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A bibliometric analysis of knowledge mapping in Chinese education digitalization research from 2012 to 2022

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The digital transformation of education should be continuously promoted to guarantee its sustainable development. Extensive research has been conducted in this field but has not comprehensively addressed Chinese education digitalization. To fill this research gap, discover the gaps between Chinese and international research on the digitization of education and provide well-founded, innovative ideas for future research, we perform a bibliometric analysis of knowledge mapping in Chinese education digitalization. WOS and CNKI databases were used to gather literature on Chinese education digitalization research from 2012 to 2022. CiteSpace was used to draw a knowledge map of Chinese education digitalization research through co-occurrence analysis of core authors, issuing institutions and regions and cluster analysis and burst terms analysis of keywords, combined with intensive manual studying of the literature. The results show the research status and hot spots of Chinese education digitalization research are divided into four dimensions: studies of lifelong education research in digital open universities and the online teaching transformation in higher education; studies of digital educational publications, the development and application of digital learning resources in vocational colleges and universities, and the equity of basic education resources in the digital context; studies on artificial intelligence technology empowering the digital transformation of education in China; and studies of digital integration of production and teaching in rural revitalization and improvement of digital literacy of university students and faculty. Future digital education research trends in China are likely to focus on the normalization of online education; the development of online education resources in the context of new infrastructure; “new technology plus education”; the impact of digital games on education; a more diversified digital divide in education; and digital rights, digital ethics, digital maturity and the Global Digital Education Development Index.

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Introduction

The Education 2030 Framework for Action, which was issued by UNESCO in 2015, emphasizes the Sustainable Development Goals for education and proposes a direction for the future digitalization of education (UNESCO 2015). As a response to the United Nations 2030 Global Goals for Sustainable Development, the Organization for Economic Cooperation and Development (OECD) launched the “Education 2030: Education and Skills for the Future” project in 2015 and published “OECD: The Future of Education and Skills-Education 2030” in 2018 (OECD 2019). All of the education policy documents issued by these important world organizations emphasize the need to strengthen research on the digitalization of education to achieve the vision of sustainable global education in 2030.

The Outline of the Fourteenth Five-Year Plan and Vision 2035 for National Economic and Social Development of the People’s Republic of China depicts the goals and tasks of digitalized economic and social development (Ministry of Education of the People’s Republic of China 2021). In this process, the Central Committee of the Communist Party of China (CPC) and the State Council issued the document “China Education Modernization 2035” in 2019, which clarifies that the goal and path to achieve education modernization is the implementation of digital education (Ministry of Education of the People’s Republic of China 2018).

As seen from the abovementioned policy documents, both the international community and countries in particular attach great importance to the digitization of education. Indeed, the digitization of education is an important revolution in the field of education in today’s digital era; moreover, the digitization of education is also an important means of guaranteeing the sustainable development of education in the future. The study of education digitization not only follows the development trends of the digital era so that education advances with the times and adapts to the needs of the digital society but also provides new solutions and methods for addressing some of the existing problems in education, such as the uneven distribution of educational resources, the poor quality of education, etc. Through the study of education digitization, the directions, reforms and trends of the future of education can be explored and improved. Therefore, the digitalization of education needs to be examined.

Literature review and research questions

Current status of research on “education digitalization”

Current status of research on “International education digitalization”. At present, the international literature on the digitalization of education has been more complete and richer from both the specific and the comprehensive perspectives.

A review of the literature shows that, from a specific perspective, international research on digitalization in education mainly focuses on topics such as research related to teachers’ and students’ digital literacy (Audrin and Audrin 2022), research on the impact of video games on education (Boyle et al. 2016), and research on equity in education under digital teaching (Kerras et al. 2020).

From a comprehensive perspective, numerous authors have provided systematic overviews of topics related to the “digitization of education”. For example, through a comprehensive econometric analysis of the WOS literature, we observe that the hot topics of international research on the digitization of higher education include the popularization and development of online education, the rise and development of massive open online courses (MOOCs), the construction and sharing of digital learning resources, the innovation and change in distance education, and the impact and effect of digital transformation

on the field of higher education (Díaz-García et al. 2022). As another example, through the visual analysis of international online learning research, it is concluded that the main topics of international online education research include MOOC, flipped classrooms, COVID-19, computer-supported collaborative learning, the technology acceptance model, the community of inquiry, and distance learning (Shen et al. 2022). Furthermore, a literature review of international digital campus research has revealed that ICT plays a crucial role in the process of the digital transformation of campuses, revealing the factors that schools should consider to achieve effective and efficient digital change (Timotheou et al. 2023). These review papers provide a panoramic view of the extent of international research on the “digitization of education” and future research directions.

Current status of research on “Chinese education digitalization”. In recent years, due to the continuing development of digital technology, digital education has been involved at all school levels in China. Many studies have discussed how to realize the digital transformation of Chinese education. For example, studies have proposed that the development path of digital education transformation in China must be supported by a perfect “guarantee mechanism” as the basic conditions and then start from “things”, “people”, and “numbers” and aim at the “digital aspect” and the two major business application areas of “teaching” and “management” to realize the comprehensive digital transformation of education with high quality (Wu et al. 2022).

However, the current literature on the digitalization of education in China is still mainly from specific perspectives, focusing on various types of digitalization topics in specific areas, e.g., digital literacy (Huang 2015) and digital technology (Zhao 2021).

Moreover, no comprehensive and systematic compendium of research on the digitization of education in China has yet been conducted from a global perspective. Most of the relevant studies rely on the subjective opinions of researchers and lack objective bibliometric and quantitative analyses. Although there is much literature on the digitization of education in China, there is a gap in terms of panoramic studies that analyze the digitization of education in China from a comprehensive and objective perspective.

Research questions and research implications. Our study attempts to use CiteSpace to visualize and analyze the literature on education digitization. By comprehensively searching through the research on education digitization in China, we present a panoramic view of the current status of research on education digitization in China, research hotspots and future research trends and reveal the far-reaching impact of digital education on China’s education career.

This study can not only fill the gap of comprehensive research on the digitization of education in China but also reveal the differences or gaps between the research on the digitization of education in China and that in the international arena by comparing the current situation and hotspots of the research on this topic in the international arena horizontally to provide well-founded and innovative ideas for future research on the digitization of education in China.

Methodology

This study uses a combination of bibliometric analysis and manual reading to analyze the “Digitalization of Education Research in China, 2012–2022”. Specifically, this study seeks to uncover the current status, hotspots, and future research trends of

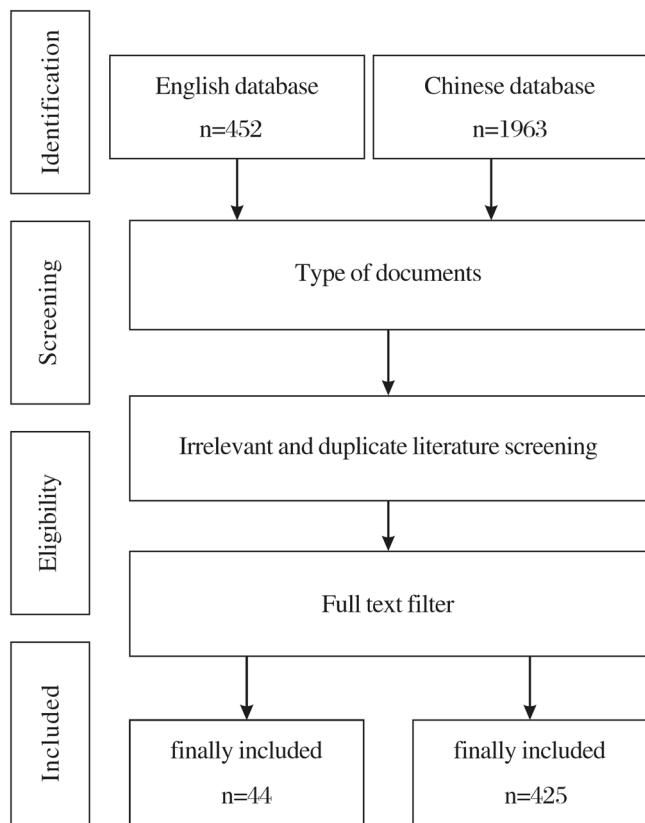


Fig. 1 The research processes 1.

