

The Logical Motivation, Realistic Obstruction and Breakthrough Path of Digital Transformation in Vocational Education

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Abstract

Digital transformation in vocational education is a key measure for promoting high-quality education development and adapting to the demands of the digital economy era. Based on policy orientation and practical difficulties, this paper systematically analyses the logical motivation, realistic challenges, and practical paths of digital transformation in vocational education. The study found that digital transformation is driven by four factors: policy, economic demand, technological empowerment, and educational reform. However, it still faces cognitive bias, resource imbalance, inadequate talent matching, weak industrial-educational integration, and an outdated assessment system. To overcome these obstacles and achieve the transformation of vocational education from "technical empowerment" to "value reconstruction", the paper proposes the following practical paths: building a multi-dimensional cognitive system, optimising digital infrastructure, innovating talent cultivation models, deepening industrial-educational integration mechanisms, and refining data-driven assessments. This will provide theoretical support and practical references for the digital transformation of vocational education in China.

Keywords

Vocational Education; Digital Transformation; Driving Logic; Practical Pathway.

1. Introduction

The 20th National Congress of the Communist Party of China included 'promoting digital education' in its national strategy, and the 2024 government work report further emphasised the importance of using digitalisation to promote high-quality education. Vocational education, as a type of education, is an important part of the national education system and human resource development, and plays a key role in cultivating diverse talent, transmitting technical skills, and promoting employment and entrepreneurship [1]. Its digital transformation is not only a response to the national strategy but also a critical approach to adapting to industrial upgrades and technological innovations. Currently, digital technologies such as 5G, big data, and cloud computing are transforming the form, model, and ecosystem of vocational education. In the face of the significant technological benefits brought by digital technologies, promoting the digital transformation of vocational education is essential for achieving high-quality development and shaping a new growth model for vocational education [2]. However, China's vocational education digitalisation is still in its early stages, and it is crucial to clarify the transformation logic, overcome practical obstacles, and explore practical solutions to support the construction of an education-strong country.

2. Literature Review

As one of the important issues for the high-quality development of vocational education in the new era, the digital transformation of vocational colleges and universities has been researched by many scholars at home and abroad. The existing literature mainly takes "digitalization" as a

tool to promote the development of vocational education, and some scholars recognize “vocational education digitalization” as “vocational education informatization”. With the deepening of the research, the connotation of vocational education digitization is deepened, and the digital change of vocational education is neither addition nor subtraction, but a holistic change in the ecology.

On the one hand, the connotation, value logic, significance, and problem characterization of digital transformation of vocational education are explored from a theoretical perspective. For example, Zhu Dequan and Xiong Qing (2022) believe that high-quality promotion of the development of digital transformation of vocational education needs to crack the problems in economic and social development by promoting the change of vocational education itself, and then cracking the problems in economic and social development with the digital transformation of vocational education[3]. Qi Zhanyong and Wu Shitao (2024) elaborated on the digital transformation to empower the high-quality development of vocational education from the aspects of internal logic, value implication, and promotion strategy, and proposed that through the four-in-one strategy of constructing the data system, digital technology, digital synergy, and digital social layer, they focus on directional and interactive empowerment of the high-quality development of vocational education in terms of the top-level design, expanding digital resources, optimizing the real and virtual venues, and reinforcing the training of teachers. The development of vocational education[4]. Wu Chengcheng and Zhou Guozhong (2023) explored the theoretical traceability of digitally empowered vocational education from the value dimension theory, digital toughness theory, technology acceptance model and digital governance theory, and found that digitally empowered vocational education currently exists in the dilemmas of weak transformation of empowering value, insufficient digital literacy of students, insufficient system toughness, and incomplete integration of technological elements, and put forward the proposal of creating digital vocational education governance by constructing a synchronous system of supply, digital education and curriculum system, and building a digital education governance system. Curriculum system to create a closed loop of digital vocational education governance[5]. Liu Xiao and Qing Jintao (2023) explored the “why”, “what”, “what to turn” and “how to turn” of the digital transformation of vocational colleges and universities based on the perspective of system theory, and discussed the “why”, “what”, “what to turn” and “how to turn” of the digital transformation of vocational colleges and universities based on the perspective of system theory. ”, “how to turn” and so on[6]. Based on the digital era, Chen Feng (2021) reviewed and thought about the historical background, foundation, core and direction of the transformation of Chinese higher education and vocational education, and put forward two major tasks of deepening the integration of industry and education and accelerating the digital transformation of education in the new period, which depicted the future picture of the shape of higher education and vocational education in the digital era[7]. Zhu Zhiting and Dai Ling (2023) proposed that the profound connotation and representational form of digital development of higher vocational colleges and universities can be understood from three aspects: technology iteration, order generation, and paradigm shift[8]. In addition, Li Yüwen(2024) and Song Ge(2024) have analyzed the challenges faced by vocational education in Germany and the United States in the context of digitization and the strategies to overcome these challenges, and based on the sustainable cooperation between vocational colleges and enterprises, they have put forward a theoretical framework for maintaining the sustainability of vocational education in the digital era from the three dimensions of industrial service capacity, attractiveness and adaptability[8].

