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Pathways and outcomes of digital transformation in Chinese vocational colleges

Xinyan Ma[1], Meirong Chen[1], Junfeng Diao[2,*]

[1]Department of Modern Educational Technology, College of Education, Hainan Normal University, Haikou 571100, Hainan Province, China

[2]Research Center for Digital Transformation of Education, Hainan Normal University, Haikou 571100, Hainan Province, China

ABSTRACT

With the advent of the digital era, Chinese vocational colleges are undergoing significant digital transformation aimed at reshaping technical and skilled talent training models. This paper employs a case analysis method to investigate the pathways and outcomes of digital transformation in these institutions. From four perspectives—policy support, infrastructure development, digital teaching resource creation and application, and the enhancement of teachers' and students' digital competencies—this study examines the practical experiences and achievements of vocational colleges in their digital transformation, complemented by real-world cases. The findings reveal that national policies provide solid strategic guidance and essential resource allocation for digital transformation efforts. Infrastructure upgrades substantially improve the digital learning environment, thereby advancing educational modernization. Furthermore, innovative digital teaching resource applications promote learning flexibility and interactivity. Finally, systematic training and practice have markedly elevated the digital skills of teachers and students, optimizing teaching quality and learning outcomes. By analyzing typical cases, this paper summarizes best practices for digital transformation in vocational education and offers recommendations for future progress.

Key words: vocational colleges, digital transformation, educational policy, educational practice

INTRODUCTION

The digital transformation of Chinese vocational colleges is a critical initiative to modernize vocational education, elevate talent training quality, and drive industrial transformation and upgrading. Guided by a national strategy, the strategic reform framework—"one body, two wings"—propels educational innovation and high-quality development (Xinhua News, 2022). In 2022, the comprehensive revision of the "Vocational Education Law of the People's Republic of China" reinforced the differentiated evolution of vocational education and clarified its core role in serving economic and social development. Vocational education was established as an independent category on par with general education (Ministry of Education, 2022).

Digitalization is the core driving force in transforming vocational education, revolutionizing teaching, management, and resource development. Initiatives such as smart campuses, virtual simulation training bases, and digital resource libraries optimize teaching environments, enhance flexibility and personalization, and transcend temporal and spatial barriers to provide convenient learning opportunities (Li, 2024). Simultaneously, digitalization empowers industry-education integration through data-driven decision-making, intelligent courses, and virtual training that are precisely

***Corresponding Author:**
Diao Junfeng, Research Center for Digital Transformation of Education, Hainan Normal University, No. 99 Longkun South Road, Qiongshan District, Haikou 571100, Hainan Province, China. Email: 920268@hainnu.edu.cn; https://orcid.org/0009-0008-8325-1185

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aligned with industry demands. National policies, including the "Action Plan for Education Informatization 2.0", chart a clear digitalization roadmap, advancing teaching quality, sharpening students' practical skills, and reducing regional disparities in educational resources.

Vocational colleges have emerged as powerful engines for regional economic development by leveraging digital technologies to transform teaching and management. In this study, an in-depth case analysis of how Chinese vocational colleges utilize digital technology to enhance instructional quality and optimize management models in the current era will be conducted (Zhao *et al.*, 2024). The paths taken and outcomes achieved in their digital transformation will also be discussed, providing actionable insights and strategic recommendations for guiding future reforms and sustained development.

LITERATURE REVIEW

Characteristics and models of digital transformation in foreign vocational colleges

The digital transformation of vocational education in Switzerland focuses on enhancing teachers' digital literacy, establishing "digital facilitators" to lead technology integration (Cattaneo *et al.*, 2021), and fostering an innovative learning culture to meet the skill demands of Industry 4.0. German vocational colleges prioritize learner-centered digital transformation by incorporating advanced technologies, customized assessment tools, and interdisciplinary collaboration, ensuring continuous improvement in educational quality and skill assessment (Rüschoff, 2022). In Indonesia, vocational colleges drive digital transformation with online learning models and platforms like Google Classroom, ensuring students have continuous access to educational resources while enabling flexible online teaching for educators (Muktiarni *et al.*, 2021). Russian vocational institutions adopt a competency-based model, strengthening essential digital economy skills and using personalized learning paths and innovative strategies to prepare professionals for the future workplace (Vetkina *et al.*, 2018).

Comparison of the characteristics of digital transformation in domestic and foreign vocational colleges

Vocational colleges abroad emphasize enhancing teachers' digital literacy, adopting learner-centered approaches, integrating advanced technologies such as virtual reality (VR) and artificial intelligence (AI), and encouraging interdisciplinary collaboration in their digital transformation. By contrast, the digital transformation of vocational colleges in China, driven by strong national policies, not only prioritizes infrastructure development and resource creation but also places special emphasis on resource sharing and continuous improvement. This approach addresses challenges such as uneven resource distribution and rapid technological advancements, thereby improving teaching quality, enhancing adaptability to the labor market, and contributing more effectively to national economic growth.

Policy-driven and practical aspects of digital transformation in domestic vocational colleges

Policy support and implementation for digital transformation in vocational colleges

The digital transformation of vocational colleges in China has advanced significantly under robust policy support. National policies, including "China's Education Modernization 2035" and the "Implementation Plan for National Vocational Education Reform", provide clear direction and guidance for digital transformation (Yang & Zhu, 2025). These policies drive comprehensive information infrastructure improvements through funding and resource allocation, encompassing campus network expansions, data center upgrades, and procurement of cutting-edge teaching equipment. Policies also incentivize the development and application of digital teaching resources, including online courses, virtual laboratories, and intelligent teaching platforms, thus enriching pedagogical methods and content. Moreover, focused efforts on enhancing teachers' digital literacy have spurred related training programs and technical support systems. While these policies have laid a solid foundation for digital transformation in vocational colleges, further efforts are needed to refine strategies, address implementation challenges, and achieve a holistic transformation.