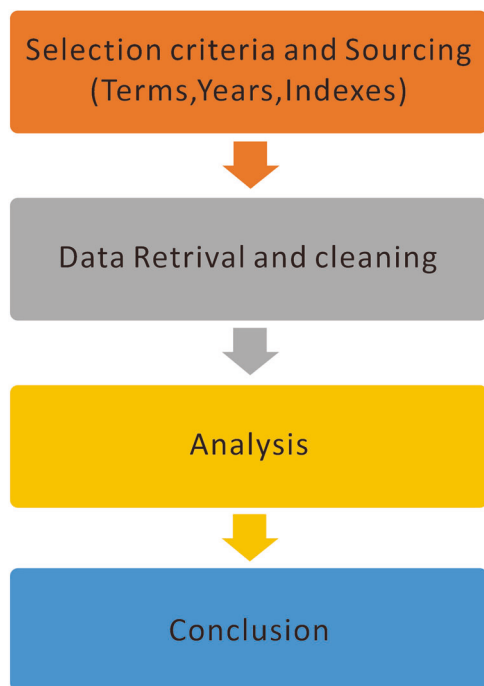


Fig. 2 The research processes 2.

educational digitization research in China during this period. Figures 1 and 2 show the process of the research.

Selection of databases. The first step of this study was to identify the databases used. Two databases were selected for this study,

namely, the Web of Science (WOS) Core Collection and the China National Knowledge Infrastructure (CNKI).

To account for the possible emergence of foreign literature related to the “digitization of education in China”, the internationally recognized Web of Science Core Collection database was selected for this study. The database was chosen for the following two reasons:

1. WOS is a multidisciplinary large-scale database that includes information from hundreds of national and regional institutions worldwide and has the three most authoritative citation index databases (SCI-E, SSCI, A&HCI). CiteSpace software supports the import of literature from WOS.
2. For the Chinese literature related to the “digitization of education in China”, this study employed the China Knowledge Network (CNKI) database, which is the largest and most authoritative database in China, covering all types of literature in China. CiteSpace also supports the import of CNKI documents. Since China was chosen as the target country for educational digitization research for this study, CNKI is a very important database.

Data collection. After WOS and CNKI were selected as the databases for Chinese education digitization research for this study, a search for relevant literature in these two databases was conducted.

Literature search strategy

Literature search strategies for WOS Core Collection: The WOS Core Collection was searched with the theme of “Chinese education digitalization” or “digital education in China”. The period of 2012–2022 is a typical period for the rapid development of education digitization in China. Therefore, this study utilizes the literature from the databases within the time span of 2012.1.1–2022.12.31, and 452 works were retrieved.

Literature search strategy for CNKI: In the CNKI database, since almost all published authors are Chinese scholars, most of the literature on the topic of “education digitalization” in the database is research literature on “education digitalization in China”. Therefore, the keywords or themes of “education digitalization” or “digital education” were used to search the literature in the CNKI database within the period of 2012.1.1–2022.12.31, and 1963 works were retrieved.

Inclusion and exclusion criteria

Inclusion and exclusion criteria for WOS Core Collection: First, of the literature uncovered in the literature search strategy, the works that were not of the document type ARTICLE had to be excluded.

Second, on this basis, the categories were refined to “Education or Educational Research” or “Psychology Multidisciplinary” or “Humanities Multidisciplinary”, while other categories irrelevant to the education field like “environmental science” were excluded, and a total of 96 articles were retrieved. Each of these articles is peer-reviewed and contains information such as title, authors, abstract, keywords, references and source publications.

Third, the 96 papers retrieved were manually read to determine whether they were indeed in line with the theme of “Digitization of Education in China” based on their titles, keywords and abstracts. Through manual screening, finally, a total of 44 relevant studies that met the above search strategy and fulfilled the inclusion criteria were finally obtained.

Inclusion and exclusion criteria for CNKI: First, works about education digitalization in other countries or international organizations were excluded. For example, a study titled “Digital Transformation of Education in the European Union: A Study of Policy Evolution, Key Initiatives, and Implications” was excluded. Since the percentage of this literature was very low, such studies were manually excluded.

Furthermore, any studies in nonthesis form were excluded.

Finally, due to the limitation of the type of literature that can be imported into CiteSpace, the relevant dissertations were further excluded on this basis, while peer-reviewed and publicly published core papers were selected and a total of 425 valid papers were obtained.

Analysis. In this study, CiteSpace V.6.1. R6, a visualization and analysis software developed by Professor Chao-Mei Chen of Drexel University, USA, was used to process the data from CNKI.

CiteSpace is an effective tool for quickly accessing knowledge on specific topics, and its research includes the visualization of information and the analysis of knowledge graphs and atlases of scientific frontiers. In this study, the processing conditions were set as follows: the time range was 2012–2022, divided into 11 time zones; the term type was set as burst terms; and the node type was set as keyword.

Because CiteSpace has certain requirements on the imported papers and databases: the number of papers is generally 400–3000 (not including dissertations), and the papers in Chinese and English databases need to be imported separately. Therefore, according to the CiteSpace import requirements, this study chose to import 425 documents from CNKI into CiteSpace; the remaining 44 documents from WOS were not suitable for importing into CiteSpace for analysis because the number of articles was too small, and these 44 documents from WOS were manually studied.

The selected 425 documents were imported into CiteSpace, and then the keywords extracted from the imported files were subjected to co-occurrence analysis, cluster analysis and burst analysis. After the relevant knowledge map was obtained, combined with 44 documents from WOS database manually studied, the current status, hotspots and future research trends of education digitalization research in China during the period of 2012–2022 were examined through Excel integration and analysis of specific documents.

Results and discussions

Results and discussions of research status and hotspots. A bibliometric analysis of research institutions and research authors using CiteSpace revealed that the research institutions and scholars of “Digitization of Education in China” are mainly Chinese scholars led by Prof. Zhu Zhiting at East China Normal University in Shanghai, China, as depicted in Figs. 3 and 4.

Then, the word frequency statistics, co-occurrence analysis and cluster analysis of keywords for the papers imported into CiteSpace can be organized in Figs. 5 and 6.

Combined with manual studying of the 44 papers from WOS, the following conclusions may be made on the research status and hotspots of Chinese education digitalization.

According to The Education Informatization 2.0 Action Plan, an important document on the digitization of education issued by China’s Ministry of Education, outlines the elements of the digitization of education in the following four major areas:

1. Digital educational resources: These include digital teaching materials, books, courseware, cases, etc., as well as a variety of online courses, web courses and other resources.

