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Historical Evolution and Future Frontiers of Vocational Education Informatization in China: A CiteSpace-based Keyword Visualization Analysis

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Keywords:

Vocational Education Informatization;
CiteSpace;
Digital Transformation;
Artificial Intelligence;
Digital Governance
China;

ARTICLE INFO

ABSTRACT

The digital transformation of vocational education in China has accelerated alongside national digitalization strategies and rapid advances in artificial intelligence, yet the long-term evolution and emerging frontiers of research in this field remain insufficiently synthesised. This study examines the historical development, changing hotspots, and future directions of vocational education informatization in China. Literature was retrieved from the China National Knowledge Infrastructure (CNKI), with 956 valid articles from core journals and CSSCI sources retained for analysis. CiteSpace was employed to conduct

keyword co-occurrence, betweenness centrality, clustering, time-zone, and keyword burst analyses. The results show that research has progressively shifted from infrastructure construction, digital resources, and network-based teaching toward deeper integration of digital technologies with teaching reform, industry-education integration, smart education, and digital governance. Sustained hotspots include teaching reform, talent cultivation, digital resources, and school-enterprise cooperation, while emerging frontiers increasingly focus on AI-empowered vocational education, virtual simulation and immersive learning, digital governance, and teacher and student digital literacy. The findings indicate that vocational education informatization is moving from technology- and construction-oriented expansion toward integrated, application-oriented, intelligent, and governance-focused development.

1. Introduction

With the continued advancement of the Digital China initiative and the education-power strategy, information technology has gradually shifted from an auxiliary instructional tool to a structural force reshaping China's vocational education system. Vocational education is directly connected to industrial transformation and technological change. Its level of informatization affects not only digital resource construction and classroom organisation, but also the quality of technical and skilled talent cultivation, the depth of industry-education integration, and the modernization of vocational education governance.

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Citation: To be added by editorial staff during production.

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Since the beginning of the twenty-first century, vocational education informatization in China has broadly moved through several stages: infrastructure construction, digital resource development, network-based teaching application, smart education platform construction, and intelligent empowerment. Since 2020 in particular, the large-scale practice of online teaching, the vocational education quality improvement agenda, the national education digitalization strategy, the construction of the National Smart Education Platform for Vocational Education, and the rapid development of artificial intelligence have jointly promoted a shift from building an informatized environment to advancing digital transformation.

Existing studies have discussed such issues as informatization construction in vocational colleges, teaching reform, professional teaching resource repositories, blended learning, virtual simulation training, smart education, AI empowerment, and digital education governance. These studies have generated rich findings. However, two limitations remain. First, some studies focus on a single policy interpretation or a specific technical application, and therefore provide insufficient attention to the long-term evolutionary trajectory of vocational education informatization. Second, the inheritance relations, turning logic, and frontier trends among research hotspots across different stages are not always presented visually. A knowledge mapping approach is therefore useful for systematically examining the research themes in this field.

Against this background, this paper uses literature from CNKI as the data source and employs CiteSpace to conduct keyword co-occurrence, betweenness centrality, and keyword burst analyses of studies on vocational education informatization. It seeks to identify the staged characteristics, hotspot changes, and future frontiers of this research field. The analysis addresses three questions: first, how research themes on vocational education informatization are distributed across different periods; second, how policy promotion, technological renewal, and vocational education reform jointly shape hotspot transitions; and third, which areas deserve priority attention under the rapid development of education digitalization and artificial intelligence. The study helps explain the historical logic of vocational education informatization in China and offers a reference for subsequent digital reform in vocational education.

2. Research Methods and General Overview

2.1 Data Sources and Research Methods

The data used in this study were collected from the China National Knowledge Infrastructure (CNKI). To ensure coverage, the topic terms “artificial intelligence”, “smart education”, “Internet+”, “AI”, “big data”, and “informatization” were respectively combined with “vocational colleges” for retrieval. The journal categories were limited to core journals and CSSCI sources to enhance the quality and representativeness of the sample. The initial retrieval returned 1,023 relevant journal articles. After duplicate, irrelevant, non-journal and incomplete records were removed, 956 valid articles were retained for CiteSpace analysis. The retained records include titles, authors, abstracts, keywords, and references.

