and Skills for All People*. The document defines “*digital literacy and skills*” as “*a collection of qualities and abilities such as digital access, production, use, evaluation, interaction, sharing, innovation, safety and security, ethics and morality, etc. that citizens in the digital society should have for learning, working and living*”. This may be the first time that “digital literacy” is clearly defined in an official document in China, and also reflects China's generalization and summary of the concept of digital literacy at home and abroad (Liu & Cen, 2023).

The Central Internet Information Office, the Ministry of Education and other four departments jointly issued (2022) the “*Key Points for Enhancing Digital Literacy and Skills of the Whole Population in 2022*”, which puts forward the number of “high-quality courses for basic education” as the main indicator. In the same year, the Ministry of Education of China released the “*Teachers Digital Literacy*” standard, which mentions that the framework of teachers' digital literacy includes five aspects: digital awareness, knowledge and skills of digital technology, digital application, digital social responsibility and professional development (Ministry of Education of the People's Republic of China., 2022). The Central Office of the Internet Information Office and other four departments issued (2024) the “*Key Points for Enhancing Digital Literacy and Skills of the Whole Population in 2024*”, which clarifies the annual work objectives and deploys 17 key tasks in six areas.

With the introduction and implementation of relevant policies, teachers' digital literacy faces higher requirements. Despite the growing importance of digital literacy, many teachers still encounter many challenges in actual teaching, such as insufficient adaptation to new technologies, lack of information literacy and effective application of digital tools. Therefore, we hope to provide a theoretical basis and practical reference for improving teachers' digital literacy through a comprehensive and in-depth analysis of teachers' digital literacy and exploring the latest developments in this field.

2. Methods

2.1 Inclusion criteria

2.1.1 limited to research related to Chinese teachers' digital literacy.

2.1.2 Articles published on CNKI (China Knowledge Network).

2.1.3 Search by “theme=digital literacy AND theme=education AND theme=teacher OR theme=teacher trainee OR theme=pre-service teacher OR theme=in-service teacher” , exact match.

The search results were organized by removing some entries such as journals unrelated to the topic and no authors, resulting in 1,738 relevant papers spanning the period 2007-2024.

2.2 Research questions

This paper focuses on the following key research questions:

Q1: Analysis of the current situation of research on teachers' digital literacy in China.

Q2: Analysis of hot spots of digital literacy research for teachers in China.

Q3: Analysis of research frontiers and trends of teachers' digital literacy in China.

2.3 Data analysis

We used Citespace 6.3.1 software to visualize and analyze the 1738 articles selected in the previous section. In this paper, we use a variety of visual analysis methods such as literature co-citation, co-occurrence cluster analysis, keyword co-occurrence, keyword clustering, etc. to explore the development process of the research on the improvement of teachers' digital literacy in China (Chen et al., 2015).

This paper adopts the methods of annual analysis graph visualization, visualization of carrier institutions and authors, research theme co-occurrence matrix, and annual cross-analysis visualization of major research themes to analyze the current status of teachers' digital literacy research in China. Keyword co-occurrence analysis, keyword clustering and other methods are used to analyze the hotspots of teachers' digital literacy research in China. The development trend of digital literacy related research is analyzed by keyword chronogram, and the emergent word analysis of keywords is used to explain the emerging trend of research field aggregation.

3. Results

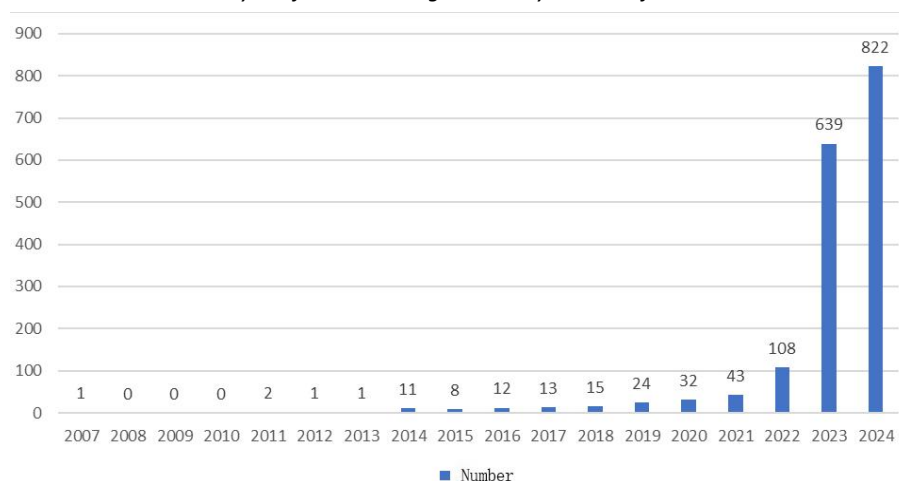
3.1 R1: Analysis of the current situation of research on teachers' digital literacy in China.

3.1.1 Visual analysis of the year in which the article was published

The selected 1738 CNKI literature data were imported into Citespace to get the annual data statistics of the loaded articles, and the data were imported into an Excel sheet to create an annual analysis chart of the loaded articles of the domestic teachers' digital literacy research for visualization and analysis (shown in Fig. 1).

Figure 1

Annual analysis of articles on digital literacy research for teachers in China



China's research on teachers' digital literacy began in 2007 when Liu Qiang (2007) first mentioned the training of teachers' ability to use information technology for teaching and learning in his interpretation of the European Union's digital learning program. China's research on teachers' digital literacy was thus kicked off, but because digital literacy

was not defined as a standard concept in China at that time, there was relatively little research literature in the field from 2007 to 2021, with limited research content and little relevance. In January 2020, in order to interrupt the spread of the new Crown Pneumonia outbreak to campuses, the Ministry of Education issued a delayed start notice and initiated a "The call for stopping classes without stopping teaching and learning", which undoubtedly puts forward higher requirements for teachers' digital literacy, and the epidemic pushes China's higher education teaching from offline teaching to online, Xiamen University Xue Chenglong et al. (2020) pondered on the reform of higher education online teaching steering and coping strategies, to realize the comprehensive enhancement of the teachers' informatization literacy and online teaching ability. The "Action Program for Enhancing the National The issuance of the "Outline of Action for Enhancing Digital Literacy and Skills for All" in 2021, China has a standard definition of "digital literacy and skills", and due to the continued spread of the new crown epidemic has had a huge impact on the education system in all countries around the world, scholars began to make suggestions for online teaching, including more prominent Dong Lili et al. (2021) through the interpretation of the EU's "Digital Education Action Plan (2021-2017)". Digital Education Action Plan (2021-2017) to think about the new picture of digital education in the post epidemic era, elaborating on the current challenges, actions and reflections to realize the overall improvement of teachers' digital competence, digital literacy and digital teaching skills. In addition, Du Yanyan et al. (2021) used the DigComp Edu Check-In survey tool to conduct a small-scale survey and analysis of 464 teachers in two provinces in the north of China, and summarized a variety of effective ways to improve the digital literacy of primary and secondary school teachers, such as improving teachers' perception of the value of digital literacy and meeting teachers' personalized learning aspirations for digital literacy. Immediately after November 2022, the Ministry of Education released the standard of Teachers' Digital Literacy, which includes five first-level dimensions, 13 second-level dimensions and 33 third-level dimensions. In response to the national policy, scholars in China have launched research around teachers' digital literacy, and the number of articles issued in 2023 has been on a straight upward trend, from about double-digit number of articles issued, to more than six hundred articles in 2023, and rising year by year. Overall, although the development of teachers' digital literacy in China is still in the preliminary stage, the importance attached to it has risen sharply in recent years, and the research in related fields has attracted extensive attention.

3.1.2 Institution and author visualization and analysis of the text

Using Citespace software, set the node type of the corresponding data as Institution and Author to draw the analysis graph. In order to facilitate the observation of the analysis graph, this paper sets the number of displays and the size of nodes in Citespace, and at the same time adjusts the position of the nodes in the analysis graph, so that there is as little blocking as possible between the contents of the graph.