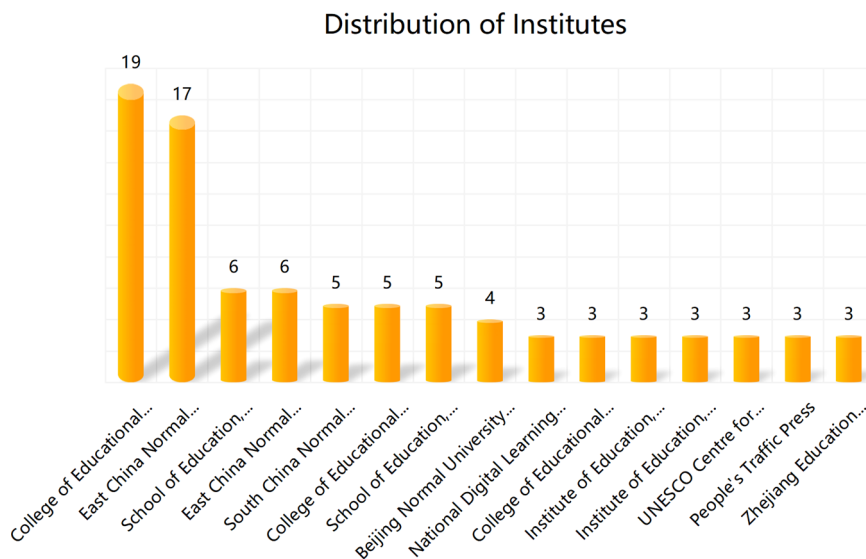


Fig. 3 Distribution of institutes.

Distribution of Core Author

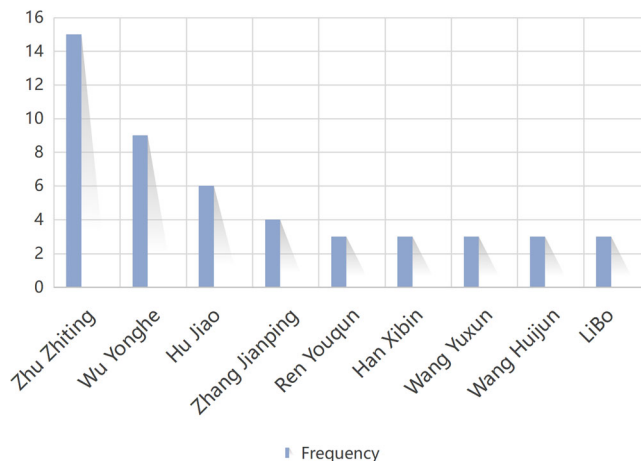


Fig. 4 Distribution of core author.

CiteSpace v.5.10.R1 (64-bit) Basic
 January 20, 2023 at 5:19:11 PM CST
 CNM3: 0; CiteSpace (设置): 0; data
 Timespan: 2012-2022 (Slice Length=1)
 Selection Criteria: g (Index)=0.3, L/N=5, LB=8, E=2.0
 Network: N=92, E=58 (Density=0.0139)
 Largest CC: 31 (33%)
 Nodes Labeled: 2.0%
 Pruning: Pathfinder

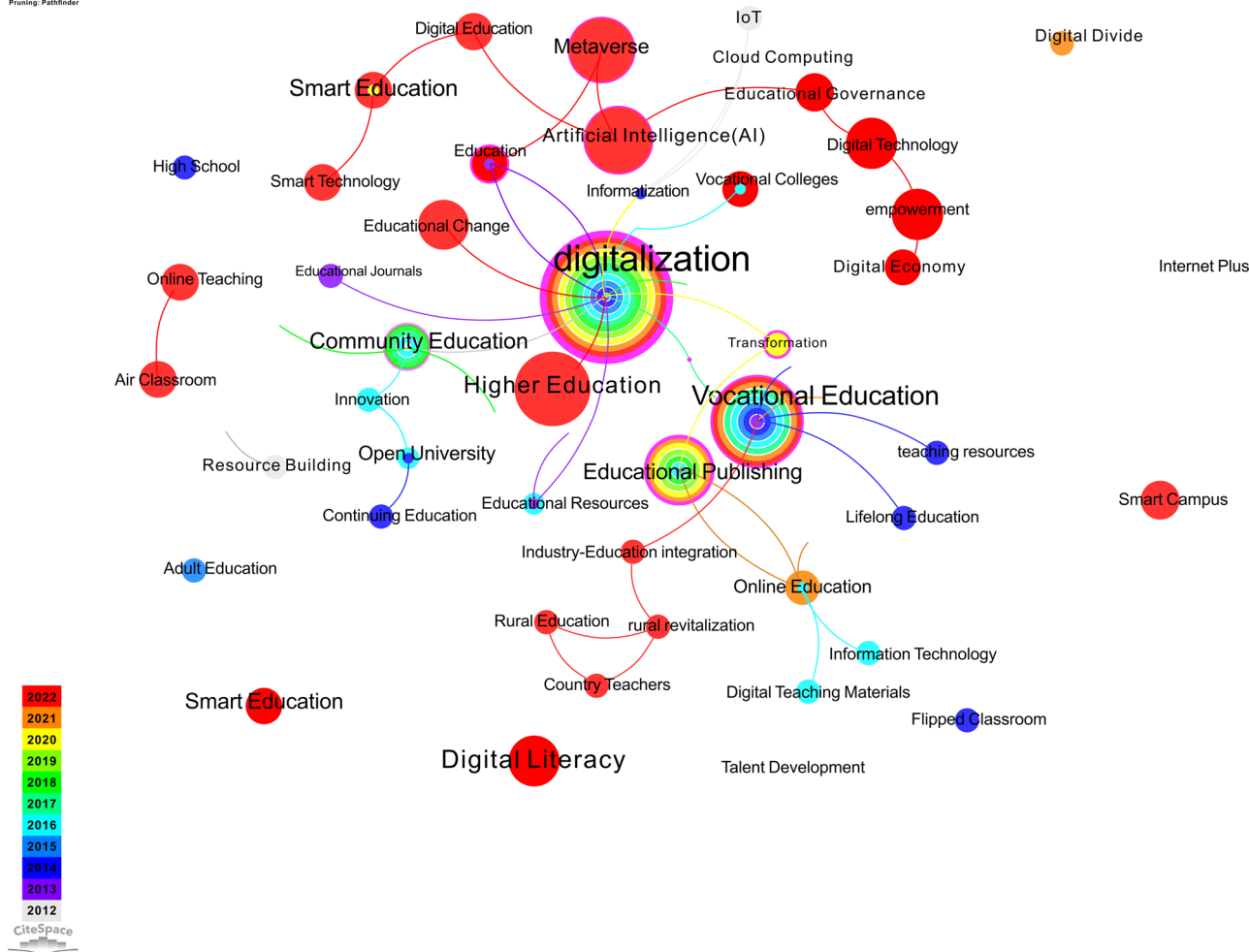


Fig. 5 The co-linear analysis of the literature related to the digitalization of education in China.

A	B	C
Cluster No.	Year	LLI algorithm keywords
0	2017	(10.34) Vocational Colleges; (9.97) Higher Education; (6.64) Transformation; (6.43) Education; (6.26) Digital
1	2017	(9.66) Vocational Education; (8) Rural revitalization; (8) Lifelong Education; (8) Teaching Resources; (7.75) Industry-education integration
2	2017	(13.29) Educational Publishing; (10.34) Online Education; (8) Information Technology; (8) Digital Teaching Materials; (8) Scenes
3	2021	(12) Artificial Intelligence; (8) Empowerment; (8) Digital Education; (8) Big Data; (8) Metaverse
4	2014	(8) Digital Reading; (7.75) Community Education; (7.75) Innovation; (4.54) Education; (4) QR Code
5	2013	(8) IoT; (4.83) Informatization; (4) Digital Campus; (4) Health Communication; (4) Healthy Education
6	2019	(10.34) Home Education; (8) Digital Age; (4.28) Education; (4) Digital Literacy; (4) Digital Music

Fig. 6 Cluster analysis of keywords.

2. Digital educational platforms: These include online education, distance education, mobile education, and smart education platforms, as well as a variety of online learning communities and online communication and interaction platforms.
3. Digital educational technology: This includes a variety of digital, information, and network technologies and other means, such as AI, big data, cloud computing and IoT.
4. Digital educational management: This includes the management of digital teaching and of assessing the digital literacy of teachers and students, as well as various digital education and teaching assessments and quality monitoring (Ministry of Education of the People’s Republic of China 2018).