Construction and development of digital transformation infrastructure

The construction and development of digital transformation infrastructure in Chinese vocational colleges have made significant strides through policy support. National and local governments have increased investments in information infrastructure, enabling many colleges to successfully upgrade campus networks, augment bandwidth, and expand wireless coverage to ensure stable network environments. New and renovated data centers provide stronger data processing and storage capabilities, facilitating the seamless integration of online courses and digital teaching resources. On the hardware front, vocational colleges have adopted advanced technologies, including smart classrooms, interactive whiteboards, and VR tools, complemented by mobile terminals to meet the demand for learning anytime, anywhere. Software innovations, such as integrated teaching management systems and

digital resource platforms, have boosted teaching and administrative efficiency (Conde *et al.*, 2014). However, despite this progression, persistent challenges—including insufficient funding, rapid technological obsolescence, and inadequate technical maintenance—require sustained attention to achieve a comprehensive and sustainable digital transformation.

Current status of development and concomitant issues

Chinese vocational colleges have attained remarkable achievements in developing and applying digital teaching resources, marking a transformative shift in educational delivery. Many institutions have launched comprehensive online course platforms and virtual laboratories, producing a rich array of digital content, including multimedia courseware, electronic textbooks, and sophisticated simulation systems (Clark *et al.*, 2003). These developments not only enhance the interactivity and flexibility of teaching but also provide students with more learning methods and practical opportunities. Moreover, the implementation of educational digitalization policies has accelerated the sharing and exchange of teaching resources, with many colleges maximizing resource utilization through inter-college collaboration and resource integration.

Despite these achievements, challenging issues remain. First, there is an uneven distribution of resources during the development process. Due to funding and technical limitations, some colleges are unable to develop and maintain high-quality digital resources. Second, the effectiveness of digital teaching resources varies across colleges and subjects, as teachers and students exhibit differing levels of adaptability to new technologies, thus impacting the practical outcomes of digital integration. Third, the rapid pace of technological advancement creates significant difficulties in updating and maintaining resources. Existing digital platforms and content require continuous upgrades to remain relevant and functional, posing high demands on colleges' technical support and maintenance capabilities.

Enhancement and evaluation of digital competencies

Chinese vocational colleges have made notable progress in enhancing and evaluating digital competencies, but challenges remain that hinder further progress. As educational information policies advance, vocational colleges have ramped up efforts to improve digital skills among both teachers and students (Fernández-Batanero *et al.*, 2022). Many colleges have implemented systematic training programs for faculty, focusing on essential areas such as the use of teaching tools, online course design, and data analysis, with the goal of strengthening their digital teaching capabilities. Furthermore, colleges have introduced teaching seminars and exchange platforms to encourage educators to share their experiences and best practices in digital pedagogy.

For students, vocational colleges are enhancing digital skills through updated curricula and practical activities. For instance, new courses in programming, data analysis, and digital media production have been added, along with a wealth of online learning resources and practical opportunities, thus helping students master skills related to digitalization (Alenezi, 2023). These initiatives not only improve students' digital literacy but also provide a strong foundation for their future careers in the rapidly evolving job market.

Despite these accomplishments, significant challenges in evaluation and continuous improvement persist. First, there is no unified standard for assessing digital competencies; different colleges and subjects use varied definitions and assessment methods, which compromises the comparability and reliability of evaluation results (Falloon, 2020). Second, the tools and methods used for assessment have not kept pace with advancements in digital technology and teaching methods, which could undermine the accuracy and practicality of evaluations. Finally, the long-term sustainability of improvements in digital competencies requires ongoing attention. The rapid pace of technological change necessitates continuous investment in resources and support to ensure that both teachers and students can stay ahead of digital trends.

In summary, while Chinese vocational colleges have made notable progress in their digital transformation, particularly in areas like digital resource development and application, infrastructure building, and digital competency enhancement, several critical areas still need attention. These include the equitable development of resources, optimizing their usage, maintaining and updating infrastructure, standardizing evaluations, and ensuring continuous competency growth. Despite significant advancements in infrastructure, challenges such as limited funding, fast-paced technological change, and inadequate technical maintenance and support persist (Wu, 2022). These issues must be addressed in future work to fully realize the potential of digital transformation in vocational education. Therefore, this research will explore the trajectories and outcomes of digital transformation in Chinese vocational colleges from four key lenses: policy support, infrastructure construction, development and application of digital teaching resources, and enhancement of teachers' and students' competencies.

THEORIES AND MODELS SUPPORTING DIGITAL TRANSFORMATION

Theory of workplace learning

In workplace learning, the activity theory serves as a significant theoretical foundation. It focuses on the complexities and contradictions present in real workplace environments. By applying the activity theory, one can understand and explain learning processes in the workplace and identify ways to effectively promote such learning. Workplace learning integrates work and learning within a work context, aiming to foster continuous development for both individuals and organizations. This approach highlights the agency of individuals while also considering the organizations in which they operate. It addresses individual-level aspects, such as learning content, professional knowledge, motivation, and identity, as well as organizational-level factors like learning environments in technological and socio-cultural contexts. In the digital age, workplace learning faces new requirements from both organizations and individuals. To adapt to the evolving competitive environment, workplace learning must embrace digital technology and facilitate systematic digital transformation. Activity theory provides a framework to analyze and promote digital transformation by suggesting specific actions and paths for change (Zhu & Zhang, 2024). In the context of vocational colleges, this theory plays an important supporting role, as evidenced by the aspects expounded below.