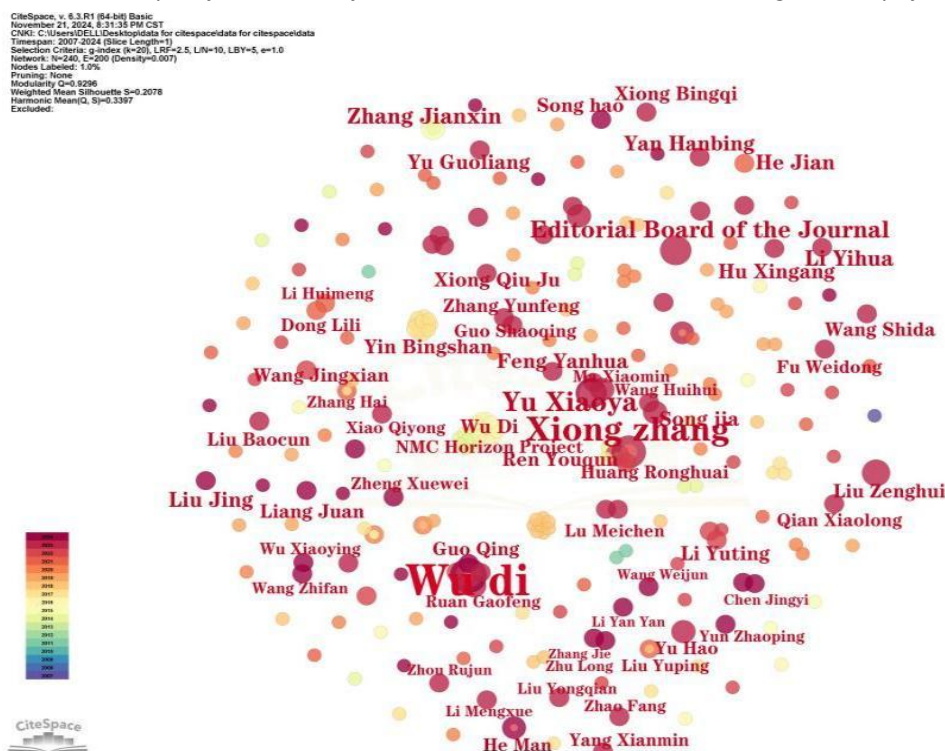
Figure 2

Analysis of the institutions that carry research on teachers' digital literacy in China



Figure 3

Analysis of the authors of the articles contained in the research on digital literacy of teachers in China



We can judge the number of occurrences of the institution and authors by the size of the appearing institution name and author name, the larger the font indicates the greater the number of research outputs in the field, and vice versa the smaller the font is the less. As can be seen in Figure 2, the institutions with the largest output of research literature on teachers' digital literacy in China are the six ministry-affiliated teacher training universities, and the number of articles issued, in descending order, is East China Normal University (53), Beijing Normal University (44), Central China Normal University (43), Southwest University (30), Northeast Normal University (22), Shaanxi Normal University (20), followed by Jiangsu Normal University (19) and Guangxi Normal University (19) tied for seventh. At the same time, the more the number of articles issued, the more the institution's cooperation branch is huge, the top ten institutions in the number of articles issued, except for East China and Central China Normal University, which have more cooperation, the rest of the institutions basically cooperate with teacher training colleges and universities in their own provinces or neighboring provinces. The main institutions engaged in the field of teachers' digital literacy research in China are mostly teacher training colleges and universities, especially concentrated in teacher training colleges and universities directly under the Ministry of Education, and the research departments are mainly colleges of education, colleges of teacher education, colleges of artificial intelligence, and so on. Other provincial teacher training colleges or general teacher training universities have published less relevant literature in this field, and there is very little cooperation with primary and secondary schools around the country.

From this, we can initially conclude that the research on teachers' digital literacy at all levels and types of teacher training colleges across the country is still relatively small, and that many important research topics in this field have not yet been developed.

From Figure 3, we can see that Wu Main (8 articles), Xiong Zhang (7 articles), and Yu Xiaoya (5 articles) are the most prolific in this field, while the rest of the authors have published no more than 5 articles. Wu et al.(2023) has conducted several in-depth studies on the path of teachers' digital literacy enhancement in the context of digital transformation of education, and has interpreted the standard of Teachers' Digital Literacy in depth, which provides ideas and references for the theoretical and practical research on teachers' digital literacy in China from the connotation of teachers' digital literacy, the analysis of the standard of Teachers' Digital Literacy, and the evaluation path of Teachers' Digital Literacy. Xiong et al.(2022), on the other hand, mainly researches the improvement of teachers' digital literacy in information technology courses, and he mentions in From Information Technology to Information Technology - Dialogue on the Compulsory Education Information Technology Curriculum Standards (2022

Edition) that frontline teachers should, on the one hand, teach according to the requirements of the standards and utilize all kinds of teaching resources and, on the other hand, bring into play their own digital literacy and skills, and innovate their own teaching mode. Yu Xiaoya mainly draws inspiration from the analysis of the development of teachers' digital literacy and related policies in foreign countries, and she brings a lot of inspiration for the development of this field in China by studying the characteristics of teachers' digital literacy in four countries, namely, Canada, Japan, South Korea and the United Kingdom (Yu et al., 2023). It can be seen that several of the scholars with the largest number of publications have their own research scope and hardly collaborate with each other. The most cited of the independently issued articles in this field is Yuan Zhenguo's (2023) Digital Transformation of Education: What to Turn, How to Turn, which proposes that the current key tasks of education digitization are to innovate educational scenarios, to develop digital resources, to improve teachers' digital literacy, and to govern digital education with digital thinking. The sparseness of the distribution of nodes in the figure also shows that the communication among scholars is limited to a few high-productivity authors, most of whom come from the same institution, and other authors are not closely connected, and most of the authors are members of colleges and universities or national educational institutions, and there are relatively few primary and secondary school frontline teachers.

Overall, there is a lack of communication and integration between most of the scholars due to the different scopes of research that different scholars focus on, and there is still a need to improve both the depth and popularity of research in this field among primary and secondary school frontline teachers.

3.1.3 Analysis of relevant research themes in the article

This paper categorizes the themes of China's teachers' digital literacy research with the help of the visual analysis tool of China Knowledge Network, and draws a co-occurrence matrix analysis chart of the main themes of domestic teachers' digital literacy research (Fig. 4), as well as an annual cross-analysis chart of the main themes of domestic teachers' digital literacy research (Fig. 5).

Figure 4

Analysis of the co-occurrence matrix of the main themes of digital literacy of teachers in China