On this basis, an analytical framework of the ELEMENTS of educational digitization was designed in our study. Based on a combination of the above charts and manual studying, the research status and hotspots of education digitization research in China during the period of 2012–2022 were organized, as showed in Fig. 7.

Research on the platform dimension of Chinese education digitalization. Digital educational platforms are the carriers of digital

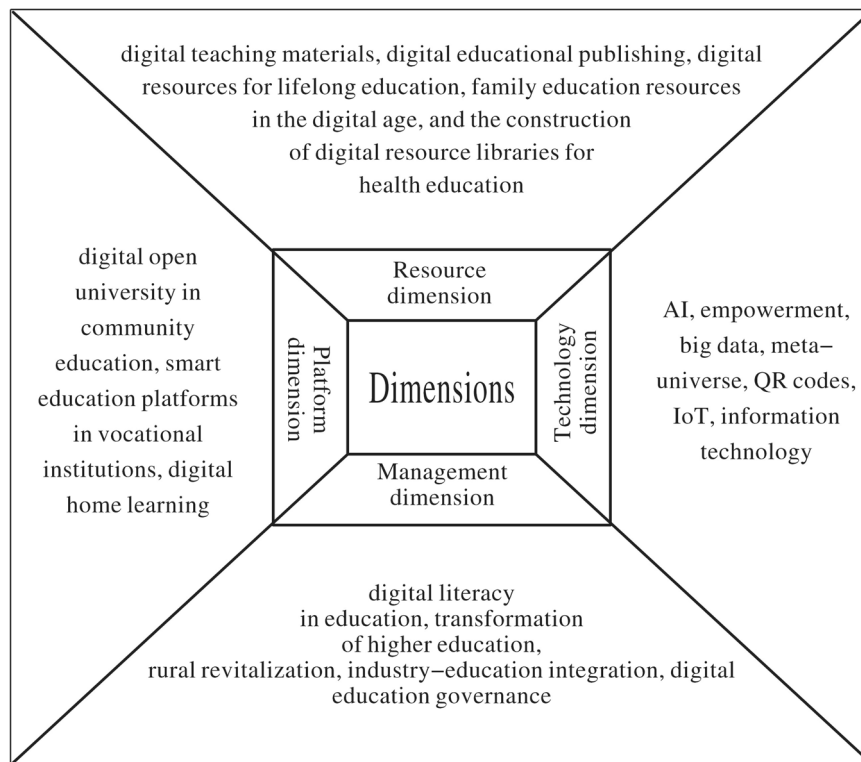


Fig. 7 Conclusions on the status and hotspots of Chinese education digitalization research.

education. Such platforms provide a place for the integration, sharing and exchange of resources for education digitization, and enable the effective management and efficient use of educational resources. Research on China’s education digital platforms can improve the teaching efficiency at all school levels and promote the sharing of teaching resources and educational equity.

A study of lifelong education in a digitized open university: Open universities constitute a new type of university with Chinese characteristics that mainly serves members of society and provides them with continuing education services (Yu et al. 2014). From 2012 to 2020, there has been much research on digital education in China’s open universities, which is closely related to a series of transformation and upgrading policies issued by China regarding the development of these universities during the period. In July 2012, National Open University was inaugurated, and pilot construction began to advance. In September 2020, China’s Ministry of Education issued the Comprehensive Reform Plan for the National Open University, and the digitalization of the open university reform was fully rolled out.

A digitized open university can not only build a lifelong learning service system for all people and thus promote the interconnection and sharing of various types of education but also enable the open university to better serve its base. For example, a digitized open university can build high-quality online course resources for nondegree education for rural areas, communities and industrial enterprises, focusing on the needs of new farmers, new citizens and elderly individuals, to bridge the digital divide between urban and rural areas and regions.

The literature published during this period mainly focuses on how to realize the digital transformation of China’s open universities. The strategies for this transformation can be summarized as follows: absorbing colleges and universities, research and consulting institutions, industrial enterprises and employers to participate in the construction of online course resources; introducing high-quality digital education resources

from home and abroad to enrich the online resource library of the open university; perfecting the pricing of resources to form a sustainable and market-oriented resource supply and demand mechanism; cultivating special majors and courses, promoting the learning modes of online and offline blended learning and interdisciplinary integration, strengthening the management of the learning process, reforming the assessment and evaluation methods, and optimizing the quality control (Zhang 2021).

A transformative study of online teaching and learning in higher education: With the outbreak of the COVID-19 pandemic in 2020, China’s Ministry of Education proposed “stopping classes without stopping teaching, stopping classes without stopping learning”. Thus, online teaching and learning have become the norm (Khong et al. 2023). Therefore, in recent years, the current situation, characteristics, and strategies of online teaching and learning have been a hot topic for researchers in China, especially in higher education.

Online teaching has led to the following four transformations in Chinese higher education: educational resources have shifted from segmentation to sharing; student learning has shifted from linear to nonlinear; curricular reform has shifted from structured to unstructured; and educational technology has shifted from an auxiliary means to a deep integration with teaching (Xue and Guo 2020). As a result, the digitization of Chinese higher education has begun to show the following typical features: Chinese universities view digitization as characterized by instrumentality (e-campus construction and application) and modernization (continuity and efficiency of teaching innovation), which can also be seen in other countries. The unique goal of online higher education in China is to build a positive cyber-spirit and develop political and ideological education through digitalization (Xiao 2019).

Accordingly, strengthening online teaching in colleges and universities can be summarized as follows: (1) the need to strengthen the investment in infrastructure construction in

central and western regions and to establish a mechanism for sharing higher education resources and a mechanism for recognizing course credits; (2) the need to establish the concept of lifelong learning, cultivate students' lifelong learning ability, build a diversified talent cultivation system, and provide students with a more flexible learning system; (3) the need to change the narrow-minded thinking of specialized education, establish a more open sharing mechanism for course resources, and comprehensively update and improve the academic evaluation system; and (4) the need to strengthen the construction of resource platforms for online teaching in colleges and universities, reshape the university learning space, and comprehensively improve teachers' informatization literacy and online teaching ability (Liu et al. 2015).

Research on the resource dimension of Chinese education digitalization. Digital educational resources are tools to provide of digital educational content and support personalized learning. This research mainly covers the study of digitalized teaching content, teaching materials, teaching courseware, etc. for various school levels. Research on digital educational resources can accelerate the popularization and sharing of educational resources, help provide students with convenient and diverse learning materials, and facilitate personalized learning.

Study on the digitization of educational publications: Since 2017, educational publishing, especially that of digital teaching materials, has been a research hotspot for scholars in the field of the digitization of education in China. Various scholars focus on the current situation of the digitization of educational publishing, the problems encountered and their reasons, coping strategies, and specific cases in which to develop their research on the digitization of educational publishing in China.

The COVID-19 pandemic of 2020 precipitated a boom in online education, and as a result, the field of educational publishing has correspondingly spawned a need for the digitalization of educational publishing. The most prominent development is that publishers have begun to provide many online education services, with content services as the main body. In addition, many publishers provide many recorded courses, audio-visual videos and other digital educational resources. Some publishers have even begun to try to launch live education (Chen and Fan 2015).

All these developments show that publishers have the ability to provide diversified educational services. Given the hotspot of online education during the pandemic, publishers should pay attention to several points when promoting the digitization of educational publishing: paying close attention to the construction of digital teaching materials and accurate content; expanding the construction of audio-visual content, focusing on creating systematic microvideo and online courses; and based on the content and the regional market, moderately expanding the online training industry, creating vertical platforms, and advancing the transformation from content resource providers to educational service providers (Luo 2018).