Practice-oriented learning

Digital transformation involves more than just adopting technology; it also necessitates changes in teaching and learning methods. The theory of workplace learning emphasizes experiential learning in real work environments. Vocational colleges can establish virtual simulation training bases and intelligent training workshops, enabling students to practice operations in simulated real work scenarios. For example, technologies such as VR and augmented reality (AR) technologies allow students to perform equipment operations and troubleshoot issues in a virtual environment, thereby improving their practical skills.

Situated learning

This theory posits that learning occurs in specific contexts and that learning content should be aligned closely with real-world work scenarios. In the process of digital transformation, vocational colleges can leverage digital teaching resources and online learning platforms to integrate theoretical knowledge with practical work cases, offering contextually relevant learning experiences. For example, case analyses in online courses enable students to better understand how theoretical knowledge is applied in real-world work settings, thereby increasing the relevance and practicality of their learning.

Collaborative learning

The theory of workplace learning underscores the importance of interaction and collaboration among learners. During digital transformation, vocational colleges can use online collaboration platforms to foster communication and cooperation among students. For instance, team projects and online discussions provide opportunities for students to share experiences and address challenges together, enhancing their collaboration and communication skills. At the same time, teachers can offer timely guidance and feedback through these platforms, further enhancing the interactivity of the teaching process.

Technology acceptance model (TAM)

TAM was first proposed by Davis in 1989 (Hong, 2024). Davis applied the theory of reasoned action to the field of information technology user acceptance, thereby creating TAM. According to Davis, the model includes two main factors: perceived usefulness and perceived ease of use. Perceived usefulness refers to the extent to which users expect that using an application system in an organization will enhance their job performance. Perceived ease of use refers to the extent to which users expect the target system to be simple to use. Attitude toward use presents the subjective positive or negative feelings users have about using the system. Behavioral intention to use reflects the degree to which an individual plans to engage in a specific behavior. The model posits that the use of the target system is primarily determined by the users' behavioral intention, which is influenced by their attitude toward use and perceived usefulness. Attitude toward use, in turn, is shaped by perceived usefulness and perceived ease of use. Perceived usefulness and perceived ease of use are both influenced, with perceived ease of use also directly affecting perceived usefulness (Wang & Xu, 2024). In the context of digital transformation, the TAM model offers valuable theoretical support, as explained in the sections below.

Perceived ease of use

Perceived ease of use refers to the effort users believe is required to operate a particular technology system. During digital transformation, vocational colleges must ensure that digital tools and platforms have user-friendly and intuitive interfaces to minimize user difficulty. For instance, interactive electronic whiteboards and VR devices in smart classrooms should feature intuitive operational interfaces, enabling teachers and students to quickly familiarize themselves with the technology and reduce learning costs. When users perceive that a technology is easy to use, they are more willing to accept

and adopt it, thereby increasing the likelihood of successful digital transformation.

Perceived usefulness

Perceived usefulness refers to the extent to which users believe a technology system can enhance their work or learning efficiency. In the digital transformation of vocational colleges, digital teaching resources and platforms should demonstrably improve teaching quality and learning outcomes. For example, online course platforms enable students to learn anytime and anywhere, while teachers can monitor students' progress in real time and provide personalized feedback. When users perceive a technology as useful, they are more likely to actively engage with it, thereby fostering deeper digital transformation.

Attitude

Attitude refers to users' overall evaluation and emotional reaction to using a particular technology system. To facilitate digital transformation, vocational colleges must foster a positive attitude among teachers and students toward digital technology through training, awareness campaigns, and demonstrations. For example, hosting digital teaching seminars and experience-sharing sessions allows teachers to showcase successful digital teaching practices, inspiring others to adopt similar methods. A positive attitude enhances users' behavioral intentions, thereby increasing the frequency of technology use.

Behavioral intention

Behavioral intention reflects the extent to which users plan to use a particular technology system. Vocational colleges can strengthen teachers' and students' willingness to adopt digital technology by providing policy support, resource investment, and technical assistance. For example, integrating the use of digital teaching tools into teachers' performance evaluations can encourage greater adoption of digital resources. When users have strong behavioral intentions, they are more likely to actively utilize these technologies, thereby driving the implementation of digital transformation.

PATHS OF DIGITAL TRANSFORMATION IN CHINESE VOCATIONAL COLLEGES

Path one: policy promotion—establishing a strategic framework for digital transformation

China considers educational digitalization to be a vital component of its national development strategy and has implemented several strategic measures to promote the digital transformation of vocational colleges. The "2022 Work Key Points" explicitly calls for the implementation of an educational digitalization strategy aimed at shaping new advantages in higher education reform and development (Guo & Wang, 2025). China is actively participating in the United Nations Educational, Scientific and Cultural Organization's (UNESCO's) global educational reform initiatives, emphasizing the critical role of educational digitalization (Guo & Wang, 2025). UNESCO's "Education 2030 Framework for Action" underscores the significance of educational digitalization, promoting the application of information and communication technology (ICT) to enhance knowledge dissemination, access to information, learning quality, and service efficiency. These efforts aim to achieve inclusive and equitable quality education and provide lifelong learning opportunities for all. The Chinese government's "Opinions on Promoting High-Quality Development of Modern Vocational Education" reinforces the vocational education system through digitalization and internationalization reforms, enabling adaptation to rapid economic and technological changes (Xinhua News, 2021). This policy seeks to enhance vocational colleges' contribution to the national economy, improve their responsiveness to the labor market, and establish strategic goals for advancing educational quality and equity (Zhang *et al.*, 2025).