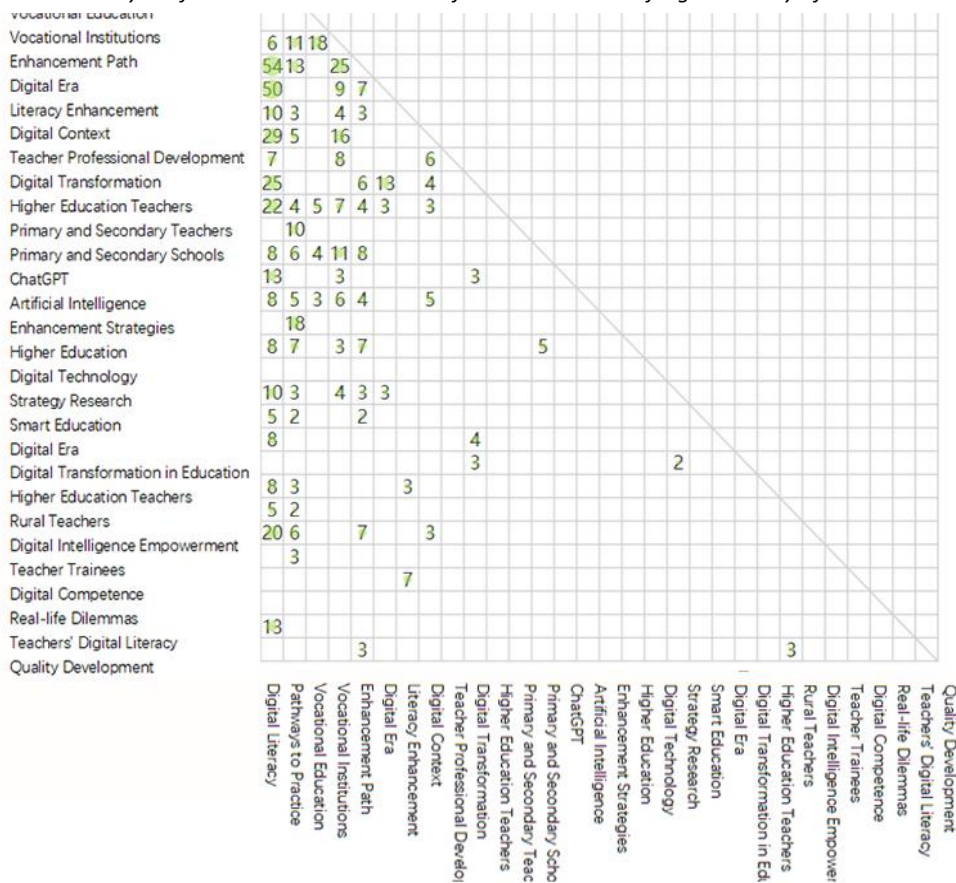
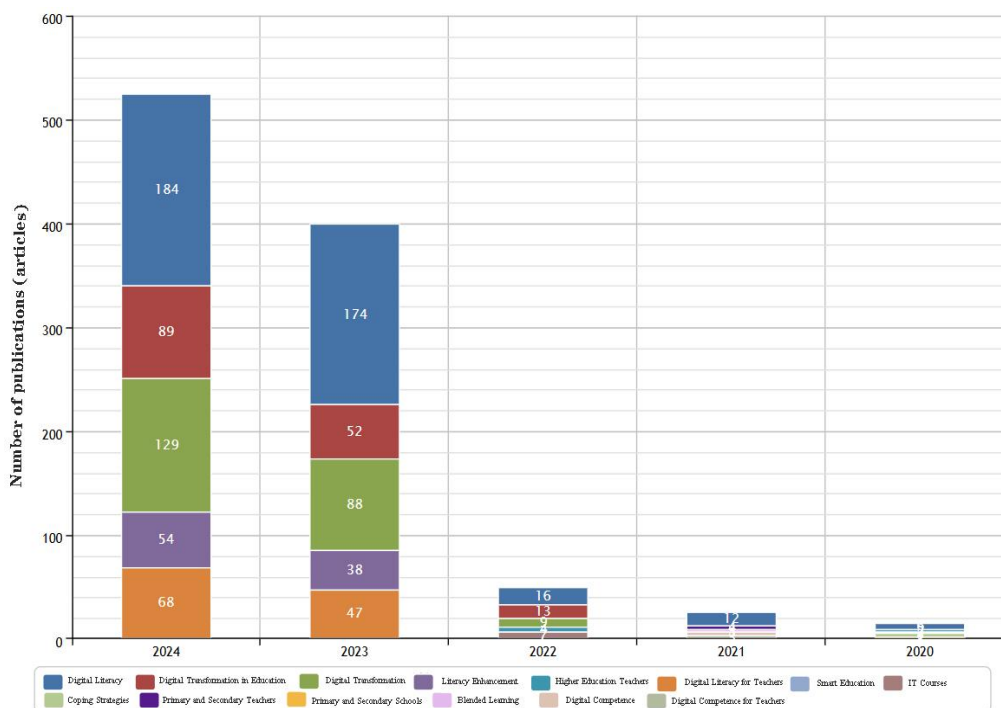


Figure 5

Annual cross-tabulation of the main themes of digital literacy of teachers in the country



As can be seen in Figure 4, under the core theme of “digital literacy”, “enhancement path” and “digital era” are the two most relevant themes. In addition, “practice path”, “digital context” and “digital transformation” are also closely related to this core theme. Among them, the newer research themes include “Artificial Intelligence” and “ChatGPT”. As we all know, the rapid rise of ChatGPT has attracted a lot of attention in the field of education, and its ability to deal with complex teaching tasks is expected to reshape the current teaching model. The leap in artificial intelligence technology not only brings new teaching tools and methods, but also brings complex emotional experiences for teachers' professional development, prompting them to reflect on and update their educational concepts (Kasneji E et al.,2023). Wu et al. (2023) analyzed the opportunities and challenges of ChatGPT for teachers' professional development, and proposed an “motivation-empowerment-promotion-quality-enhancement-effectiveness” approach. ChatGPT empowers teachers' professional development, providing theoretical and practical references for improving teachers' digital literacy. Through these studies, it can be seen that the focus of the research on “improving teachers' digital literacy” is concentrated in the areas of “path”, “digitalization” and “artificial intelligence” and “Artificial Intelligence”.

Figure 5 shows that in addition to the core theme of “digital literacy”, the themes with more research each year include “digital transformation of education” and “digital transformation”, “Literacy Enhancement”, ‘Teachers in Higher Education’, and ‘Teachers’ Digital Literacy’. These themes are the key research directions in the field, and although the number of related documents fluctuates from year to year, the distribution of the number of articles published in each theme has basically remained stable. This shows that “digitalization” and “literacy enhancement” have always been the core issues in the field of teachers' digital literacy enhancement, and have had a profound impact on the development of the field.

3.2 R2: Analysis of hot spots of digital literacy research for teachers in China.

3.2.1 Keyword co-word analysis

(1) Keyword Frequency Analysis

Keywords can be used to describe the main research content and direction of the literature, and if the keywords include the corresponding topic, it means that the literature also belongs to the category of selected literature. In a specific research field, the keywords that appear many times are high-frequency keywords, indicating that scholars have studied the corresponding content more, and this part of the content is also the research hotspot of the field. We

analyzed the exported literature data for keyword frequency in Citespace software, and obtained the keyword high-frequency analysis mapping of digital literacy research in China (Fig. 6) as well as the high-frequency statistics Table 1.

Figure 6

Plot of high-frequency analysis of keywords for digital literacy research on teachers in China

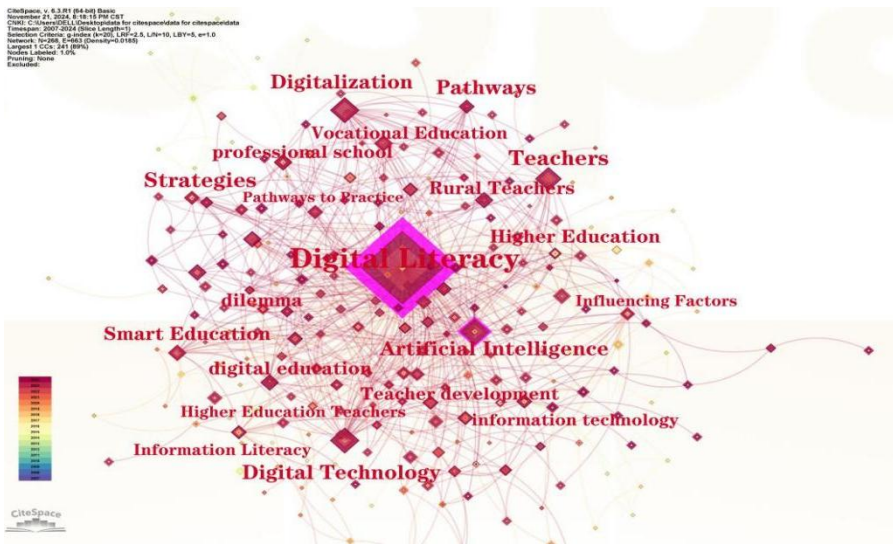


Table 1

Statistics of high-frequency keywords of digital literacy research for teachers in China

Keywords	Year	Frequency	Keywords	Year	Frequency	Keywords	Year	Frequency
Digital Literacy	2014	481	Enhancement Strategies	2021	37	Teacher Training	2021	22
Digitization	2018	80	Higher Education	2016	34	Information Technology	2014	22
Digital Technology	2019	76	Rural Teachers	2021	33	Talent Cultivation	2019	22
Artificial Intelligence	2017	72	Digital Age	2022	30	Influencing Factors	2017	21
Teachers	2021	56	Enhancement Path	2023	29	Digital Education	2019	21
Higher Education Teachers	2020	45	Smart Education	2020	27	Digital Competence	2019	20
Vocational Education	2022	43	Higher Education	2023	25	Basic Education	2019	20
Higher Education Institutions	2016	40	Vocational Schools	2023	23			