Other scholars have focused on the digitization of publishing in the field of higher education. The digital transformation of Chinese higher education publishing faces some development difficulties. For example, the homogenization of educational resources is serious, the dominant position of content resources has been impacted, the interactivity of products is weak, and the transformation of operation mode is difficult. In the face of this dilemma, Chinese higher education publishing units should actively explore the path of digital transformation, including developing service-oriented digital products, cultivating intelligent publishing service capabilities, exploring omni-channel

marketing models, creating an all-media publishing format, and innovating the mechanism of convergent publishing (Zhou and Liu 2016).

Study of the development and application of digital learning resources in vocational institutions: In 2017, China's Ministry of Education proposed the comprehensive implementation of reforms to vocational education. In 2018, the National Implementation Plan for Vocational Education Reform was officially promulgated. As seen from the above charts, from 2017 to the present, the study of the digital transformation of vocational education has been a research hotspot in the digitization of education in China.

Based on the integration and analysis of related literature, it was found that some scholars have sorted out the construction of digital teaching resource platforms for vocational education in China, classified the types of platforms, dissected the current problems in the use of digital teaching resources in China's vocational education, and proposed corresponding solution strategies.

The scale of vocational education in China is enormous, with nearly 20,000 vocational and technical schools (colleges) at the middle and higher levels and approximately 640,000 adult education institutions. At present, China has established a considerable number of digital education and teaching resource platforms for vocational education at the national, provincial, local and school levels. The completed national-level websites specializing in vocational education include the China Vocational and Technical Education Network (www.Chinazy.org), the China Vocational and Adult Education Network (www.cvae.com.cn), and the National Digital Learning Resource Center. Provincial, municipal and regional vocational education networks have been set up and include Jiangsu Vocational Education Network (www.jsve.edu.cn), Nanjing Vocational and Social Education Network (www.njzj.net), and so on. Furthermore, many websites of secondary vocational schools and higher vocational schools have been established on a school basis. These websites provide all kinds of rich online education information and teaching resources at different levels for the audiences of vocational education in China (Wang, 2013).

The integration of the current literature on digital learning resources in Chinese vocational institutions reveals that the vast majority of online resources have the following problems. First, a unified national standard for the construction of resources on China's vocational education digital platform is still lacking, which prevents better resource sharing on the platform. Second, most digital teaching resource platforms have a veneer webpage form with few intractable resources, which does not fully reflect the characteristics of digital learning and online learning. Third, the online resources of Chinese vocational colleges and universities do not highlight the advantages and resource characteristics of their vocational education (Jin and Rong 2022).

Some scholars have utilized questionnaire surveys to understand the actual digital teaching resource usage of teachers and students at vocational colleges and universities. Moreover, based on rationalized suggestions from frontline vocational education teachers and students, scholars have proposed strategies related to the development and application of digital learning resources in vocational colleges and universities: (1) strengthening the infrastructure and resource environment construction of digital teaching resources in vocational education; (2) integrating digital teaching resources into vocational education and sharing well; and (3) creating a network exchange platform for vocational education digital teaching resources. Nearly 10 years after the study of vocational education digitalization, in 2022, some scholars proposed a strategy that is more suitable for the

development and application of digital learning resources in today's vocational colleges and universities: (1) the construction of digital campuses should move from a model "with borders" to one "without borders"; (2) teaching reform should move from uniform standards to individualized teaching resources; (3) the construction and reform of digital teaching resources should move from uniform standards to individual customization; (4) professional construction should move from accompanying industries to leading industries; (5) resource development should move from innovation to sharing; (6) conceptual enhancement should move from the main body of teachers to participation of the whole staff; and (7) input guarantees should move from government-led to multi-participatory (Cheng 2016).

Study on the equity of elementary education resources in the context of digitalization: Digital educational resources are a powerful means of promoting the balanced development of education and provide an opportunity to narrow the regional, urban-rural and interschool Digital Divide. The CiteSpace visual analysis shows that after the promulgation of the "double-decrease" policy in education, China has attempted to further expand the coverage area of basic education digitization (Wang and Li 2023). Therefore, the study of the digital transformation of basic education in promoting education equity and narrowing the gap in education quality has been one of the hot research topics among scholars in recent years.

In the relevant literature, a status quo survey on the equity of digital resources for basic education in urban and rural areas has been developed. For example, after the COVID-19 outbreak, the Chinese New Century Primary Mathematics Materials (NCPM) Committee developed a series of micro courses (referred to as NCPM micro courses), which were viewed by more than 25 million teachers and students across the country during the three-month social isolation period. A total of 132,740 data points on Chinese elementary school students' viewing of the microlessons were collected, and the extent to which Chinese elementary school students recognized NCPM microlessons after social isolation was investigated. Based on the survey, it was concluded that primary school students in urban areas were generally more likely to recognize micro classes, while primary school students in rural areas were generally less likely to recognize micro classes. Moreover, other studies employed questionnaires and revealed that students from rural or migrant schools scored lower on all Internet inequality indicators (digital access, autonomy of use, social support, Internet use, and self-efficacy) and that they were at a disadvantage in terms of their Internet use status compared to their urban counterparts. In other words, rural and urban schools in China are currently at different stages of ICT development (Li and Ranieri 2013). Thus, rural schools should focus on improving ICT infrastructure and developing quality digital resources. The digital transformation of education will become an important tool for the high-quality development of rural education and even China's basic education (Wu et al. 2019).

Accordingly, measures to improve the digital transformation of rural education and to reduce the inequality of basic education resources between urban and rural areas have been proposed in the literature. To realize the digital transformation of rural education, it is possible to upgrade and transform the infrastructure and environment of rural education, build a public service platform for "smart education" that facilitates interaction between teachers and students, and establish a database for rural education (Yang and Yu, 2014). To improve the efficiency of the digital transformation of rural education, the opportunity of the national education digitalization strategy needs to be seized to realize the parallel development of the three phases of computer-

assisted teaching, "Internet plus Education" and "Artificial Intelligence plus Education" to improve the effectiveness of rural teachers' use of digital teaching resources (Wang and Li 2023).

The relevant literature also focuses on the advantages and significance of education digitization for rural education and the realization of education equity, proposing that the digital transformation of rural education can gradually narrow the gap between urban and rural education and provide an effective way to promote their balanced development, thereby promoting the equity of compulsory education. In the process of education and teaching, the rational use of digital technology can promote equality in the starting point of education and provide a formal guarantee of equality in both the process and the outcome (Zhu and Hu 2022).

Research on the technological dimension of Chinese educational digitalization. Digital educational technology represents the driving force of digital education. Research on education empowered by advanced technologies such as big data analysis, cloud computing, and artificial intelligence can provide new possibilities and models for the future direction of education.

Study on artificial intelligence technology empowers digital transformation of education in China: Technology is the fundamental feature that distinguishes digital education from traditional education (Zhu and Hu 2022), and among the hot topics of "research on the digitalization of education in China", many studies examine digital technology. As seen from the above chart, in earlier years, for example, in 2013, technological research on the digitization of education in China mainly focused on the impact of relatively elementary information technologies, such as the IoT and two-dimensional codes (QR codes), on education. Along with the further development of digitization technology, research on the integration of technology and education, represented by AI, has become a research hotspot from 2021 onward.

Some scholars have innovatively proposed the "empowerment theory" of the digital transformation of education, which means that the true meaning of the digital transformation of education is to give full play to the advantages of modern technology to promote the modernization of education, develop high-quality education, and empower educational innovation. Technology is used not only to support teaching but also to empower education, as digital technology is used to establish new educational services, implement new methods or form new models that transcend the boundaries and development patterns of traditional education (Zhu and Hu 2022).