The "Ten-Year Development Plan for Educational Informatization (2011-2020)" marked the initial efforts for digitalization in vocational education by targeting the comprehensive integration of digital technology with teaching and learning. This plan aims to digitalize and network educational resources, enhance interconnectivity and accessibility within the education system, and lay the foundation for educational modernization, thereby improving international competitiveness (Ministry of Education, 2012). The "Standards for Digital Campuses in Vocational Colleges" focuses on modernizing curriculum content, teaching methods, and management services. These standards promote the integration of industry and education by establishing information-based teaching and training systems, research and development initiatives, and teaching management and evaluation frameworks. These efforts collectively aim to achieve comprehensive digital transformation.

The implementation of these policies has laid a solid foundation for the digital transformation of Chinese vocational colleges. These measures enable vocational colleges to respond more effectively to economic and technological demands while providing students with diverse and personalized learning experiences. Through these initiatives, China's vocational education system is continuously advancing to meet the challenges of social and economic development. Several provinces have also responded to the national call for educational digitalization strategies by issuing region-specific policies to promote the digital transformation of education. For example, Shandong province has released the "Shandong Education Digitalization '14th Five-Year'

Plan", Guangxi Zhuang Autonomous Region has issued the "Guangxi Education Development '14th Five-Year' Plan", Zhejiang province has released the "Zhejiang Education Informatization '14th Five-Year' Development Plan", Guangdong province has issued the "Guangdong Education Development '14th Five-Year' Plan", Sichuan province has published the "Sichuan '14th Five-Year' Education Development Plan", and Hebei province has unveiled the "Hebei Education Development '14th Five-Year' Plan".

Path two: infrastructure upgrade—creating intelligent teaching environments

Digital infrastructure construction is a critical aspect of the digital transformation process in vocational colleges, directly impacting the improvement of teaching quality and management efficiency (Ministry of Education, 2018). First, vocational colleges must ensure that all areas of the campus are covered by high-speed internet, which is fundamental for digital teaching and management. To ensure network stability and security, schools should equip themselves with advanced cybersecurity devices and software, establishing a comprehensive network security protection system. In accordance with the Ministry of Education's "Education Informatization 2.0 Action Plan", schools should fully promote "broadband networks connecting all schools", ensuring internet access for all institutions and enhancing network infrastructure (Ma, 2022).

On the foundation of secured network infrastructure and safety, vocational colleges should equip themselves with modern teaching devices and smart classrooms. Examples include interactive electronic whiteboards, smart podiums, high-definition projectors, as well as computers, tablets, and VR and AR devices. These facilities support multimedia teaching and remote interaction, thereby enhancing students' practical skills and learning experiences. The Ministry of Education's "Opinions on Promoting High-Quality Development of Modern Vocational Education" clearly states that vocational colleges should improve teaching quality and students' practical abilities through these modern devices.

AI technology holds significant application value in modern vocational education. AI technologies—such as automatic recognition and translation, context-aware computing, intelligent robots, and computer vision—significantly enhance teaching quality and learning outcomes. These technologies foster increased classroom interactivity, personalized teaching, and students' practical skills (Qasim, 2024). To achieve efficient information management, vocational colleges must establish and improve management information systems, including student information management systems, academic management systems, financial management systems, and human resource management systems. These systems facilitate efficient management and support decision-making through data interchange and information sharing. By leveraging data-driven approaches, vocational colleges can effectively implement and promote digital education, ensuring that digital infrastructure construction supports improved teaching quality and management efficiency, thereby advancing comprehensive digital transformation.

For instance, the Shandong Vocational College of Information Technology has invested approximately 150 million yuan in educational digitalization, establishing a public application platform centered on campus data. Henan College of Transportation has built smart classrooms and collaborated with China Mobile to create a digital campus. Guangzhou Panyu Polytechnic has invested significant funds in the construction of smart classrooms, equipping them with advanced multimedia teaching devices, interactive electronic whiteboards, smart projectors, and high-speed wireless networks. Chengdu Aeronautic Polytechnic has constructed multiple smart classrooms equipped with advanced teaching devices and intelligent management systems. Jiangxi Modern Polytechnic College has established 102 standardized examination rooms, six Internet of Things (IoT)-controlled smart classrooms, and 78 regular smart classrooms. The total number of online courses for teaching applications has reached 1892, achieving online teaching for all public elective courses across the school. The cumulative number of students using the platform has exceeded 45,000.

Path three: innovative resource application—enriching teaching content and methods

The development and application of digital teaching resources, including digital textbooks, courseware, simulation software, and online platforms, significantly improve the teaching quality, enhance the learning experience, and increase management efficiency in vocational colleges, thereby accelerating educational modernization. Digital textbooks integrate video, audio, and interactive content to boost students' intuitive understanding and knowledge acquisition. Digital courseware, such as PPTs, video lessons, and micro-lectures, makes teaching more vivid, increasing classroom interactivity and student participation (Zhao, 2022). Simulation training software replicates real work environments, reinforcing students' practical skills (Xinhua News, 2021). For example, the Shandong Vocational College of Information Technology has developed over 800 online open courses and 73 sets of virtual simulation training resources, including five virtual simulation training courses, such as

"Fundamentals of Mechanical Design". Similarly, Guangzhou Panyu Polytechnic has created more than 300 online courses.

The "Vocational Education Professional Teaching Resource Database" project provides extensive simulation software resources across various specialties, as published by the Ministry of Education's Department of Vocational Education and Adult Education. The National Smart Education Platform serves as the core digital resource platform, offering rich teaching materials that deeply integrate with curriculum systems, thereby building a comprehensive and diverse teaching resource database (Zhu *et al.*, 2016). Digital libraries, such as the China Academic Library and Information System (CALIS), provide vast academic resources, while career experience centers use VR technology to offer students realistic career experiences.