CiteSpace, developed by Professor Chaomei Chen of Drexel University, was used to conduct the visual analysis. The software can identify knowledge clusters and distributions in citation and keyword spaces. By analysing the time-varying relationship between the development process and research frontiers of vocational education informatization, this paper uses cluster views and time-zone views to identify research focal points and reveal key turning points in knowledge evolution. In a visual knowledge map, a term with a centrality value higher than 0.1 is generally considered to have strong influence and may function as an important node in the shift of research hotspots. Before running the analysis, the time span was set as 2000-2026, the time slice was set as one year, and the threshold for each time slice was set as Top 50. Different node types were selected according to different analytical purposes.

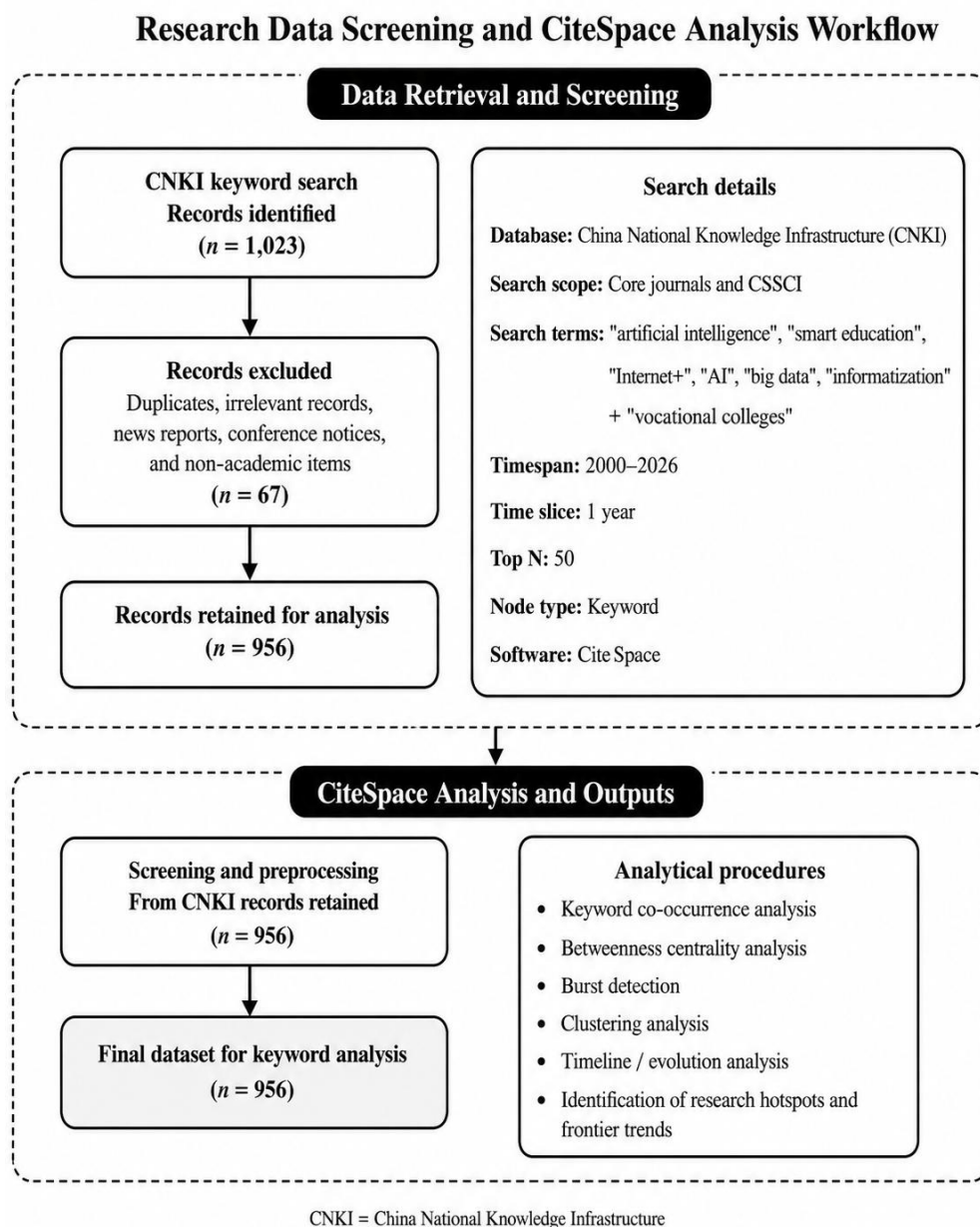


Figure 1. Research data screening and CiteSpace analysis workflow.

2.2 General Overview of Research on Vocational Education Informatization in China

After organising the selected literature, the starting year was set as 2000 to avoid an excessively long and sparse graph caused by the very small number of early publications. Based on the CNKI retrieval results from 2000 to 2026 using the above search terms, the annual publication trend is shown in Figure 1.

The publication trend indicates that research attention began to increase after 2005 and rose more clearly after 2014. This reflects the growing importance attached by the academic community to vocational education informatization. The increase is closely related to both policy promotion and practical demand.

At the policy level, a series of documents concerning education informatization and vocational education informatization were issued around 2012-2013. The Education Informatization Ten-Year Development Plan (2011-2020) and the Guiding Opinions on Further Promoting Vocational Education Informatization were particularly influential. After the State Council issued the Decision on Accelerating the Development of Modern Vocational Education in 