Various scholars have proposed different views on how digital technologies represented by AI can "empower" the digital transformation of Chinese education. Among them, the viewpoint recognized by Chinese digital education researchers is that the development and application of new-generation digital technologies, such as AI, has had a disruptive impact on various industries. However, to realize the development of China's education digitization, "AI plus Education" is not equal to the simple application of intelligent technology in education; instead, AI should be used as an endogenous variable for the overall change in education, supporting and leading its innovative development (Cao 2020).

Research on the management dimension of Chinese education digitalization. Digital educational management, which plays a planning and coordinating role in the development of digital education, serves as its guarantee. Research on the management of digital education in China includes studies on the formulation and implementation of relevant policies, as well as studies on evaluating and monitoring the effectiveness of the implementation of

digital education and digital literacy. These studies can safeguard the environment of digital education in China and ensure the healthy and orderly development of digital education in China.

Study on the digitalized industry-education integration in the context of rural revitalization: The research on the digitization of Chinese education has typical Chinese characteristics.

In 2017, the Chinese government clearly noted in the work report that it would implement the strategy of “rural revitalization”. From the cluster analysis table, it can be seen that since 2017, “the deep integration of rural revitalization and vocational education in the context of digitization” has become a hot research topic connected to the digitization of education in China.

In vocational education in China, the integration of industry and education has always been emphasized. Therefore, in the study of the digital transformation of vocational education in China, some scholars have proposed and endorsed the transformation mode of “Internet + Vocational Education” and linked it to the “rural revitalization” proposed by the Chinese government in recent years. These scholars have suggested that in the context of rural revitalization, efforts should be made to build a digital education management mechanism for the in-depth integration and synergistic development of industry and education to empower and strengthen the high-quality development of rural industries and the realization of industrial prosperity and common prosperity for rural farmers (Jin and Rong 2022).

The digital integration of industry and education involves the use of digital technology to create the mechanism of “Internet + vocational education”, giving full play to the dualistic nature of education and industry in vocational education. At the theoretical level, the government, vocational colleges and universities, agricultural research institutes and other subjects can increase their research efforts to change the rural industry talent training mode through the form of scientific research projects, focusing on the construction of network learning platforms, the development of digital curriculum resources and other fields. Moreover, the logic and path of the practice of the digital transformation of vocational education can be systematically explored to help revitalize rural industry talent, and theoretical guidance for the improvement of the quality of the training of rural industry talent can be provided. At the practical level, vocational colleges and universities should strengthen cooperation with digital enterprises and scientific research institutions, implement digital cooperation projects in upgrading digital teaching resources and building “cloud classrooms”, and establish an “Internet + ” skills training system to support the development and prosperity of rural industries (Jin and Rong 2022).

Study on the digital literacy of teachers and students: In China’s education digitization research, many studies have examined improving teachers’ and students’ digital literacy. In addition to “digital literacy”, the terminology also includes “digital competence” and “digital capability”. Digital competence is becoming more important for our current information society and plays an essential role in the process of digital informal learning (He and Zhu 2017).

ICT and media have challenged traditional education and changed the way teachers think. Teachers’ digital literacy directly affects their teaching and plays an increasingly important role in education (Zhao et al. 2016). Some Chinese scholars, based on the current situation of Chinese higher education, have utilized a questionnaire survey and built upon the relevant studies of previous researchers to propose the novel idea that we should construct an index system for evaluating the digital literacy of teachers in Chinese universities and colleges. We can evaluate the digital literacy of college teachers on five dimensions and

18 specific indicators: digital technology use, digital information management, digital content creation, digital community building and digital security ability (Yang and Zhou 2019).

In addition to studies on teachers’ digital literacy, there are also many studies on students’ digital literacy. Relevant studies have mainly focused on the current situation, problems and strategies for enhancing the digital literacy of contemporary Chinese undergraduates. Some scholars have developed and validated a questionnaire to assess the digital skills of Chinese undergraduate students based on previous literature and the Chinese educational environment. The survey shows that Chinese undergraduates are still deficient in these digital literacy skills, such as the ability to access digital information, the ability to create digital content, the awareness of digital security, and the comprehensive ability to solve digital problems. Scholars in this field believe that digital literacy that includes critical thinking is an important source of creativity for current college students and should become an important goal of higher education and one of the most important standards for measuring the quality of college students. Therefore, the strategy to enhance the digital literacy of Chinese college students should be emphasized from the top of the national top-level design to the cooperation of specific colleges and universities so that multiple parties can work together to formulate a digital literacy framework for college students that meets the actual situation in China and to determine the specific educational standards of digital literacy (Ling 2020). Furthermore, a few studies have explored the development of digital literacy for younger students in China. Due to the intense debate about the benefits and risks of the early use of digital devices, 1953 parents of younger children from a province in central China were recruited for a dissertation experiment to examine their children’s digital literacy. The findings suggest significant within-group differences in early digital literacy and multimodal practices, which are mainly due to family SES and parental factors. Therefore, we should pay more attention to low SES families and parental education to narrow the digital divide among Chinese children (Dong et al. 2022).

The interrelationships and interactions of the various dimensions of Chinese educational digital transformation. Digital education resources, digital education platforms, digital education technologies, and digital education management are interconnected and interdependent; together, they act on digital education transformation, forming a dynamically developing ecosystem that promotes the digitalization of education in China.

Their comprehensive effect on the digitization of Chinese education is mainly reflected in the following three points.

This comprehensive effect is first reflected in synergy. The richness and quality of digital resources enhance the value and attractiveness of digital platforms; the innovation and application of digital technologies promote the functional upgrading and service optimization of digital platforms; and the effectiveness and foresight of digital management guarantee the healthy and sustainable development of the entire ecosystem of China’s digital education. Their synergistic effect enables the digitization of education in China to continuously adapt to the needs of development, meet the diversified needs of different user groups, and promote the fair, high-quality and innovative development of education in China.

Second, this combined effect significantly improves the user experience. The synergy of the four dimensions—integrating high-quality resources, building a powerful platform, applying advanced technology, and implementing effective management—has allowed the development of an efficient, convenient, and highly personalized learning environment for digital education in China. In such an environment, teachers and students can

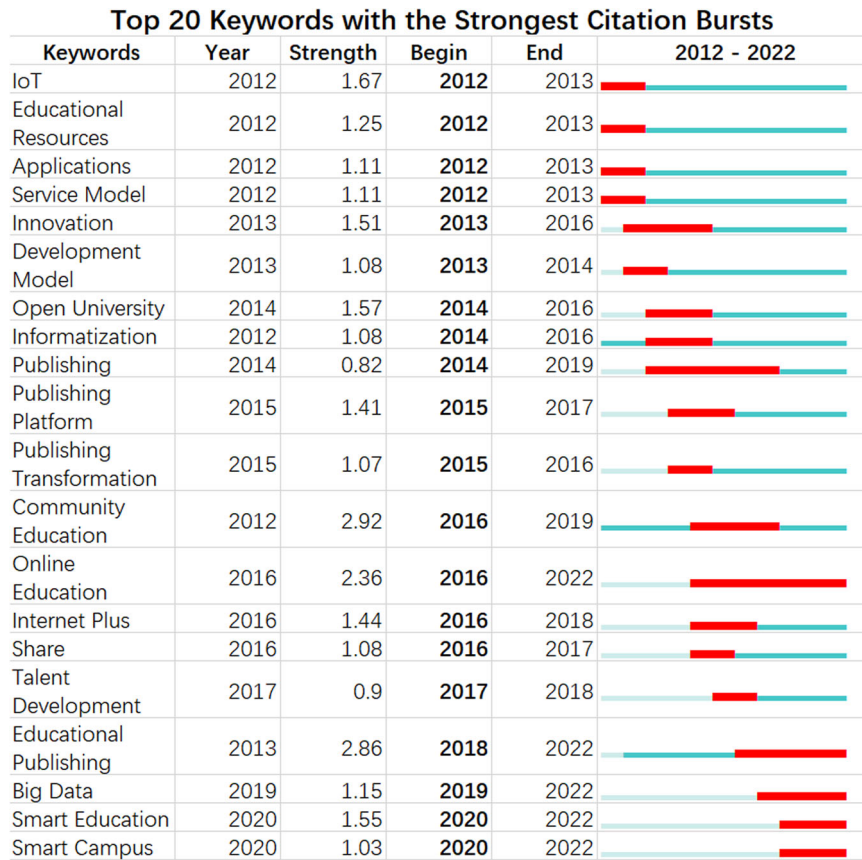


Fig. 8 Top 20 keywords with the strongest citation bursts.

experience richer and more diverse content and enjoy more flexible and customized learning methods, which not only improves the effectiveness of education and teaching but also enhances the digital literacy of teachers and students.