Digital museum platforms, such as the China Digital Culture Network, provide virtual exhibitions of cultural and scientific resources, broadening students' perspectives (Dong *et al.*, 2011). Online education platforms and courses, such as massive open online courses (MOOCs) and small private online courses (SPOCs), enable students to learn anytime and anywhere, promoting the widespread adoption and quality enhancement of vocational education. Blended teaching models, which combine the benefits of online and offline instruction, further improve teaching effectiveness and student engagement. Integrating these digital teaching resources and platforms not only enriches teaching content but also significantly enhances students' learning experiences and engagement, providing strong support for the modernization of vocational colleges.

Path four: capability enhancement initiatives—improving digital literacy of teachers and students

The digital transformation of vocational colleges depends not only on technological advancements but also on the comprehensive development of teachers and students. Enhancing teachers' digital literacy is a crucial step in advancing digital education. Systematic training programs help teachers master digital teaching tools and methods, thereby improving classroom teaching effectiveness. Additionally, establishing online professional development platforms promotes communication and collaboration among teachers. These platforms enable teachers to share resources, exchange experiences, and participate in online training, further enhancing their teaching skills and professional competencies. Promoting the development of a "dual-qualified" teacher team through regular training and industry practice is another vital measure. This approach enhances teachers' professional skills and information literacy, enabling them to better guide students. For example, Jiangxi Modern Polytechnic College has developed a Teaching Competence Cultivation Platform to digitally monitor data on teachers' professional development and conduct scientific assessments based on big data. Similarly, Urban Vocational College of Sichuan has created a Smart Teaching Platform that utilizes AI technology to support teachers in designing teaching strategies and optimizing resource utilization. The platform also collects data on teaching behaviors, such as the rationality of instructional design and the effectiveness of teaching resource applications, to evaluate teachers' digital literacy.

Cultivating students' digital literacy is equally important in the digital transformation of vocational colleges. Digital teaching methods help students better grasp digital technologies and enhance their vocational skills. Encouraging students to engage in virtual simulation training and online learning provides them with flexible learning opportunities, improving their hands-on skills and self-directed learning capabilities. Moreover, educating students on information security and internet ethics ensures they adhere to relevant norms and protect their personal information while navigating a digital environment. For instance, Urban Vocational College of Sichuan has developed a Smart Education Platform that records and analyzes students' campus activities, including access control, campus card usage, internet access, and attendance data. These data help assess students' digital habits and literacy, providing insights into their learning and living patterns in a digital environment.

Through these initiatives and policy support, vocational colleges can significantly enhance the digital literacy of teachers and students, driving comprehensive digital transformation. This transformation not only improves teaching quality and management efficiency but also offers students diverse and personalized learning experiences, enabling vocational colleges to effectively meet the demands of modern economic and technological development.

THE EFFECTIVENESS OF DIGITAL TRANSFORMATION IN CHINA'S VOCATIONAL COLLEGES

UNESCO categorizes the application of digital technology in education into four developmental stages: initiation, application, integration, and transformation (UNESCO, 2021). In the initiation stage, the focus is on building infrastructure and enhancing teachers' capacity to utilize digital technologies. Progressing into the application stage, high-quality digital educational resources and efficient learning management systems become essential components. The integration stage is

characterized by the use of digital technology to enhance teachers' instructional abilities and innovate teaching methods within digital environments. Finally, the transformation stage emphasizes leveraging emerging technologies to reconstruct the educational ecosystem.

The role of vocational education extends beyond the mere cultivation of technical skills; it also encompasses character education, the nurturing of social responsibility, and the inheritance and innovation of culture (Xie, 2024). This multifaceted role supports students' holistic development, preparing them to contribute as high-quality, skilled professionals to sustainable socioeconomic growth. This study examines the digital transformation process of vocational colleges, exploring the pathways, effectiveness, and strategies for further promoting high-quality development in China's vocational education.

Policy support: accelerating the implementation of digital transformation strategies in vocational colleges

The digitalization of vocational education in China has evolved from infrastructure construction to deep application. This evolution began with the popularization of basic digital tools and platforms, which laid a solid foundation for the subsequent systematic transformation of education through digital means. Under the guidance of policy initiatives, significant advancements have been made in the digitalization of vocational education. Provinces are actively responding to national directives by issuing documents to promote the digital transformation of vocational colleges within their jurisdictions. For example, under policy guidance, Shandong province has designated 100 vocational colleges as provincial pilot institutions for educational digitalization. Additionally, 10 vocational colleges have been selected as pilot units for the Ministry of Education's demonstration virtual simulation training base project. Shandong Vocational College of Information Technology has facilitated high-quality development through digital construction, earning recognition as a national pilot unit for digital campus construction in vocational colleges and a research base for "Internet + Education" applications in Shandong province. Similarly, in the Guangxi Zhuang Autonomous Region, all 14 prefecture-level cities have achieved interconnectivity of educational networks, establishing a solid network foundation for the co-construction and sharing of high-quality educational resources.

In 2022, Tsinghua University's Institute of Education released the "Vocational education information development report (2021 edition)", which surveyed 995 vocational colleges. The report revealed that over 74% of vocational college teachers use information technology in their teaching. Additionally, more than 58% of students acknowledged the effectiveness of digital learning, and 90% expressed satisfaction with virtual simulation training. Notably, only 3.82% of students reported having never used virtual simulation training software (IOE Tsinghua *et al.*, 2022). In June 2023, the Ministry of Education issued the "National Vocational Education Smart Brain School Mid-Platform Higher Vocational Data Standards and Interface Specifications (Trial)" and the "Guidelines for the Construction of National Vocational College Big Data Centers". These guidelines provide specific requirements for incorporating digital means into all aspects of vocational education, further accelerating the digital transformation of vocational colleges.