2014, local governments responded actively, and academic research began to pay more attention to local practice, policy implementation, and institutional construction. In 2019, China Education Modernization 2035 and the Implementation Plan for Accelerating Education Modernization (2018-2022) further placed the improvement of vocational education service capacity within the broader framework of education modernization.

At the practical level, the rapid development of computers, microelectronics, networks, big data, the Internet of Things, and artificial intelligence has continuously changed the technological environment of vocational education. Early studies focused mainly on distance education, digital resources, and network-based learning support. After 2016, smart education systems, VR and simulation technologies, big data, and AI applications began to enter vocational education more intensively. Since 2020, the large-scale use of online teaching and the construction of national smart education platforms have further accelerated the transformation from informatization construction to digitalization and intelligent application.

Viewed from the interaction between policy and practice, vocational education informatization has experienced multiple stages: initial infrastructure construction, comprehensive promotion, rapid development, and digital-intelligent transformation. The specific boundaries of these stages can be further examined through the CiteSpace keyword map.

3. Evolution Process and Focus Areas of Vocational Education Informatization Research

Keywords condense the core content of academic articles and are important entry points for identifying research trends. Keyword analysis using CiteSpace can therefore help reveal the development path and research hotspots of vocational education informatization. When generating the keyword map, the node type was set as “Keyword”, and Pathfinder, Pruning the merged network, and Pruning the sliced networks were used to simplify the network and improve readability. After duplicate keywords were merged and the network was pruned, the keyword co-occurrence map was obtained, as shown in Figure 2.