Finally, this combined effect has become a powerful driving force for the continued innovation and development of digital education in China. The combined effect of these four dimensions can bring positive impacts to resource optimization, platform enhancement, technological innovation and management improvement for the digital development of education in China and promote China’s education to create a more digital, intelligent and personalized future.

Results and discussions for future evolutionary trends. The analysis of the future evolutionary trends of China’s educational digitization research in this study is based on three aspects: a burst term analysis using CiteSpace, the disparities between Chinese and international educational digitization research, and the insights gained from digital education industry reports. This discussion aims to provide a comprehensive understanding of the future directions of educational digitization in China, taking into account both domestic and international perspectives.

CiteSpace-based analysis of burst terms. Chaomei Chen defines research frontiers as a set of emergent dynamic concepts and potential research questions in CiteSpace, and these are represented by burst terms that were extracted based on literature titles (Title), abstracts (Abstract), keywords (Descriptor) and identifiers (Identifiers). To identify the frontiers of research on education digitization in China, this study utilized citation bursts to highlight the frontier terms and organize the burst terms by burst

value, resulting in the top 20 burst terms with the highest burst values.

From the Fig. 8, Online Education, Educational Publishing, Big Data, Smart Education, and Smart Campus are not relatively high in strength but also that they end in 2022. Since the selected time span of our literature is only up to 2022, research related to these burst words will likely continue to be a hot topic for future studies on the digitization of education in China.

First, research on the normalization of online education in the post-pandemic era is a future evolutionary trend based on the burst terms of CiteSpace. At the start of 2020, the sudden outbreak of the COVID-19 pandemic forced China to shut down schools, from elementary schools to colleges and universities. The pandemic caused both schools that were already using a blended model and those that were not fully prepared for online teaching to switch to online teaching at the same time. As a result, the amount of literature on the study of digitization of education in China has increased dramatically since 2020. However, the results of a nationwide questionnaire survey of frontline teachers and students on the implementation of online education indicated that most teachers and students were not ready to implement online education in the long term, as they believed that it was only a temporary coping strategy in the face of the COVID-19 pandemic and that online education failed to achieve the effect of teachers’ face-to-face lectures (Xie and Yang 2020). In December 2022, when the Chinese government reclassified COVID-19 as “Category B”, the pandemic prevention policy was discontinued. It is unclear whether teachers will be interested in continuing the online mode of education after the pandemic subsides. Although classes may revert to a face-to-face model when the COVID-19 situation improves, online teaching will play a critical role in the future of education. In addition, under China’s “Class B, Category

B” regulatory requirements, Chinese schools in the post-pandemic era may occasionally shift to online teaching (Khong et al. 2023). Since the beginning of the COVID-19 pandemic, online education has become an increasingly important and indispensable form of teaching in Chinese education. Therefore, in the post-pandemic era, the normalization of online education will continue to be a major topic in future research on the digitization of Chinese education.

Second, research on the development of online educational resources in the context of the “new infrastructure” is another future evolutionary trend based on the CiteSpace burst terms. The concept of “new infrastructure” was first proposed in China in December 2018, and the construction of new infrastructure centered around new-generation information technology such as AI, big data, IoT, 5 G and other new-generation information technology has begun in various industries. With the continuous promotion of China’s new infrastructure process, the connotation of the new infrastructure is constantly being enriched. In April 2020, China’s Development and Reform Commission clarified the specific scope of the “new infrastructure” for the first time. That is, with the new development concept as the lead concept, driven by technological innovation, based on the information network, and oriented to the needs of high-quality development, this infrastructure system provides digital transformation, intelligent upgrading, and convergence and innovation services and includes information, convergence and innovation infrastructures (Zhu and Hu 2022). Against the backdrop of China’s new infrastructure, the new educational infrastructure has been developed at the right time. In the post-pandemic era, the change in the teaching paradigm of online-offline integration in the education industry has become the driving force of China’s new infrastructure for education, and the technological empowerment of 5 G + VR, education big data, AI and the booming development of online education have brought important opportunities for the development of a new technology-driven new infrastructure for education (Zhu et al. 2021). In 2021, the Ministry of Education and five other departments issued the Opinions on Vigorously Strengthening the Construction and Application of Online Educational and Teaching Resources for Primary and Secondary Schools, proposing that by 2025, a clearly positioned, interconnected, and shared online education platform system should essentially be formed, and that a disciplinary curriculum resource system covering various types of thematic education and versions of textbooks should be established for the use of online educational resources for teaching and learning to become the new normal.

Third, research on “new technology plus education” is also a future evolutionary trend based on the CiteSpace burst terms. In 2021, the “Metaverse” concept was widely used, and one by one, scholars in China’s education sector began to study the possibility of developing “Metaverse + Education”. Some scholars started by deconstructing the concept of “Metaverse”, clarifying its evolution and basic structure, and analyzing the opportunities and challenges it brings to education. The meta-universe is a higher-dimensional virtual space that transcends the real world and is characterized by an in-person immersive experience, cocreation, sharing and co-governance, the symbiosis of reality and reality, and real-time online interaction, which coincides with the development concepts and directions of future education (Li and Wang 2022). Metaverse-related technology has great potential for application in teaching scenarios such as contextualized teaching, personalized learning, game-based learning and teacher training. In the future, exploring the deep integration of metaverse and education will be very valuable (Wang and Zhang 2022). In addition to the concept of “Metaverse + Education” proposed in 2022, ChatGPT, an AI technology, has gained much

attention since its launch in 2023. Ways in which to apply ChatGPT to digital education and better integrate AI technology with education have become a research trend for related researchers. The concept of “new technology plus education” will continue to be studied by more scholars in the future digitalization of education. Future research may focus on the following topics: (1) exploring teaching models and strategies based on new technologies in education; (2) determining the educational forms and main application scenarios of the “new technologies plus education” model; (3) defining the future challenges; (4) researching the construction of new educational infrastructure under the “new technology plus education” model; and (5) conducting ethical research on digital education under the new technology model.

Gap analysis of digital education based on Chinese and International educational systems. To better analyze the future research direction of digitization of education in China, this study not only examines the CiteSpace analysis of the burst terms of the literature on digitization of education in China but also makes comparative studies between Chinese digital education and international digital education. The comparative study mainly starts from two major aspects: the review literature, and the strategies and outcomes of the digitization of education.

To begin with, the study considers the review literature on the research of “international digitization of education” mentioned in the literature review section of the previous article. Thus, it is found that some hot topics of international research on digitization of education are not covered in the current research on digitization of education in China or are examined in less detail; however, these are the topics to which scholars of China’s education digitization research should pay attention in the future.