On the other hand, the practice perspective explores the important content and direction of digital transformation in vocational education. For example, Cattaneo et al. (2021) studied the digital transformation of vocational education in Swiss vocational education, which focuses on improving teachers' digital literacy by building the role of “digital facilitator” to lead the

integration of technology[9], and Ruschoff (2022) conducted a comparative study of digital transformation of vocational colleges and universities in Germany and Indonesia, respectively[10]. Ruschoff (2022) conducted a comparative study of digital transformation in vocational institutions in Germany and Indonesia respectively, and found that the digital transformation of vocational institutions in Germany is student-centered, incorporating digital technology, interdisciplinary assistance, and customized assessment tools to improve the quality of digital education and digital competence of teachers and students, while vocational institutions in Indonesia are driving the digital transformation through online learning modes and platforms such as Google Classroom, which ensures that students have continuous access to educational resources, while at the same time offering teachers the flexibility to teach online[11]. Muktiarni et al. (2021) Russian vocational institutions have adopted a competency-based model to strengthen basic skills for the digital economy[12], using personalized learning paths and innovative strategies to train professionals for the future workplace (Vetkina et al., 2018)[13]. Zhou Rujun et al. (2023) combed and analyzed the current hot trends of digital transformation in vocational education based on knowledge mapping, mainly focusing on the themes of school-enterprise cooperation for digital development of higher vocational institutions, digital talent training mode, digitalization of curricula and teaching, construction of information resources, and digitization of teaching management[14]. Han Xibin et al. (2022) pointed out that the digital transformation of education is a systematic project covering all levels of the education field, and the core lies in the promotion of all-round changes in the teaching thinking, teaching paradigm, teaching process and teaching evaluation of vocational colleges and universities, and the efforts to realize the transformation from supply-driven to demand-driven, to form a good education ecosystem with a high level of adaptability and sustainable development, and then realize the high-quality development of vocational education[15].

Through the literature combing, it is found that the keywords of the existing literature on the research of digital transformation of vocational education are mainly divided into six themes: ① research on the construction of digital teaching resources; ② research on the theory of digitalization; ③ research on the informatization of vocational education; ④ comparative research on the digital transformation of vocational education; ⑤ research on the digital campus; and ⑥ research on the “Three Teachings” reform in the context of digitalization of vocational education. Research on the reform of vocational education in the context of digitization. Existing studies have mostly explored digital transformation from the perspective of tools, but there is insufficient research on logical motives, practical challenges, and systematic paths. This paper combines the perspectives of system theory and ecology to discuss the logical motivation, practical challenges, and practical way out of the digital transformation of vocational education, which is of strong practical significance.

3. The Logical Motivation of Digital Transformation of Vocational Education

Digital transformation is a necessary path for the reform and development of vocational education in the new era, which is driven by the integration of multiple factors. In terms of policy drive, the strategic layout of national education digitalization leads the change direction of vocational education digital reform; in terms of economic demand, the upgrade of the national industrial structure and the real demand for matching the structure of skilled personnel. In terms of technological empowerment, digital technology reshapes the ecology of vocational education and promotes the adaptive development of vocational education; in terms of educational change, digital transformation restructures the vocational education system to adapt to the needs of the times and create a new competitive advantage in the future.

(1) Policy-driven: The National education digital strategy lays out the direction of change of digital reform in vocational education

In 2021, the “Fourteenth Five-Year Plan Outline” explicitly proposed “accelerating the development of digitization and building a digital China”. In 2022, the Ministry of Education explicitly proposed “implementing the strategic action of education digitization and vigorously promoting the digital transformation and intelligent upgrading of education”. In 2022, the Ministry of Education explicitly proposed to “implement the strategic action of education digitization, and vigorously promote the digital transformation and intelligent upgrading of education. The report of the 20th Party Congress put forward “promoting education digitization”, elevating education digitization to a national strategy and pointing out the direction for further deepening education reform and development. As an important part of the national education system and human resources development, the digital transformation of vocational education is a systematic and comprehensive process of change, which profoundly affects the high-quality development of the digital transformation of national education. The Party and the State's strategic action deployment for the digital transformation of education leads and promotes vocational education to accelerate the digital transformation, improve the construction of digital infrastructure, build a national public service system for digital educational resources, promote the improvement of the effectiveness of digital social governance, optimize the digital high-quality supply of vocational education, and empower the digital high-quality development of education.

(2) Economic demand: the upgrade of national industrial structure and the real demand for matching the structure of skilled personnel.