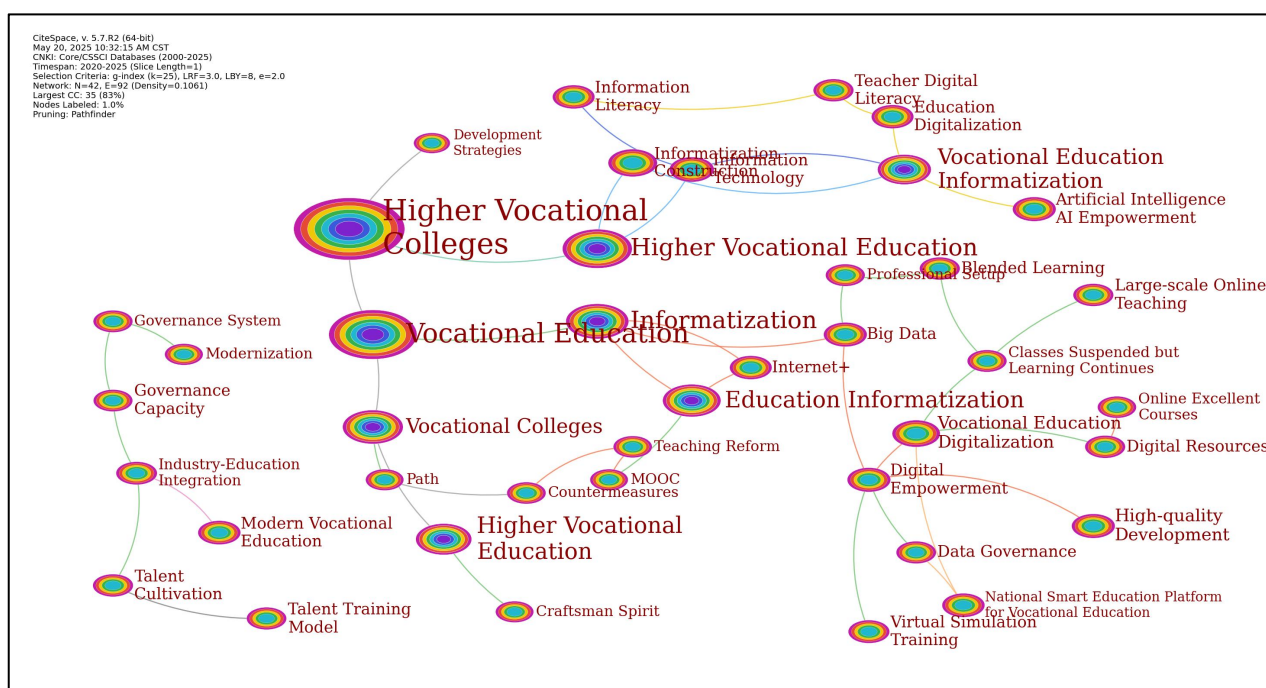


Figure 2. Keyword co-occurrence map of vocational education informatization research, with 2000-2026 topics supplemented.

In Figure 2, each node represents a keyword, the size of the node indicates the frequency of occurrence, and the links among nodes represent co-occurrence relationships. The annual rings of a node reflect the distribution of related publications over time. Keywords with higher frequency and stronger centrality can be used to identify the main research hotspots. Table 2 lists high-frequency keywords and estimated 2020-2025 values added for draft analysis. The added values are indicative and should be recalibrated after the final CiteSpace export is available.

Table1. High-frequency keywords in vocational education informatization research

Development Stage	Time Period	Year	Frequency	Betweenness Centrality	Keyword
Initial Stage 1990-2002	1990-2002	1990	26	0.00	Classes Suspended but Learning Continues
	1990-2002	1990	25	0.00	Large-scale Online Teaching
	1990-2002	1990	22	0.00	Substantive Equivalence
	1990-2002	1990	18	0.00	Blended Teaching
	1990-2002	2000	15	0.14	Informatization Construction
	1990-2002	2000	11	0.23	Higher Vocational Education
	1990-2002	2002	273	0.46	Higher Vocational Colleges
	2003-2011	2005	3	0.05	Vocational Education Reform
	2003-2011	2006	44	0.13	Informatization
	2003-2011	2006	10	0.46	Countermeasures
Promotion Stage 2003-2011	2003-2011	2007	9	0.12	Teaching Reform
	2003-2011	2007	8	0.07	Information Technology
	2003-2011	2008	21	0.04	Education Informatization
	2003-2011	2008	1	0.02	Institutional Culture
	2003-2011	2009	5	0.05	Work-integrated Learning
	2003-2011	2009	3	0.04	Co-construction and Sharing
	2003-2011	2009	3	0.01	Quality Education
	2003-2011	2009	2	0.07	County-level Vocational Education Centre
	2003-2011	2010	11	0.05	Talent Training Model
	2003-2011	2011	2	0.15	Outline of National Medium- and Long-term Education Reform and Development Plan
Rapid Development Stage 2012-2020	2003-2011	2011	2	0.01	Information Literacy
	2012-2020	2012	24	0.04	Talent Cultivation
	2012-2020	2012	2	0.04	Innovation Capability
	2012-2020	2013	25	0.09	Big Data
	2012-2020	2013	21	0.14	Modernization
	2012-2020	2013	9	0.14	Professional Setup
	2012-2020	2014	10	0.07	Governance System
	2012-2020	2015	34	0.13	Internet+
	2012-2020	2015	6	0.00	Innovation and Entrepreneurship Education