The first topic is research on the positive impact of digital games on education. In international settings, especially in Europe and the United States, where education is more advanced, more attention has been given to exploring the positive impact of digital games on education in recent years. For example, in a review of relevant literature published in *Computers & Education*, a leading international journal on education digitization, it was found that the international education community is increasingly interested in research on the positive impacts and outcomes of video games on education (Boyle et al. 2016). In addition, *Humanities & Social Sciences Communications*, a leading comprehensive journal in the field of humanities and social sciences, has included a survey on the impact of video games on teaching performance. The present study indicates that contrary to the stances of certain governments (e.g., those of China, Korea, or Vietnam) and media scholars who consider games to be violent or addictive, several critical aspects of games facilitate learning among gamers (Jung 2020). However, this topic has rarely been addressed in research on the digitization of education in China. Therefore, scholars in China can pay more attention to the research on the positive effect of digital games on education in the future.

The second topic is the research on diversification of the Digital Divide. Promoting the balanced development of education and realizing equity in education have always been the focal points of common concern worldwide. A comparison of international and Chinese papers published in recent years shows that although both are concerned with educational equity and the digital divide, Chinese research on this topic has mainly focused on the digital divide in education between urban and rural areas in China. However, international researchers, especially those from developed countries such as European nations and the United States, have a broader and more diversified perspective on the digital divide in education. They are concerned not only with

the digital divide in education between countries and regions but also of the gaps between men and women and the differences in living conditions and in educational attainment (Kerras et al. 2020). Thus, In the future, in addition to researching the topic of equity in the importation of digital resources for urban and rural education, scholars in China can incorporate a more diverse study of the digital divide into the study of equity in the digitization of education in China.

In addition to comparing China and foreign countries from the perspective of disparities in hot spots of literature, this study also compares China's education digitization strategies and outcomes with international education digitization strategies and outcomes (Wang and Yuan 2022), and finds that there are a number of differences between the two in terms of digital education transformation. In China, due to the vastness of the country and its uneven economic development, there are obvious differences in the development of infrastructure for the digital education transformation between urban and rural areas, as well as between regions. To address this challenge, the Chinese government has implemented a series of strategic initiatives, such as the Modern Distance Education Project for Rural Primary and Secondary Schools, which aims to improve the level of informatization of education in rural areas and narrow the digital divide. These efforts reflect the emphasis on infrastructure development in China's education digitization strategy, especially in rural areas. Such strategies help ensure that students in all regions can enjoy the convenience and resources brought by digital education. In contrast, developed countries in Europe and the United States had an earlier start in digital education transformation and their digital education development has become relatively mature. These countries have a more balanced infrastructural development, with fewer differences between urban and rural areas and in development among regions. Therefore, their strategies focus more on improving the quality and depth of education digitization, such as focusing on citizens' digital rights and interests, digital ethics, and the maturity of education digitization (Department for Education 2022). Their attention to these topics as hot spots reflects the pursuit of comprehensive and high-quality development of education in developed countries. For China, with the continuous transformation and upgrading of education digitization, the focus can also be gradually expanded to these aspects in the future. The exploration of digital rights and digital ethics involves an exploration of how to protect students' privacy and data security while using digital technology to improve the quality of education; enhancing the maturity of education digitization implies the need to continuously improve the ecological environment of digital education, including optimizing teaching resources, improving teachers' digital teaching ability, innovating teaching modes, etc., which will help to realize the sustainable development of education digitization in China.

Analysis based on industry reports. At the World Conference on Digital Education in 2023, China proposed building a higher education digital development index for the first time.

As an important measure of the digital development of higher education in the world, the Higher Education Digital Development Index (HEDI) is an important tool for monitoring and assessing the level of digital development of higher education in foreign countries. This index is helpful for mapping out the current situation of the digital construction and application of higher education in all countries and regions of the world, comparing the development gaps of countries in all regions, and studying and judging the future development of higher education. Many countries and international organizations have explored and implemented the construction of an education digital

development index. These include the "Framework for Digital Transformation in Higher Education" carried out by the OECD, the "School Digital Maturity" survey implemented by the UK, the "National Digital Experience Survey" carried out by Ireland, the International Association of Universities (IAU), the "Digital Development Index for Higher Education" carried out by the United Kingdom and the "Global Survey on Digital Transformation of Higher Education Institutions" organized by the International Association of Universities (IAU) of the Research Group on the Report on the Digital Development of World Higher Education in 2023.

Currently, existing international explorations and practices focus on certain meso-level elements (e.g., digital maturity of higher education institutions) and microlevel elements (e.g., digital competence of faculty and students, as well as the state of digital infrastructure development in schools) (Xu and Zhang 2022).

China can approach this topic from a more macro level. At the latest World Digital Education Conference 2024, for the first time, China released the Global Digital Education Development Index (GDEI) and the Chinese Smart Education Development Report 2023 (Yangguang Net 2024). The report proposes to evaluate the development of digital education in each country from six evaluative dimensions: digital literacy enhancement, digital education system construction, digital education institutional innovation, digital education content reconstruction, digital teaching reform, and digital education governance upgrade, in order to identify the most suitable path for the development of digital education in each country.

In the future, China can continue to delve deeply into the Global Education Development Index, and through the evaluation of GDEI, provide Chinese wisdom, experience, and solutions for the world to monitor and assess the level of digital education development, and jointly build a new international education ecology that may be mutually learned, applied universally, and mutually promoted.

Conclusion

Research conclusions. In conclusion, based on a bibliometric analysis of knowledge mapping in Chinese education digitalization research from 2012 to 2022 and the study of specific related literature, it can be concluded that, at present, Chinese scholars, led by Zhu Zhiting of East China Normal University, have focused on the digitization of education in China.

In the period 2012–2022, the hot spots in the research on the digitization of education in China can be analyzed in the framework of digital elements of education in China, which can be divided into four dimensions: 1. Platform Dimension: Studies of the lifelong education research in digital open universities and the online teaching transformation in higher education; 2. Resource Dimension: Studies of digital educational publications, the development and application of digital learning resources in vocational colleges and universities, and the equity of basic education resources in the digital context; 3. Technological Dimension: Studies on AI technology empower digital transformation of education in China; and 4. Management Dimension: Studies of digital integration of production and teaching in rural revitalization and improvement of digital literacy of university students and faculty.

Future digital education research in China is likely to focus on the normalization of online education; the development of online education resources in the context of new infrastructure; "new technology plus education"; the impact of digital games on education; a more diversified digital divide in education; digital rights, digital ethics, digital maturity and the Global Digital Education Development Index.

Limitations and future prospects. In this bibliometric analysis, CiteSpace was used as the main tool combined with a manual reading method to evaluate papers on “Digitization of Education in China” based on the CNKI and WOS databases for the period from 2012 to 2022. However, despite the excellent accuracy of CiteSpace, this method has some limitations. First, due to the limitation of databases that can be included in CiteSpace, only WOS and the CNKI were selected as the databases for this study. Although the databases are well recognized authoritative databases both internationally and within China, studies in other databases may have been left out. Second, other publications, such as dissertations and policy documents on the digitization of education in China, were not included in CiteSpace for visualization and analysis due to the type of literature that could be included in CiteSpace analysis. This could also have an impact on a more comprehensive and precise understanding of research on the digitization of education in China. Finally, although keywords and topics related to education digitization were selected for the search in this study, some keywords were inevitably missed. In the future, the researcher can further expand the search paths and search strategies to collect more comprehensive and accurate literature to obtain a more comprehensive and systematic picture of the research on the digitization of education in China.

Data availability

The datasets analyzed during the current study are available in the supplementary file.

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Author contributions

RS had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Concept design and drafting of the manuscript: RS Data search: RS Statistical analysis: RS, XW. Acquisition, analysis, or

interpretation of data: RS Supervision: XW. All authors reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

Competing interests

The authors declare no competing interests.

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This article does not contain any studies with human participants performed by the author.

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Additional information

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