Infrastructure development: enhancing technical support for teaching and management in vocational colleges

The digital transformation of vocational education in China is being actively promoted nationwide, with several provinces achieving significant progress. The following analysis focuses on Shandong province, Xinjiang Uyghur Autonomous Region, Guangxi Zhuang Autonomous Region, Inner Mongolia Autonomous Region, and Henan province. The rationale for selecting these provinces is as follows.

From a geographical perspective, these provinces encompass the eastern, central, western, and northern regions of China, making them highly representative. Shandong, located in the eastern coastal developed area, boasts prominent advantages in industry and finance. This province has the potential to explore pathways for applying frontier technologies, demonstrating how developed regions leverage resources for digital infrastructure construction. Xinjiang, situated in the northwestern frontier, features a unique geographical environment and diverse ethnic culture. Studying this region helps address the challenges of network and technology popularization in remote areas, promote educational equity through digital means, and serve as a model for vocational education development in border regions. Guangxi, located in the southwestern coastal area, is at the forefront of connecting with the Association of Southeast Asian Nations (ASEAN). Analyzing its digital infrastructure highlights how vocational colleges in regions with characteristic industries can bolster international competitiveness through digitalization, such as the joint construction and sharing of teaching resources in majors like cross-border e-commerce. Inner Mongolia, which has a vast territory, faces many challenges in traditional vocational education. Investigating this region can reveal how digitalization addresses infrastructure issues, such as

remote teaching for vocational education in characteristic industries like animal husbandry and energy, creating a connection between talent cultivation and digitalization. Finally, Henan, a central province with a large population, agriculture, and manufacturing industries, is home to numerous vocational colleges and a substantial student population. Focusing on this province allows the exploration of universal construction pathways for digital infrastructure.

The following sections outline specific developments in infrastructure construction for the digital transformation of vocational education in these provinces.

Shandong province

Shandong has made significant progress in infrastructure construction for the digital transformation of vocational colleges. According to the Shandong Provincial Department of Education, the province actively responds to the national educational digitalization strategy by promoting top-level design, carrier construction, and application innovation to empower the modern vocational education system efficiently. In terms of specific digital teaching applications, Shandong has innovated digital teaching and training applications by integrating technologies such as VR and AR into related disciplines This integration enhances students' learning interest and workplace adaptability.

Shandong Vocational College of Information Technology has driven high-quality development through digital construction. It has been recognized as a pilot unit for digital campus construction in national vocational colleges and a research base for "Internet + Education" applications in Shandong province. The college integrates hardware and software, solidifying the foundation for its digital campus, with an accumulated investment of approximately 150 million yuan in educational digitalization initiatives. Additionally, it has established a public application platform centered on campus data, enabling real-time data collection, precise analysis, and visual presentation.

Xinjiang Uyghur Autonomous Region

Xinjiang has initiated the pilot construction of digital campuses in vocational colleges, guiding eight pilot schools to connect with the data interface of the Ministry of Education's information center and achieve collaborative data sharing. Karamay Vocational & Technical College has significantly enhanced students' practical abilities and learning outcomes by upgrading its infrastructure to establish an intelligent training base. The virtual simulation training base at the college played a crucial role during the coronavirus disease 2019 (COVID-19) pandemic by allowing students to conduct remote training through an online platform, ensuring the continuity and effectiveness of teaching. Research findings indicate that students utilizing the intelligent training base achieved an average score in practical skill assessments that was 20% higher than those in traditional teaching modes.

Guangxi Zhuang Autonomous Region

The Guangxi Education Department has accelerated the construction of the Guangxi Education Network by fully establishing a backbone network that relies on the Guangxi Education Data Center to create the Guangxi Education Network Center. Fourteen prefecture-level cities have achieved interconnected education networks, providing a robust foundation for the co-construction and sharing of quality educational resources. Guangxi Vocational & Technical College, as a "Double High" construction institution, places significant emphasis on informatization. The college has achieved full Wi-Fi coverage across its campus, developed smart security systems, and established a smart supervision platform for food safety. Additionally, it has implemented a "5216" information construction development strategy, promoting the digital transformation of the entire educational process and all management services. As a result, it has become one of the first formatized benchmark schools in Guangxi.

Inner Mongolia Autonomous Region

Inner Mongolia has implemented multiple measures to enhance the infrastructure required for the digital transformation of vocational education. These measures include accelerating the construction of 5G networks to provide a robust network foundation for digital transformation and facilitating free access to public facilities and sites for 5G base stations. Moreover, land requirements for 5G base stations have been included in the annual land use plan with favorable electricity pricing.

Inner Mongolia Technical College Mechanics & Electrics has demonstrated outstanding performance in digital transformation. The college has established an intelligent training base, enriched its digital teaching resources, and received various national and regional recognitions for its information construction efforts. Similarly, Inner Mongolia Business & Trade Vocational College has successfully connected to the China Education and Research Network, achieving efficient network coverage across the campus and promoting the application of 5G and IPv6 technologies.

Henan province

Henan College of Transportation has constructed smart classrooms and collaborated with China Mobile to create a digital campus. As a provincial model for informatization in vocational education, the college has accelerated its digital transformation process and enhanced the informatization level of educational

teaching and campus management.