In Figure 6, the frequency of keywords can be judged by the size of the circle and the size of the font, from which it can be seen that the words “digital literacy”, “digitization” and “digital technology” have larger fonts and circles, indicating that they appear most frequently. From the figure, it can be seen that “digital literacy”, “digitalization”, “digital technology” and other words have larger fonts and circles, indicating that their frequency is the highest. The inside of the circle is composed of different colors, and each color corresponds to the color area of the time slice. From the center of the circle to the boundary, it indicates the time range from the appearance of the keyword belonging to the circle to the last, each color represents a time slice, and the width of the circle where each color is located determines the frequency of the keyword within the time slice corresponding to the color, and the higher the frequency, the larger the width (Han & Xu, 2023). The largest circle in Figure 6 is digital literacy, in which different colors represent different years, and red is the outermost color, which is the last occurrence of the keyword digital literacy in the collected data,

i.e., there are more studies in the field of digital literacy in 2024. Regarding the development of this field in China, as can be seen in Table 1, the word “digital” appears frequently in the research in this field, which is because it is in the context of the era of digital transformation that digital competence has gradually become the “catalyst” for teachers to effectively develop their professional competence (Xu & Wu, 2023). “It also means that with the digital transformation in all fields of society, digital literacy is becoming a necessary literacy for teachers. And scholars such as Chen Yue propose that digital teaching competence is the ontological construction of teachers' teaching, which can be used as a teaching tool by means of digital technology such as artificial intelligence (Chen et al., 2015). Therefore, keywords such as “digital technology” and “artificial intelligence” are highly discussed in the field of teachers' digital literacy. Combined with the analysis of the visualization of the carrier institutions, the six ministry-affiliated teacher training colleges and universities have the most research results in this field, which indicates that the current research in the field of teachers' digital literacy is mainly concentrated in the higher education stage, so the keywords of “college teachers”, “vocational education”, “teacher education”, Therefore, keywords such as “college teachers”, “vocational education”, and “teacher trainees” are also hot topics in the research of this field. 2021: On July 26th, the Ministry of Education and other nine departments issued the “Directed Training Program for Excellent Teachers in Less Developed Regions of the Midwest” to solve the problem of the source and arrival of primary and middle school teachers in less developed regions of the Midwest through a directional approach (Qin, 2021), and to improve the teaching force of primary and middle school teachers in less developed regions of the Midwest from the source. The quality of primary and secondary school teachers in the less developed regions is improved from the source, so from 2021 onwards, “rural teachers” and “enhancement strategy” have become hot keywords in the field of teachers' digital literacy research.

(2) Analysis of Keyword Centrality

Centrality refers to a keyword mediator between two documents, i.e., a keyword that is at the center pivot, or a keyword that connects more than one document. The larger the centrality data corresponding to a keyword, the closer the keyword is connected to other keywords. In this paper, the corresponding keyword centrality data can be obtained by directly exporting the knowledge graph according to the keyword nodes, and the high school centrality keyword statistics Table 2 is obtained.

Table 2

Keyword statistics for high school centrality in digital literacy research for teachers in China

Keywords	Year	Centrality	Keywords	Year	Centrality	Keywords	Year	Centrality
Digital Literacy	2014	1.04	Online Teaching	2020	0.28	Development Strategies	2018	0.23
Higher Education	2016	0.73	Response Strategies	2018	0.27	Open University	2019	0.21
Educational Technology	2015	0.55	Information Technology	2014	0.26	Curriculum Standards	2016	0.21
Training Modes of Education	2018	0.46	MOOCS	2020	0.25	Hot Spots	2018	0.21
Challenges	2018	0.40	Higher Education Teachers	2020	0.24			
Learners	2021	0.37	Information Literacy	2016	0.23			

Table 2 shows that the centrality of the keywords “digital literacy”, “higher education”, and “educational technology” are all higher than 0.5, which shows that these keywords are very much related to the content of digital literacy development and play a key role in connecting the whole research system of digital literacy development. It can be seen that these contents are greatly related to the contents of digital literacy and play a key role in connecting the entire digital literacy research system. From the perspective of centrality, we can still conclude that the research on digital literacy in China mainly focuses on the higher education stage. At the same time, research in this field focuses on the exploration of digital literacy “cultivation mode” for teachers and the development of new teaching resources such as “online teaching” and “catechism”. This fully demonstrates that the current research system in this field can fully respond to the current context, and the research system is also relatively sound.

3.2.2 Keyword clustering analysis

Clustering is to divide a class of keywords with a high degree of association closeness into a collection, from which some hidden features that may exist between keywords can be discovered. Using Citespace to cluster analysis of the domestic digital literacy development related literature, we get the keyword cluster analysis map (Figure 7), and generate the keyword cluster analysis Table 3, in which the Q value of this cluster analysis is 0.8511 and the S value is 0.9545, which are both close to 1, and the clustering results are reasonable.

Figure 7

Cluster analysis mapping of high form keywords for digital literacy research on teachers in China

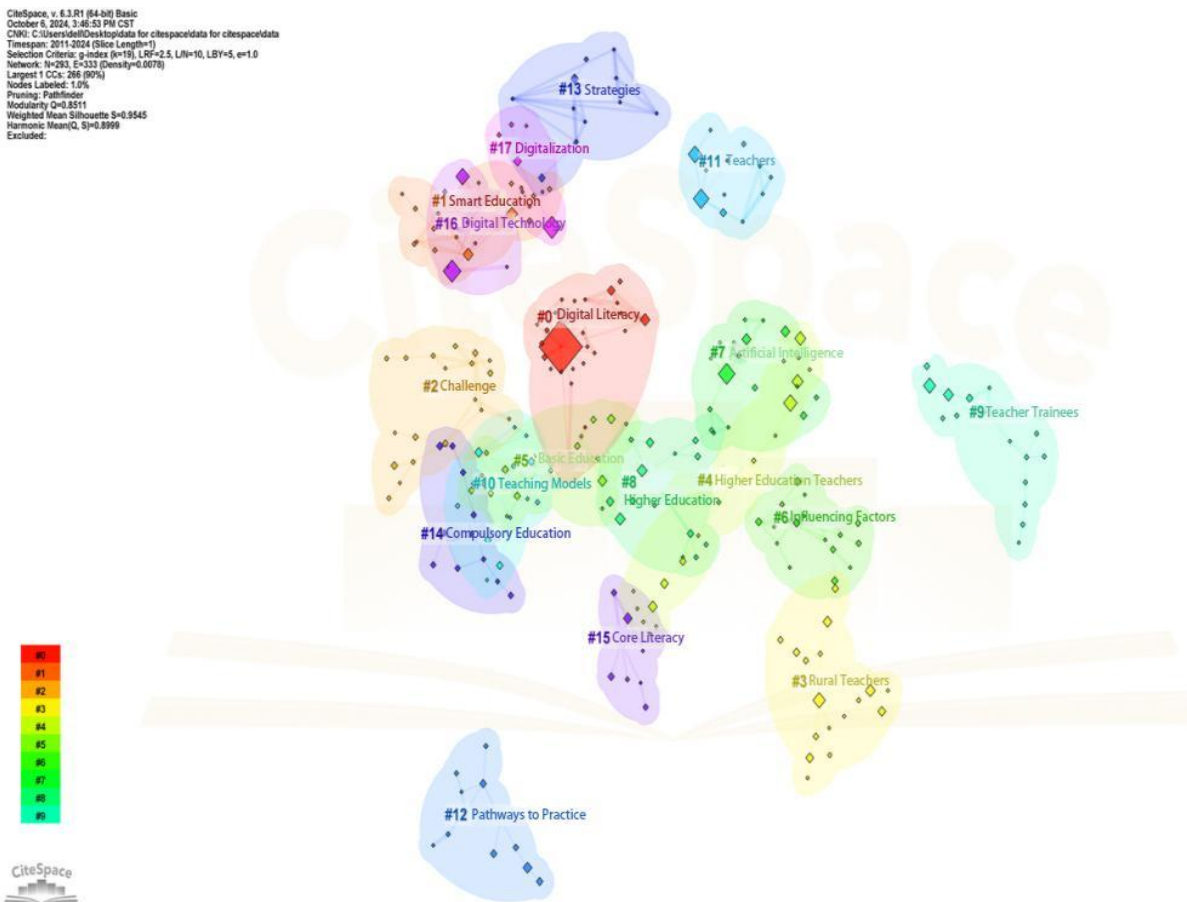


Table 3

Cluster analysis table of keywords of digital literacy research for teachers in China