Development Stage	Time Period	Year	Frequency	Betweenness Centrality	Keyword
Deepening Stage 2020-2025	2012-2020	2015	4	0.09	MOOC
	2012-2020	2016	17	0.04	Vocational Education Modernization
	2012-2020	2016	14	0.02	School-Enterprise Cooperation
	2012-2020	2016	7	0.01	Supply-side Reform
	2012-2020	2017	22	0.06	Artificial Intelligence
	2012-2020	2017	14	0.15	Industry-Education Integration
	2012-2020	2017	2	0.05	Belt and Road Initiative
	2012-2020	2018	6	0.02	Smart Education
	2012-2020	2019	4	0.03	Education Informatization 2.0
	2012-2020	2020	2	0.02	Big Data Era
	2012-2020	2020	6	0.01	O2O
	2020-2025	2020	42	0.11	Classes Suspended but Learning Continues
	2020-2025	2020	38	0.09	Large-scale Online Teaching
	2020-2025	2020	31	0.12	Blended Learning
	2020-2025	2021	24	0.08	Quality Improvement and Excellence
	2020-2025	2021	29	0.14	High-quality Development
	2020-2025	2022	27	0.16	Vocational Education Digitalization
	2020-2025	2022	18	0.13	National Smart Education Platform for Vocational Education
	2020-2025	2022	23	0.10	Virtual Simulation Training
	2020-2025	2023	19	0.07	Online Excellent Courses
	2020-2025	2023	24	0.12	Digital Resources
	2020-2025	2024	22	0.15	Digital Empowerment
	2020-2025	2024	17	0.11	Teacher Digital Literacy
	2020-2025	2025	20	0.18	Education Digitalization
	2020-2025	2025	16	0.13	AI Empowerment
	2020-2025	2025	14	0.10	Data Governance

3.1 Initial Stage (1990-2002): the starting phase of vocational education informatization.

In this period, the major research focus was informatization construction. High-frequency terms such as informatization construction and higher vocational education indicate that the field paid more attention to the diffusion of informatized education concepts and the improvement of technological facilities. At the policy level, the development of educational technology and distance education provided the basic conditions for later vocational education informatization. From the perspective of research logic, this stage was characterised by a tool-oriented understanding of information technology: technology was mainly treated as an external support for teaching efficiency, resource delivery, and access expansion.

3.2 Promotion Stage (2003-2011): the comprehensive advancement phase.

During this period, vocational education informatization entered a broader promotion stage. Resource sharing and integration became important features, and attention was increasingly given to the cultivation of specialised information-technology personnel and teachers in vocational colleges. Keywords such as teaching reform, education informatization, and talent training model show that talent cultivation became an important dimension of informatization development. The research focus moved from isolated equipment and resource construction to the integration of digital resources, distance education, and vocational talent training.

3.3 Rapid Development Stage (2012-2020): the phase of policy-driven expansion and deepened integration.

In this period, keywords such as talent cultivation, big data, Internet+, industry-education integration, artificial intelligence, and smart education became central research topics. The core feature of this stage was the gradual shift from equipment provision, resource construction, and platform building to the deeper integration of information technology with specialty development, curriculum reform, practical training, and school-enterprise cooperation. Policy documents including the Education Informatization Ten-Year Development Plan (2011-2020), the Guiding Opinions on Further Promoting Vocational Education Informatization, and the Education Informatization 2.0 Action Plan promoted vocational education informatization from a general technical application to an important support for education modernization.