Digital teaching resources: expanding learning channels and enhancing teaching flexibility

Significant achievements have been made in the construction of digital teaching resources in China. Central to this success is the construction and widespread application of the National Smart Education Platform, now recognized as the world's largest educational resource repository. This platform connects 519,000 schools, serving 18.8 million teachers and 293 million enrolled students while also providing learning opportunities to a vast number of learners in society; its reach extends to over 200 countries and regions worldwide (Huang *et al.*, 2024). With more than 100 million registered users, the platform has recorded over 36.7 billion views and 2.5 billion visits, playing an integral role in supporting core educational objectives and advancing major national strategies.

The platform offers a vast array of digital teaching resources: 88,000 materials tailored for primary and secondary education, over 10,000 high-quality online courses for vocational education, and 27,000 high-quality MOOCs for higher education (Cyberspace Administration of China, 2024). These resources cover various specialized education topics and multiple textbook versions, effectively addressing the diverse learning needs of students and educators alike. The advancement and effectiveness of educational digitalization have injected vitality into high-quality educational development.

Public service platform for digital teaching resources in vocational and continuing education

This platform provides vocational colleges with a wealth of digital teaching materials, fostering the co-construction and sharing of educational resources across institutions. A leading example of excellence in this area is Shandong Vocational College of Information Technology, which has set a benchmark for digital teaching innovation in vocational education.

The college has built a robust repository of digital teaching resources, including over 800 online open courses, 73 sets of virtual simulation materials, and five virtual simulation courses, such as "Fundamentals of Mechanical Design". Moreover, it has developed 15 training systems (Shandong Provincial Department of Education & Shandong Vocational College of Information Technology, 2024), creating a diverse and personalized library of digital content to support customized learning experiences.

To safeguard its digital assets, the college implemented a campus network security system with a focus on data centers, achieving comprehensive monitoring of network security operations and deep protection of business data. This ensures the integrity and reliability of digital teaching resources. Recognized as a research base for "Internet + Education" in Shandong province, the college has led efforts to integrate virtual simulation technology deeply into teaching, significantly enhancing the quality of talent cultivation in vocational colleges (Shandong Vocational College, 2023).

These initiatives have earned the institution multiple accolades, including a national-level second prize and a first prize at the provincial level for teaching achievements. Such recognition highlights the college's innovative approaches and practical achievements in digital teaching, setting a model for other vocational institutions seeking to advance educational technology integration.

Xinjiang Uygur Autonomous Region

The public service platform for basic education resources in Xinjiang has undergone a significant upgrade, connecting seamlessly with the national public service system to provide all primary and secondary school teachers and students in the region with access to high-quality educational resources. A standout initiative, the "National Language Animation Tutorial" project uses modern information technology to aid instruction in the national common language. This project has added 40 GB of animated educational resources for primary school Chinese. During the COVID-19 pandemic, the platform's online education and remote teaching capabilities proved invaluable, delivering educational content through television broadcasts, online platforms, and mobile devices. A total of 1888 high-quality recorded lessons reached students from primary to high school, benefiting 204 million learners (The China Education Information Website, 2022).

Karamay Vocational & Technical College has achieved remarkable results in building digital teaching resources, particularly in strengthening the digital capabilities of teachers and students. First, the college successfully launched 11 projects as part of the 2022 Vocational College Digital Transformation Action Research initiative. These projects cover critical areas, including digital campus construction, smart education platform applications, faculty development, teaching reforms, and the integration of virtual simulation technologies, providing firm support for comprehensive digital transformation.

Leveraging its rich digital teaching resources, the college actively drives blended teaching reforms that effectively enhance the quality of talent cultivation through innovative instructional models. This reform not only fosters comprehensive development in student compet-

itions, self-directed learning, competency attainment, and innovation but also significantly improves student learning outcomes. The college has also bolstered its digital infrastructure by establishing a network teaching platform, mobile learning systems, and a professional teaching resource library. These advancements ensure round-the-clock access to rich digital teaching resources, offering faculty and students an efficient, flexible, and personalized learning environment anytime, anywhere.

Guangxi Zhuang Autonomous Region

The 2023 Guangxi Education Digital Transformation Promotion Conference, held in Nanning, marked a significant milestone with the launch of the Guangxi Smart Education Platform (Guijiao Tong) and the Guangxi Vocational Education Smart Education Platform, advancing the region's digital education transformation. These platforms are part of an integrated "Information+" system designed to leverage information technology for school governance, professional program enhancements, and deep integration of teaching and learning. This system enables data-driven precision in both instruction and educational management, improving overall efficiency and outcomes.

Guangxi Vocational & Technical College has been at the forefront of this initiative, spearheading the development of the Guangxi Vocational Education Smart Education Platform. This platform serves as a vehicle for the application of blended teaching methodologies across vocational colleges in the province, facilitating the co-construction and sharing of educational resources.

Inner Mongolia Autonomous Region

Inner Mongolia has launched the "Pilot Implementation Plan for the Smart Education Platform in Vocational Education", aimed at integrating and developing high-quality vocational education resources. This plan offers modules for professional and course services, virtual simulation training, teacher competency development, student skills improvement, and the sharing of best practices. It supports the adoption of blended teaching approaches and teaching reform evaluation. By the end of 2023, the initiative targets the creation of resource repositories for 30 professional groups, approximately 200 high-quality online courses, and 10 types of virtual simulation training resources; in addition, five exemplary virtual simulation training bases will be established (Inner Mongolia Business & Trade Vocational College, 2022a).

Inner Mongolia Business & Trade Vocational College exemplifies this transformation, having upgraded 161 classrooms into smart classrooms to enable advanced teaching methodologies (Inner Mongolia Business & Trade Vocational College, 2025). There are currently 76 multimedia computer rooms, including 12 cloud-based computer rooms and 10 smart multimedia computer rooms. To further bolster practical training, 52 information technology training venues are available, including 32 virtual simulation and software operation training rooms.