Scales	Silhouette	Cluster ID	Mean (Year)	Top Terms (LLR)
28	1	0	2018	Digital Literacy (91.69,1.0E-4); Digital Education (27.8, 1.0E-4); Digital Economy (17.45,1.0E-4); Higher Education (12.24, 0.001); Digitization (10.53,0.005)
19	0.994	1	2020	Intelligent Education (35.72,1.0E-4); Information Technology (30.08, 1.0E-4); Educational Equity (19.57,1.0E-4); Strategic Research (13.02,0.001); Teacher Training (13.02,0.001)
19	0.885	2	2020	Challenges (29.59, 1.0E-4); Development (22.14, 1.0E-4); Value (14.72, 0.001); Technology Adoption (14.72,0.001); Trends (14.72, 0.001)
18	0.967	3	2022	Rural Teachers (48.67, 1.0E-4); Colleges and Universities (21.11, 1.0E-4); Civics and Political Science Classes (18.26, 1.0E-4); Rural Education (17.08, 1.0E-4); Rural Revitalization (16.91, 1.0E-4)

18	0.944	4	2021	Higher Education Teachers (35.03,1.0E-4); Pathways (33.57, 1.0E-4); Promotion Pathways (25.75,1.0E-4); Dilemmas (20.64, 1.0E-4); Digital Age (19.15,1.0E-4)
18	0.936	5	2022	Basic Education (24.04,1.0E-4); Information Literacy (23.11, 1.0E-4); Teaching Reform (18.13,1.0E-4); Informatization (18.01, 1.0E-4); Intelligent Age (16.61,1.0E-4)

As can be found in Figure 7, 17 clusters other than digital literacy were obtained from the cluster analysis of keywords, namely “smart education”, “challenges”, “rural teachers”, “basic education”, “influencing factors”, “artificial intelligence”, “digital literacy”, and “digital literacy”, “college teachers”, “basic education”, “influencing factors”, “artificial intelligence”, “higher education”, and “digital literacy”, “higher education”, “teacher educators”, “teaching models”, “teachers”, “Pathways to Practice”, “Strategies”, “Compulsory Education”, “Core Literacy”, “digital technology”, and “digitalization”. Then, according to the keywords contained in each cluster shown in Table 4.3, combined with the research content of the literature in which each keyword is located, we can summarize the 17 clusters into the following five themes: research on the connotation of digital literacy, research on the necessity of digital literacy cultivation, research on digital literacy and rural revitalization, research on the influencing factors of digital literacy and strategies for improving it (higher education level), and research on the current situation analysis of digital literacy and improvement Strategy (Basic Education Stage).

(1) Research on the Connotation of Digital Literacy

Research on the connotations of digital literacy involves Cluster #11 “Teachers”, Cluster #15 “Core Literacy”, and Cluster #16 “Digital Technology”. The concept of digital literacy is inextricably linked to teachers, digital education, digital technology and information literacy, and has evolved with technology. Internationally, digital literacy was proposed earlier, especially in the field of education, and the research report *Digital Literacy in the Curriculum* released by the UK FutureLab in 2010, for the first time, made it clear that teachers' digital literacy should be closely aligned with the needs and practices of teaching and learning in the subject, and listed a number of core elements that make up teachers' digital literacy (Hague & Payton, 2010). In contrast, China's conceptualization of teacher digital literacy came relatively late, and it was not until the release of *Digital Literacy for Teachers* in 2022 that it attracted widespread attention in the education community.

Nevertheless, concepts similar to digital literacy have been proposed in China before that. For example, the *Education Informatization 2.0 Action Plan* released by the Ministry of Education (MOE) in 2018 emphasized the improvement of information literacy and promoted the transition from enhancing the IT application capabilities of teachers and students to comprehensively improving information literacy (Ministry of Education of the People's Republic of China, 2018). And even earlier, in the *Standards of Educational Technology Competence for Primary and Secondary School Teachers (for Trial Implementation)* released in 2004, the professional competence that teachers should have first clarified for the construction of educational informatization, emphasizing the necessity for teachers to effectively use technology in teaching (Ministry of Education of the People's Republic of China, 2004).

It can be seen that the development of teachers' digital literacy in China has been progressing step by step, from the initial information technology application ability to the proposal of information literacy, and then to the establishment of the concept of digital literacy, this process shows the continuous enrichment and deepening of the connotation of digital literacy. Meanwhile, information literacy, digital technology and other related concepts have played a role in the development of digital literacy, laying a solid theoretical foundation for the research and practice of teachers' digital literacy.

(2) The Digital Literacy Imperative Study

The study of the need for digital literacy development covers several key themes, including cluster #2 “Challenges”, cluster #7 “Artificial Intelligence”, and cluster #10 “Teaching Models”. Driven by the rapid development of technology and the wave of digitization, the cultivation of teachers' digital literacy has become an urgent issue for educational development. Qiu et al. (2023) pointed out that in the face of the strong rise of artificial intelligence, education not only has to maintain its adherence to humanistic values, but also needs to actively respond to the challenges brought about by technological innovation, and to reposition the roles and functions of teachers, which puts forward brand-new requirements for teachers' digital literacy. The traditional teaching mode is difficult to meet the demand for flexibility and technology application in the digital era, so the reform of teaching mode based on digital technology has

gradually become a research focus. Yang et al. (2023) proposed that with the entry of artificial intelligence tools such as ChatGPT into the classroom, the teaching mode has changed from the “teacher-student” binary structure to the “teacher-machine-student” ternary structure, which breaks the limitations of the traditional teaching mode and provides new perspectives for improving teachers' digital literacy. Digital literacy provides new perspectives and practice opportunities. At the same time, the change of teaching mode is not only the simple application of technology tools, but also involves the change of teachers' thinking on teaching design and their understanding of the deep integration of technology. Teachers not only need to use digital technology flexibly and redefine the teacher-student relationship, but also need to have the ability to design for complex digital learning environments (Yin et al., 2018), in order to realize the transformation from the traditional classroom model to a new technology-supported teaching model. This change makes the improvement of teachers' digital literacy more urgent and necessary.

(3) Research on Digital Literacy and Rural Revitalization

The research on digital literacy and rural revitalization mainly includes cluster #3 “rural teachers”. Rural education is a “depression” in the digital transformation of education, and rural teachers, as the first element, can provide strong support for cracking the reality of digital transformation of rural education by improving their digital literacy level (Cui & Xu, 2024). In order to promote educational equity and narrow the gap between urban and rural education, improving the digital literacy of rural teachers has become an urgent task. However, the enhancement of rural teachers' digital literacy faces many dilemmas, such as insufficient policy support, lack of digital education resources in schools, and weak overall digital literacy ability of teachers and students (Deng & Deng, 2024). Zhu (2024) proposed that strengthening the informatization construction of rural schools, rationally constructing digital teaching teams for rural teachers, as well as creating digital teaching communities are important measures to effectively attract and retain young teachers. Ren Shenghong et al. emphasized the sharing of localized educational resources through digital technology, the development of school characteristics, and the construction of a “task-driven” training system to improve the digital literacy of rural teachers (Ren et al., 2024). Taking 12 schools in one province as an example, Xu (2023) proposed through field research that we should promote the change of teachers' concepts, accelerate the digital construction of schools, and build a social learning and exchange platform to help improve the digital literacy of rural teachers. These studies not only provide specific paths for rural teachers' digital literacy enhancement, but also lay a theoretical and practical foundation for the realization of rural revitalization and educational equity. By strengthening the informatization construction and teacher training in rural schools, the digital education gap between urban and rural areas can be effectively narrowed, thus promoting the coordinated development of rural education and economy, and contributing to the realization of the rural revitalization strategy.