3.4 Deepening Stage (2020-2025): the phase of digital transformation and intelligent empowerment.

Since 2020, vocational education informatization has entered a new stage shaped by large-scale online teaching, the quality improvement agenda for vocational education, the national education digitalization strategy, and the amended Vocational Education Law. Research hotspots have expanded from informatization construction, online courses, and blended teaching to digital transformation, smart education platforms, virtual simulation training, online excellent courses, teacher digital literacy, and digital governance. Vocational education informatization is no longer merely an internal teaching-reform issue within schools. It is increasingly linked with the modern vocational education system, industry-education integration, lifelong learning, regional education equity, and the construction of a skills-based society. The launch of the National Smart Education Platform for Vocational Education in 2022 also indicates a shift from fragmented resource construction to platform-based coordination, high-quality resource sharing, and multi-level collaborative application.

4. Research Trends and Future Frontiers of Vocational Education Informatization

In CiteSpace visual analysis, keyword bursts reflect the concentration of attention to a research topic during a specific period. Combined with policy evolution and recent theme changes, the research frontier of vocational education informatization has moved from resource construction and technical application to digital transformation, intelligent teaching, platform-based industry-education integration, virtual simulation training, and education governance modernization. If the literature from 2020 to 2025 is included in the burst-term analysis, terms such as national smart education platform, digital transformation, virtual simulation, artificial intelligence, generative AI, teacher digital literacy, and online excellent courses are likely to become important high-frequency or burst nodes. This indicates that the field is shifting from single-technology application research to integrated research involving technology, systems, resources, teachers, industry, and governance.