The college's robust infrastructure features three recording studios capable of simultaneously capturing, editing, and monitoring three different courses. Thus far, the recording system has generated video resources covering 37 majors, producing 347 collections of materials, including video lectures, micro-courses, MOOCs, demonstration classes, competition entries, and micro-videos, totaling 5205 h of digital content (Inner Mongolia Business & Trade Vocational College, 2022b).

Henan province

The Education Department of Henan Provincial has introduced an initiative to evaluate high-quality online open courses for vocational and continuing education. This effort aims to stimulate the construction and utilization of course resources, improve teaching quality, and accelerate the development of provincial-level vocational education resource repositories. Moreover, it supports the creation of virtual simulation training bases to expand the availability of high-quality digital resources, catering to the needs of diverse learners across the province.

Henan College of Transportation has seen several of its projects approved for funding by the Ministry of Education's digital transformation action research initiative for vocational colleges. These projects emphasize the innovative integration of digital technologies into education and the optimization of teaching methods through learning behavior data analysis. This approach not only advances the construction and application of the college's digital teaching resources but also improves personalized learning experiences and teaching effectiveness.

Enhancement of digital capabilities of faculty and students

Chinese vocational colleges have attained remarkable results in enhancing the digital capabilities of faculty and students, especially in the construction and application of digital teaching resources. The National Vocational Education Smart Education Platform has launched 1173 professional teaching resource repositories, over 6700 high-quality online courses, and 2200 open video courses, covering nearly 600 majors; it has also established 215 exemplary virtual simulation training bases, providing strong support for cultivating technical and skilled personnel (China Youth International, 2023).

Approximately 55% of vocational educators have adopted blended teaching methods, leveraging virtual simulation and digital twin technologies to create innovative teaching scenarios and overcome challenges in hands-on training. Through the National Smart Education Platform, nearly 16 million teachers have participated in online training, significantly enhancing their digital literacy and instructional capabilities. On the student side, learning experiences have notably improved, with over 58% of students acknowledging the effectiveness of information-based learning and 90% affirming the impact of virtual simulation training.

Vocational colleges are also actively promoting the construction of digital infrastructure, creating smart classrooms and digital twin training bases to upgrade campus networks and teaching facilities. To further standardize and advance digital transformation, China has introduced the "Digital Literacy for Teachers" industry standards, offering a comprehensive framework for improving teachers' digital competencies. Moreover, China has built the world's largest educational resource repository, providing rich resources to support lifelong learning for all.

These achievements have gained international recognition. In 2022, the National Smart Education Platform project won the UNESCO Education Information Technology Award, highlighting China's global leadership and contributions to digital education (IOE Tsinghua *et al.*, 2022).

CONCLUSION

This study delves into the pathways and achievements of digital transformation in vocational colleges in China. It reveals that the development of robust information technology infrastructure has provided a solid technical foundation, significantly enhancing both teaching and administrative efficiency. The advancement of digital teaching resources has enriched the curriculum, improving students' learning experience and vocational skills. Systematic training programs, including online platforms, have played a crucial role in boosting the digital capabilities of both teachers and students, becoming key drivers of this transformation. Strategic policies from the Chinese government have placed strong emphasis on the digitalization of education, facilitating the modernization and internationalization of vocational colleges. These policies aim to improve educational quality, meet the growing demand for skilled talent in the labor market, and increase the contribution of vocational colleges to the national economy and their market adaptability.

Despite notable progress, challenges remain. The digital transformation of vocational colleges in China has achieved remarkable results under the impetus of policies, technological advancements, and educational practices, laying a firm foundation for the modernization of education and the enhancement of global competitiveness. Looking ahead, vocational colleges must push further in advancing digital transformation to improve educational quality, increase students' employability, and support the sustainable development of both the economy and society.

The study also identifies key issues requiring further exploration. First, although policy support provides strategic direction and resources, the implementation varies significantly across regions and institutions. Colleges in economically underdeveloped areas often face dual constraints of limited funds and outdated technology in both infrastructure development and digital resource creation. Second, although digital teaching resources have yielded positive outcomes, challenges remain in their timely updating and maintenance, particularly in the context of rapid technological evolution. Ensuring the relevance and effectiveness of these resources remains an urgent priority. In addition, despite progress in enhancing the digital competencies of teachers and students, gaps remain in assessment standards and mechanisms for continuous improvement, which are essential for aligning skill development with technological advancements.

Future research should concentrate on the following areas. (1) Regional differences and balanced development: conduct in-depth research on regional variations in the digital transformation of vocational colleges, identifying strategies for balanced progress through policy reforms and resource optimization to narrow down the digital divide; (2) Sustainability of digital resources: develop robust mechanisms for the ongoing update and maintenance of digital teaching resources to sustain their effectiveness amid continuous technological change; (3) Assessment and continuous improvement mechanisms: enhance the standards for evaluating digital competencies among teachers and students and create dynamic improvement systems that adapt to evolving technologies while maintaining educational quality; (4) Technological integration and innovation: investigate the integration and innovative application of emerging technologies, such as AI, big data, and blockchain in vocational college education, to boost educational intelligence and provide personalized learning experiences; and (5) International comparison and collaboration: strengthen global research collaborations by learning from successful digital transformation models in vocational education abroad while promoting international exchanges to increase the global influence of Chinese vocational colleges. Focusing on these areas will foster a more sustainable, adaptive, and globally competitive digital transformation in vocational education.

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Conflict of interest
The authors have no conflicts of interest to declare.

Data availability statement
No additional data.

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