(4) Research on Digital Literacy Influencing Factors and Enhancement Strategies (Higher Education Stage)

Research on digital literacy in the higher education stage focuses on the two core topics of influencing factors and enhancement strategies, and covers cluster #1 “smart education”, cluster #4 “higher education teachers”, cluster #6 “influencing Factors”, Cluster #8 ‘Higher Education’, Cluster #9 ‘Teacher Trainees’, and Cluster #13 ‘Strategies’. Higher education, as the main ground for research on teachers' digital literacy in China, covers both the digital literacy training of college teachers and emphasizes the training of the pre-service teacher group, teacher trainees. Together, the two have contributed to the rapid transformation of higher education in the digital era. First of all, the factors affecting the digital literacy of college teachers are diversified and complex, which are not only related to the individual's technical ability, but also constrained by external conditions such as policies, resources and technological environment. Han et al. (2022) analyzed the core elements of digitization of higher education teaching from the perspectives of students and teachers, and proposed to formulate corresponding supportive policies from the levels of government, social organizations as well as colleges and universities, respectively, in order to strengthen the digital literacy of college teachers. Secondly, the cultivation of digital literacy of teacher trainees, as an important reserve force of future teachers, has also attracted much attention. Wang et al. (2023) constructed the U-G-S-E “three-learning” model from the perspective of intelligent education literacy of teacher educators, in order to comprehensively improve the intelligent education literacy and practical ability of teacher educators. In addition, for the specific cultivation path of digital literacy for teacher trainees, Yang et al. (2024) constructed a digital literacy framework for teacher trainees based on the standards of Digital Literacy for Teachers, proposed a “primary and secondary parallel” cultivation mode, integrated the first classroom and the second classroom, and provided a dual support system of “in-school teachers + inter-school teachers” for teacher trainees to enhance their digital literacy and practical ability. The dual support system of “in-school teachers + inter-school teachers” provides better guidance for the improvement of digital literacy

of teacher trainees. At the same time, an intelligent assessment system based on digital technology has been further explored, which strengthens the all-round assessment and feedback of teacher trainees' digital literacy and ensures that they receive comprehensive and solid digital literacy training during their school years. Through the analysis of influencing factors and the implementation of enhancement strategies, the study of teachers' digital literacy in the field of higher education provides a solid theoretical foundation and practical path for promoting teachers' professional development. It not only promotes the professional literacy of in-service teachers in the digital era, but also lays a solid foundation for the training of teacher trainees with a high level of digital literacy, so that they can better adapt to the future challenges of education.

(5) Research on the Current Situation Analysis and Improvement Strategies of Digital Literacy (Basic Education Stage)

Research on digital literacy in the basic education stage is closely related to the basic education reform, mainly covering cluster #5 “basic education” and cluster #14 “compulsory education”. At this stage, the improvement of teachers' digital literacy is not only a key link in building a high-quality teaching force and deepening the reform of teacher education, but also strategically important in promoting the high-quality development of basic education in terms of caring for the student body, innovating classroom forms, and optimizing the cooperation of teaching and research. However, there are still many problems in the current practice, such as the lack of clarity in goal orientation, the lack of attention to pre-service education, the evaluation index has not yet been formed, and many other practical misconceptions and value bias have blocked the effective development of digital literacy of basic education teachers (Jing & Lv, 2023). To cope with these adjustments and solve these problems, UNESCO supports the global promotion and development of teachers' digital literacy by providing open educational resources, developing a framework for promoting teacher education, and organizing teacher training programs (Kong & Wang, 2023). Jing & Lv (2023), on the other hand, put forward a strategy to promote the development of digital literacy among basic education teachers around five dimensions: discipline, environment, resources, evaluation and parenting. Combined with and China's national conditions, Yang & Yu (2023) taking the research and training initiatives taken by the Information Technology Application Enhancement Project for Primary and Secondary School Teachers 2.0 as a starting point for reflection, put forward digital practice paths oriented to the enhancement of teachers' digital literacy at the levels of research and training implementation and quality management. These strategies and practices provide a systematic operational guide for the improvement of digital literacy of education-based teachers. The cultivation of digital literacy in the basic education stage is not only a renewal of the content and form of education, but also the key to promoting the reform of basic education and improving the quality of education. Only through systematic strategies and measures can we truly realize the common growth of teachers and students and lay a solid foundation for the development of education in the new era.

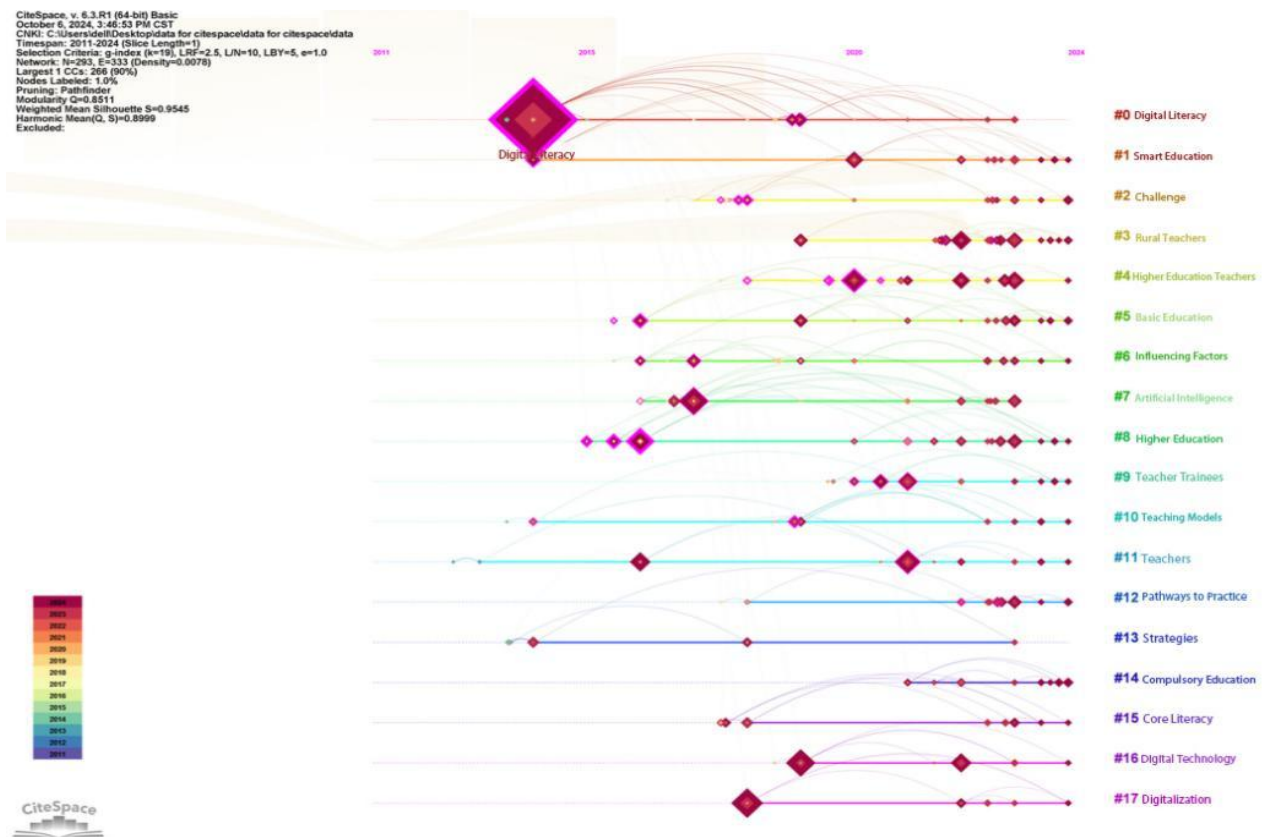
3.3 R3: Analysis of research frontiers and trends of teachers' digital literacy in China.

3.3.1 Analysis of Keyword Timing Chart

Studying the changes of keywords over time is conducive to analyzing the development trend of digital literacy-related research and revealing emerging keywords, which in turn shows the research frontiers in the field. Using Citespace software, on the basis of the previous cluster analysis, node type selects keyword, term type selects Noun Phrases, and after drawing the corresponding knowledge graph, select Timeline View in the Layout tab of the Control Panel window (Timeline View) to generate the corresponding time series graph. Timeline View in the Control Panel window (Layout tab) can produce the corresponding timing diagram (Figure 8).

Figure 8

Chronological chart of keywords of digital literacy research for teachers in China



As can be seen from the figure, since 2011, the research on teachers' digital literacy in China has been expanding, covering multiple directions, and new keywords have appeared almost every year. This indicates that the research on teachers' digital literacy has always maintained a high level of attention during this period. Through further analysis, the development of research on teachers' digital literacy in China can be roughly divided into the following three stages:

(1) 2011-2015: connotation definition stage

In this stage, scholars, inspired by the EU Digital Literacy Framework, began to explore the concept of digital literacy and its connotation. Many domestic studies began to expand information literacy to a broader digital literacy, focusing on the basic definition and practical significance of digital literacy. Ren et al. (2014) pointed out that information literacy mainly focuses on basic knowledge and basic skills related to information activities; while digital literacy rises to be a citizen's survival skill, which, in addition to emphasizing basic knowledge and skills, also emphasizes communication, innovation, management and security. By combining international theories and domestic policies, such as the Opinions of the Ministry of Education on Promoting the Construction of Teacher Education Informatization, studies during this period proposed a variety of evaluation criteria for teachers' digital literacy based on connotation definitions. For example, Wang (2015) proposed an assessment framework for teachers' digital literacy containing five first-level indicators, including basic teachers' digital literacy, applied teachers' digital literacy, developmental teachers' digital literacy, and safeguarded teachers' digital literacy, as well as 12 second-level indicators on the basis of the evaluation standards for teachers' literacy of Li Lixin, Du Zhuo Ming, and Fan Yuanyuan, etc., which has made the domestic research system of teachers' digital literacy more complete.