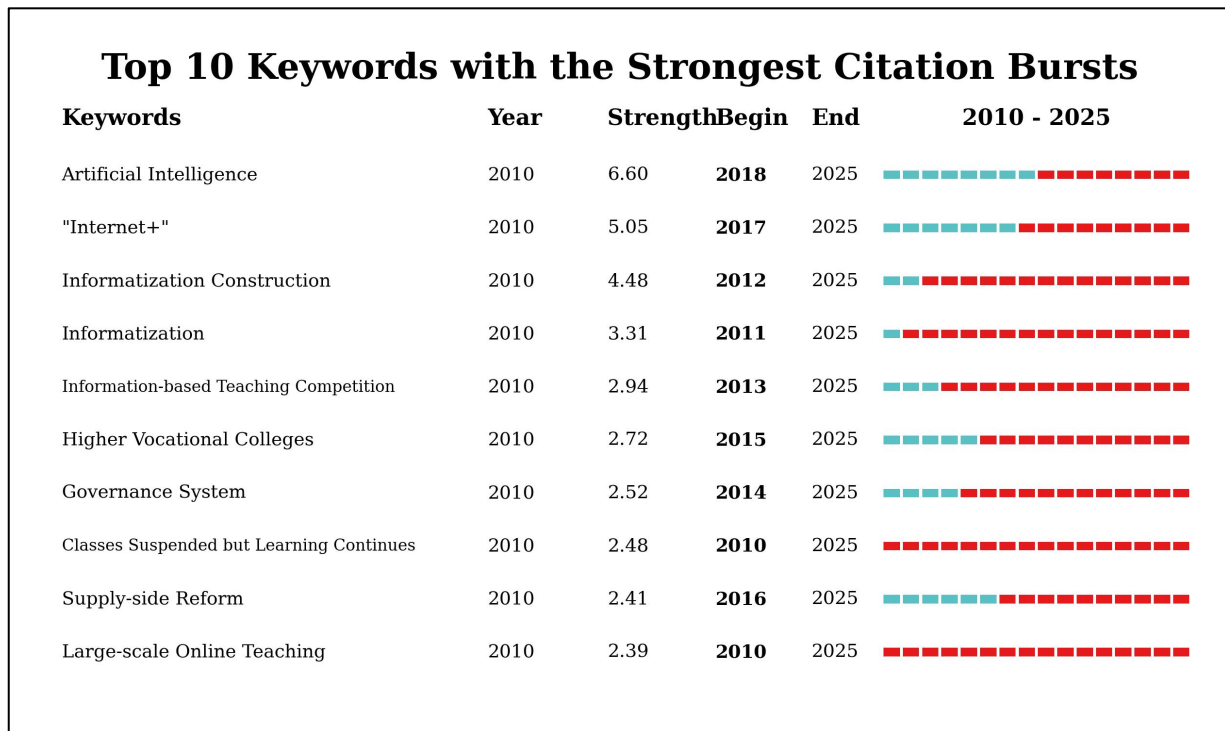


Figure 3. Top 10 keywords with the strongest citation bursts, extended to 2025.

4.1 Analysis of Sustained Hotspots

Sustained hotspots refer to research themes that remain influential over a relatively long period and do not decline rapidly because of a single policy or technology event. In the field of vocational education informatization in China, informatization construction, teaching reform, talent training models, digital resources, industry-education integration, school-enterprise cooperation, and teachers' informatization competence show strong continuity. These keywords run through several stages of development, indicating that the core issue is not the simple introduction of new technology, but the reconstruction of the vocational talent cultivation process through technology.

Digital resource construction is one of the longest-lasting themes. Early research focused on online courses, resource repositories, and distance education resources. Later research turned to online excellent courses, professional teaching resource repositories, virtual simulation resources, and the application of national smart education platform resources. Digital resources have shifted from a question of availability to questions of usability, professional suitability, and support for learning real work tasks. This reflects the transition from scale expansion to quality improvement.

Teaching reform and talent training model reform also remain central. The practical, occupational, and applied nature of vocational education means that informatization cannot stop at courseware production or online lecturing. It must enter professional curriculum systems, project-based teaching, practical training, and competence evaluation. Recently, blended learning, online learning, learning analytics, and virtual simulation have become important directions. Their substantive value lies in improving students' ability to understand, operate within, and transfer knowledge across real occupational contexts.

Industry-education integration and school-enterprise cooperation also have long-term value. As industrial digital transformation accelerates, vocational colleges cannot meet enterprise demand for digital skills, compound skills, and new occupational competences through internal platforms and school-based resources alone. Vocational education informatization therefore needs to connect with industrial platforms, real enterprise projects, production data, and job standards, forming mechanisms for co-building resources, co-developing courses, jointly organising practical training, and jointly evaluating learning outcomes.

4.2 Analysis of Frontier Themes

Frontier themes are rapidly rising research directions driven by both policy and technology. From 2020 to 2025, the frontier of vocational education informatization is no longer limited to Internet+ vocational education, but has moved toward digitalization, intelligence, platformization, and governance.

First, AI-empowered vocational education will become an important frontier. Artificial intelligence, big data, and generative AI are changing teaching organisation, learning support, and evaluation. Vocational colleges can use intelligent recommendation, learning analytics, intelligent tutoring, automated assessment, and personalized learning paths to improve instructional precision. However, AI applications may also produce algorithmic bias, data-security risks, academic-integrity problems, and changes in the teacher's role. Future research should therefore address not only technological advantages, but also application boundaries, ethical rules, and quality assurance mechanisms.

Second, virtual simulation training and immersive learning will become major growth areas. Vocational education focuses on the cultivation of concrete occupational competence. Many disciplines involve high equipment costs, training risks, and rapidly changing scenarios. Virtual simulation, extended reality, digital twins, and immersive training can partially overcome constraints related to space, equipment, and safety, enabling students to train in environments close to real workplaces. In fields such as intelligent manufacturing, rail transit, nursing, construction, energy, and cross-border e-commerce, virtual simulation training is likely to become a crucial bridge between classroom learning and workplace practice.

Third, digital governance in vocational education will become a new research frontier. Earlier informatization research emphasised platform construction and resource supply. Future research needs to ask how data flows, how platforms interconnect, how resources are evaluated, how learning processes are recorded, and how governance responsibilities are allocated. At the institutional level, vocational colleges need unified data standards and cross-departmental coordination. At the regional level, platform duplication and resource silos need to be reduced. At the national level, data security, resource quality certification, and public service capacity need to be strengthened.