(2) 2015-2020: path exploration stage

In this stage, with the rapid development of artificial intelligence, big data and other technologies, the path to improve teachers' digital literacy has become the focus of research. Scholars have proposed diverse enhancement strategies from teacher education practice, combining new technologies and digital tools. For example, She Yabin and Huang Jiao-hua advocate improving teachers' digital literacy through updating concepts, systematic training, and

technological safeguards. Research began to focus more on teacher training, teacher self-improvement and systematic support strategies during this period. The research in this phase focuses on exploring effective paths to improve teachers' digital literacy in different contexts, and a series of more mature practical strategies have gradually been formed.

(3) From 2020 to the present: the stage of theory-practice integration

Since 2020, research on teachers' digital literacy in China has entered a stage of deep integration of theory and practice, with a significant increase in the number of studies and an increasingly diversified theme, reflecting the importance of digital literacy at all educational levels. First, the promotion at the policy level has provided a strong institutional guarantee for the improvement of teachers' digital literacy. In order to help teachers actively adapt to new technological changes and enhance their awareness and ability to utilize technology to improve education and teaching, the state initiated and implemented the "Primary and Secondary School Teachers' Information Technology Application Ability Enhancement Project 2.0", which greatly promoted the in-depth development of digital literacy-related practices and research among teachers. Secondly, with the continuous development of technology, researchers have gradually focused on the multi-dimensional composition of digital literacy. Yang Xiaohong et al. proposed the "combination of main and auxiliary" cultivation system, emphasizing that teachers' digital literacy should include information analysis, critical thinking and innovation ability, which provides a scientific basis for the cultivation of teachers' digital literacy. In addition, the practice-oriented nature of the research has become more prominent, focusing on exploring how to effectively integrate the enhancement of digital literacy into the classroom and the process of teachers' professional development. The school-based, classroom-based, application-driven, innovation-focused, accurate assessment and research-training combination path effectively realizes the linkage between theory and practice. The research at this stage not only reflects the progress of policy-driven and theoretical deepening, but also pays more attention to the wide application of educational practice, gradually forming a more complete theoretical and practical system, which provides an important support for educational reform and teachers' professional development.

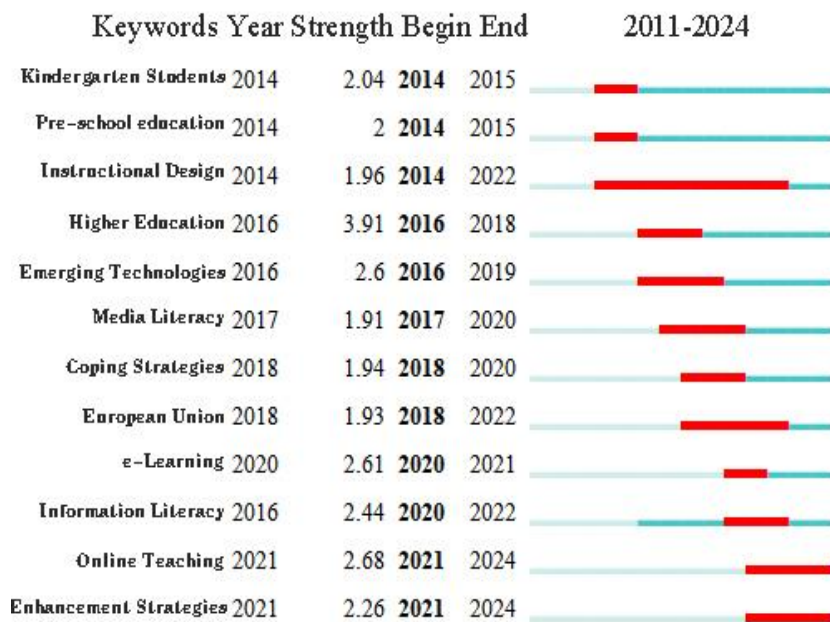
3.3.2 Keyword emergent word analysis

By analyzing the emergent words of keywords, emerging trends in the research field can be revealed, indicating the research activity of a certain field in a specific time period. The higher the intensity of the emergent words, the more attention is paid to the research of the related topics in that time period. In this paper, we used CiteSpace software to analyze the literature screened in the CNKI database for emergent words to identify the trends in the field of teacher digital literacy research in China. Figure 9 shows the results of keyword emergent word analysis in the field of teachers' digital literacy in China.

Figure 9

Analysis of keyword emergent terms in the study of digital literacy of teachers in China

Top 12 Keywords with the Strongest Citation Bursts



As can be seen from the figure, new emergent words have appeared almost every year since 2014, which indicates that scholars and research institutions in China have always invested in research in this field. Among them, “higher education” has the highest emergence intensity of 3.91, indicating that this topic has attracted a great deal of attention in the research on teachers' digital literacy. This is closely related to the rapid development of digital transformation and online education in recent years, followed by “online teaching” and “online teaching” with an intensity of more than 2.6 respectively. The intensity of the rest of the emergent words is below 2.5. Combined with the analysis of the previous keyword timing chart, it can be found that at the early stage of the research on teachers' digital literacy, the research mainly focuses on macro-concepts and broad themes, such as “smart education” and “teaching mode”. However, with the depth of research, studies in recent years have gradually focused on specific educational fields, such as “higher education” and “basic education”, and closely integrated with the context of digital transformation. This indicates that the content of the research is gradually developing in a more detailed and application-oriented direction, and the relevance, practicality and feasibility of the research is also gradually improving. It can also be predicted that in the future, the trend of China's teachers' digital literacy research may pay more attention to the in-depth study of “small-scale” issues, i.e., a more refined and specific research direction will become the main trend. This trend not only reflects the development needs of discipline segmentation, but also provides more precise guidance for educational practice.

3.3.3 Analysis of realistic research trends in the social environment

With the changes in the social environment, the research on teachers' digital literacy has shown a new trend. 2022 The Ministry of Education released the education industry standard of Teachers' Digital Literacy, which proposed a systematic framework for teachers' digital literacy for the first time. The framework not only clarifies the definition and requirements of digital literacy for teachers in China, but also covers five key dimensions: digital awareness, digital technology knowledge and skills, digital application, digital social responsibility, and professional development. This signifies that the connotation of teachers' digital literacy has been expanded from the traditional technical operational skills to a more comprehensive literacy requirement. Teachers not only need to have strong technical skills, but also need to be able to understand and utilize digital technologies, as well as take on the corresponding social responsibility to continuously promote their professional development.

For this reason, the focus of current and future research should not be limited to the digital literacy of in-service teachers, but should also be extended to specific groups such as teacher trainees and pre-service teachers. The teacher training system in higher education and vocational education, especially the path and strategy of digital

literacy enhancement for teacher trainees, urgently needs to be explored in depth. This is not only to meet the needs of the modernization of education in China, but also an inevitable trend in the development of the teaching profession in the digital era. In addition, with the promotion of national policies and the implementation of major projects such as the “Excellent Teacher Program” and the “National Excellence Program”, the research theme of teachers' digital literacy needs to be further expanded, involving “rural teachers”, “digital teachers”, “digital teachers” and “digital teachers”. The topics of research on teachers' digital literacy need to be further expanded to cover hot social issues such as “rural teachers”, “digital resource sharing” and “educational equity”. By focusing on these specific issues, we can promote the balanced distribution of digital resources, promote equity in urban and rural education, and enhance teachers' ability to adapt to teaching in the digital context, so as to build a teacher education system with Chinese characteristics in the context of the new era. Future research should be to expand both the breadth and depth of teachers' digital literacy, to comprehensively cover all stages from pre-service training to in-service development, and to respond to national policies and social demands to build a more complete research system in order to promote the continuous development of teachers' professional competence in the digital era.

4. Discussion

Through systematically combing the current research status of the field of digital literacy of teachers in China, this paper summarizes the main features and trends presented in the development process of this field, which are specifically manifested in the following aspects:

4.1 Synergistic development of policy leadership and theoretical practice

In recent years, under the vigorous promotion of national policies, the improvement of teachers' digital literacy in China has made remarkable progress. The Ministry of Education and other relevant departments have issued a series of policy documents, such as the “Information Technology Application Ability Enhancement Project for Primary and Secondary School Teachers 2.0” and the “Teachers' Digital Literacy” industry standard, which clearly define the core connotation of teachers' digital literacy and its enhancement path. These policies not only provide a systematic framework for the theoretical construction of teachers' digital literacy, but also promote extensive exploration of teacher training and teaching practice nationwide. The previous analysis of the literature shows that the guidance of policies has played a key role in promoting the deepening of theoretical research and practical application of teachers' digital literacy. At the theoretical level, researchers have gradually clarified the multidimensional composition and evaluation criteria of teachers' digital literacy by interpreting policy documents. In particular, the multi-dimensional systematic framework of digital awareness, technology application ability, social responsibility and professional development has laid a solid theoretical foundation for the research on teachers' digital literacy. At the practical level, policy-driven teacher training programs and teaching practice applications have prompted teachers to use digital tools and resources more extensively in their teaching activities, thus enhancing their own digital literacy, and these practical activities not only help teachers effectively adapt to the digital teaching environment, but also provide a practical basis for theoretical research, which in turn enriches the theoretical system of teachers' digital literacy. This policy-driven two-way interaction model fully embodies the mutual integration of theory feeding practice and practice enriching theory, and promotes the sustainable improvement of teachers' digital literacy.

4.2 Diversification and Refinement of Research Topics Expansion

With the continuous deepening of the research on teachers' digital literacy in China, the research topics have shown a trend of increasing diversification and refinement. In terms of research objects, full coverage from pre-service teachers (teacher trainees) to in-service teachers has become the main feature of current research. Research on teachers' digital literacy is no longer limited to the professional development of in-service teachers, and the current situation of digital literacy among pre-service teachers (teacher trainees) and their cultivation paths have gradually received widespread attention. Researchers have begun to explore how to help teacher trainees improve their digital literacy through curricula, practical teaching and training in digital tools, so as to ensure that they are able to play a leading role in future educational practices, and to promote the innovation of digital teaching and the continuous improvement of educational quality. This comprehensive focus on the digital literacy of pre-service and in-service teachers not only expands the scope of the research object, but also provides an all-encompassing enhancement strategy for teacher education. On the regional front, with the country's continued focus on educational equity, the

improvement of rural teachers' digital literacy has become a key topic of research in recent years. Due to the imbalance between urban and rural educational resources, rural teachers face many challenges such as lack of digital resources and insufficient technical support. Policy guidance and exploration of local practices have prompted researchers to gradually focus on how to help rural teachers overcome the difficulties in digital teaching through policy favoritism, resource allocation and targeted training. Such research has explored in-depth from the practical methods of technology training, the effectiveness of resource use to the construction of digital platforms and other dimensions, providing practical paths to enhance rural teachers' digital literacy. In addition, research has gradually focused on more specific topics, including in-depth studies on the different needs and challenges of digital literacy for teachers of different levels of education (basic education, higher education, and vocational education) as well as for teachers of specific disciplines, and in-depth discussions on a specific dimension of teachers' digital literacy. The diversification and refinement of such research not only deepens the construction of the theoretical system of teachers' digital literacy, but also provides differentiated guidance for teachers of different educational backgrounds and fields, and promotes the formation of a more targeted and systematic digital literacy enhancement path, thus promoting the digital transformation and innovative development of the entire education system.

4.3 Exploration of Technology-Enabled Digital Literacy Enhancement Paths

With the rapid development of technology, the path to enhance teachers' digital literacy gradually shows the characteristics of technology empowerment. Literature analysis shows that emerging technologies such as artificial intelligence, big data, and virtual reality have been widely used in the assessment and cultivation of teachers' digital literacy, promoting the innovation of the traditional assessment mechanism and the diversification and personalization of cultivation strategies and cultivation paths. At the assessment level, with the help of big data analysis, teachers' digital literacy performance can be monitored in real time, helping them identify their own development space. Based on the innovative application of online assessment tools and self-assessment platforms, teachers can receive customized feedback to enhance their digital literacy. At the cultivation level, the application of technology provides teachers with rich learning paths. For example, the rise of online training, MOOC courses and interactive learning platforms empowers teachers with the freedom to flexibly choose their learning modes, while sharing experiences and resources with their peers through collaborative tools, creating an active learning community. In particular, the introduction of generative AI technology has provided a new impetus for personalized learning. Generative AI is able to generate personalized feedback and resources based on the specific needs of teachers, helping them to learn deeply in key areas of digital literacy, thus significantly enhancing the relevance and effectiveness of their digital literacy development paths. In addition, generative AI shows great potential for application in teaching simulation and classroom scenario construction, helping to improve their ability to cope with complex teaching scenarios. However, although technological empowerment provides new opportunities for teachers' digital literacy enhancement, there are still some current challenges. Teachers' acceptance of new technologies and the ease of access to them are key barriers that need to be addressed. In the future, the exploration of technology-enabled digital literacy enhancement will continue to deepen, and the focus will be on smarter assessment tools and broader technological applications, especially the further application of generative AI in personalized learning and teachers' continuous professional development.

5. Conclusion

By comprehensively sorting out the research on digital literacy of teachers in China and based on the results of the above analysis, we provide the following suggestions for the subsequent development of related research:

5.1 Deepen theoretical research and clarify core concepts and research boundaries

Currently, the research on teachers' digital literacy is still ambiguous in terms of connotation definition and theoretical foundation. Therefore, the pace of theoretical research should be accelerated to clarify the core elements and boundaries of teachers' digital literacy in the context of education in the new era, and its interrelationships with teachers' educational technology competence, information technology application competence, information literacy, artificial intelligence literacy and teachers' professional development. Based on a multidisciplinary perspective, we explore the synergistic effect between these factors and promote the systematic theoretical construction of teachers' digital literacy. In addition, combining China's national conditions and educational realities, drawing on international

cutting-edge research results, creating a theoretical system of teachers' digital literacy that meets local needs, and accumulating more basic local research reflecting Chinese characteristics, in order to fully guide and plan the development of the field of teachers' digital literacy, and laying a solid theoretical foundation for the subsequent research.

5.2 Constructing a dynamic assessment system to promote accurate assessment and feedback

At present, there is room for improvement in the dimensional coverage and accuracy of the existing assessment tools for teachers' digital literacy, making it difficult to fully reflect teachers' performance in teaching practice. Therefore, it is recommended to build a flexible, dynamic and multi-intelligent assessment system that incorporates teachers' digital technology application, teaching design innovation and professional growth into the assessment. Big data and artificial intelligence technologies should be used to develop real-time assessment tools to dynamically capture the actual performance of teachers' digital literacy. At the same time, a personalized feedback mechanism should be emphasized to help teachers understand their own strengths and weaknesses, and provide targeted development advice to ensure that the assessment is not only a static assessment tool, but also a guide and driving force for the improvement of teachers' digital literacy.

5.3 Strengthening Policy Support and Promoting Sustainable Development of Teachers' Digital Literacy

Policies play an important leading and safeguarding role in the process of enhancing teachers' digital literacy. It is recommended that national and local policy frameworks be further improved to provide stable support for the sustainable development of teachers' digital literacy. Through policy guidance, in-depth cooperation among education departments, schools and research institutes at all levels in curriculum development, resource allocation and teacher training should be promoted to facilitate the popularization and deepening of digital literacy. At the same time, localities should be encouraged to summarize innovative practical experiences, promote excellent models, and form a nationwide library of practical cases of teachers' digital literacy enhancement, so as to promote the overall enhancement of teachers' digital literacy.

Through a systematic analysis of the current status of research on teachers' digital literacy in China, this paper reveals three major features and trends in the field, namely, the synergistic development of policy leadership and theoretical practice, the diversification and refined expansion of research topics, and the exploration of technology-enabled paths for digital literacy enhancement. **Based on this, suggestions are made to strengthen theoretical research, improve the measurement system, and enhance policy support.** In the future, with the continuous advancement of technology, the research on teachers' digital literacy will be more in-depth and diversified, and at the same time, we should keep exploring how to provide more accurate and effective solutions for teachers' professional development through technological innovation and policy support. This will not only have far-reaching significance for the professional development of individual teachers, but will also positively promote the improvement of overall education quality.

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