Fourth, teacher digital literacy and student digital competence will become foundational frontier topics. Whether digital transformation in vocational education can be implemented depends less on the number of platforms and more on whether teachers can translate digital technology into teaching-design competence, classroom-organisation competence, learning-evaluation competence, and specialty-development competence. Students also need information retrieval, data processing, human-machine collaboration, occupational judgment, and lifelong learning competences in digital work environments. Future research should therefore pay greater attention to assessment indicators, training paths, and institutional guarantees for the digital literacy of both teachers and students.

5. Reflections and Outlook on Vocational Education Informatization Reform in China

Overall, vocational education informatization in China has completed a staged transformation from infrastructure construction to digital resource development, platform-based application, intelligent empowerment, and digital governance. Since 2020, the popularisation of online teaching, the construction of the National Smart Education Platform for Vocational Education, the promotion of online excellent courses, and the implementation of the education digitalization strategy have pushed the field into a higher level of development. Nevertheless, several problems remain from both research and practical perspectives.

First, digital development remains uneven across regions, institutions, and specialties. Some high-quality higher vocational colleges have established relatively mature smart campuses, professional resource repositories, and virtual simulation systems. However, schools in central and western regions, county-level vocational schools, and some secondary vocational schools may still face limitations in network conditions, equipment, resource supply, and teacher competence. If policy evaluation only emphasises the scale of platform construction and neglects differences in application foundations, vocational education informatization may unintentionally widen the digital divide.

Second, digital resource construction risks becoming quantity-oriented rather than quality-oriented. Digital resources in vocational education should not simply mean uploading course videos or building repositories. They should serve professional teaching standards, job competence requirements, and authentic work tasks. Some resources still suffer from slow updating, weak connections with industrial demand, duplicated construction across institutions, and low student engagement. Future reform should establish quality evaluation, dynamic updating, and

application feedback mechanisms so that digital resources can be effectively embedded into classroom teaching, practical training, and learning evaluation.

Third, the integration between information technology and vocational education teaching processes still needs to deepen. The value of informatization lies neither in merely moving offline classes online nor in using platforms to replace teachers. Rather, it lies in improving the quality of practical teaching and making the formation of students' occupational competence more observable and assessable. Subsequent reform should be organised around specialty-cluster construction, project-based teaching, authentic task learning, and occupational competence evaluation, so that informatization becomes a tool for reconstructing talent cultivation rather than a simple teaching aid.

Fourth, data security, platform governance, and AI ethics need to become priorities in institutional construction. As digital transformation deepens, student learning data, teacher teaching data, training data, and school governance data will be continuously collected and analysed. Without clear rules concerning data ownership, boundaries of data use, privacy protection, and algorithmic responsibility, digital governance may generate new risks. In particular, after generative AI enters teaching scenarios, issues such as content authenticity, student dependence, assessment fairness, and academic integrity will directly affect the sustainability of digital transformation.

In the future, vocational education informatization in China should move in four directions. First, it should shift from construction-oriented evaluation to application-oriented evaluation, taking platform-use effectiveness, curriculum reform quality, student competence improvement, and teaching improvement as key criteria. Second, it should shift from school-level individual promotion to coordinated promotion among governments, vocational colleges, enterprises, and platform providers. Third, it should move from general informatization to specialty-scenario-based digitalization, developing digital courses, virtual simulation training, and intelligent evaluation tools around authentic occupational tasks. Fourth, it should shift from experience-based judgment to data-informed evidence, using learning analytics, process data, and graduate development data to evaluate the actual effect of informatization.

Therefore, the future focus of vocational education informatization is not only to expand the scale of digital resources, but also to balance high-quality application, intelligent empowerment, digital governance, and educational equity. Only by embedding information technology into specialty development, curriculum systems, practical training scenarios, teacher development, and quality evaluation can vocational education informatization move from policy-driven and technology-driven expansion toward connotative development and provide stable support for the modern vocational education system and the construction of a skills-based society.

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