In the era of digital economy, digital technologies represented by 5G, big data, cloud computing, blockchain, digital twin, and IoT have become the core elements driving the reconstruction of economic growth momentum and optimization and upgrading of industrial structure. According to the National Bureau of Statistics' 2023 National Economic and Social Development Statistics Bulletin and the Ministry of Industry and Information Technology's White Paper on the Development of China's Digital Economy (2024), the scale of China's industrial digitization in 2023 reached RMB 43.9 trillion, accounting for 83.2% of the value added of core industries in the digital economy, and contributing to economic growth by more than 35%, indicating that the digital transformation of China's industries has entered a new stage of deepening development. Transformation has entered a new stage of deepening development. The report of the 20th CPC National Congress further puts forward the strategic deployment of “accelerating the development of digital economy, promoting the deep integration of digital economy and real economy, and creating internationally competitive digital industry clusters”, the core meaning of which is to deepen the integration of industry and education, and to promote the transformation and upgrading of digital industry. The development of the digital economy has given rise to a large number of new industries, new forms of business, new occupations, etc. The flattening of work organization structure, the human-machine collaboration of work mode, and the hybridization of work environment have become more and more obvious, and there is a higher demand for the technical ability and professionalism of workers. In this context, vocational education, as the type of education that is most closely connected with industries and most directly serves economic transformation, plays a key role in cultivating high-quality technical and skilled talents, promoting the effective connection between the education chain and the industrial chain, and becoming an important human resource guarantee to support the high-quality development of the economy. The digital transformation of vocational education is a forward-looking strategic plan based on the changes of the times, accelerating the precise docking of the education chain with the industrial chain, proactively adapting to the new demands for the supply of highly skilled personnel in the

new situation of industrial development, and creating a modern vocational education system that resonates with the transformation and upgrading of industries.

(3) Technology empowerment: Digital technology has reshaped the ecology of vocational education and promoted the adaptive development of vocational education.

The deep penetration of digital technology has reconfigured the elemental structure of vocational education, forming an ecological development paradigm centered on technological empowerment. This systematic change breaks through the boundary constraints of the traditional education system, and builds a new ecology of vocational education with adaptive features through the optimization of educational decision-making, the reengineering of teaching processes, and the innovation of governance modes driven by data elements. Its essence is to realize the structural reorganization and functional upgrading of the education system through technological empowerment, to form a dynamic adaptation mechanism of "technology-education-industry", and to effectively cope with the challenges of technological change and industrial transformation in the era of digital economy. The governance innovation empowered by digital technology has effectively cracked the data barriers and system silos in traditional vocational education and driven the modernization and digitalization of education governance. The new generation of digital technology has constructed a digital governance framework for vocational education, and the credible data flow formed by artificial intelligence, blockchain, and other technologies has promoted the governance subject from a single, administratively dominant form to a pluralistic collaborative governance. The intelligent decision-making system based on big data analysis has realized the dynamic optimization of educational resource allocation and the precise assessment of policy effects. The virtual governance scenario constructed by digital twin technology enables education administrators to simulate the effect of policy implementation, forming a closed-loop governance mechanism of "data perception-intelligent research and judgment-dynamic regulation". Teaching innovation empowered by digital technology reconfigures the digitization of the teaching field of vocational education, promotes the innovation of parenting mode, and facilitates the dynamic adaptation of vocational education to industrial demand. The immersive teaching scene constructed by mixed reality technology breaks the time and space limitations of traditional teaching and forms a smart learning space that integrates reality and virtual reality. The personalized teaching system based on learning analysis technology constructs a dynamic adjustment mechanism of "diagnosis-intervention-feedback" by continuously collecting learning behavior data. The intelligent diagnostic system can accurately identify the cognitive characteristics of learners and generate personalized learning paths, which greatly improves the accuracy of teaching. The digital twin workshop and other industry-teaching integration platforms transform real production scenarios of enterprises into teaching resources, realizing the closed-loop teaching of "task-driven-technical standard-integrated-vocational ability generation". The ecological synergy empowered by digital technology has promoted the transformation of vocational education from unidirectional knowledge transfer to multidimensional value co-creation, formed a vocational education ecosystem with self-organizing characteristics, and fully released the systematic efficiency of vocational education. The trust mechanism of the industry-education alliance constructed by blockchain technology promotes the data coherence of the education chain, talent chain, and industrial chain. The regional education resource sharing platform based on edge computing realizes the intelligent push of quality resources across schools and regions, effectively enhancing the utilization rate of resources. The collaborative innovation network driven by digital technology has given birth to a new mode of industry-education fusion, which is "enterprise proposes - institution solves - joint incubation". The paradigm change empowered by digital technology not only optimizes the internal ecology of vocational education but also reshapes the paradigm of cultivating technical and skilled talents, which forms a strong connection between education supply and

industrial demand, and provides sustainable talent support for the construction of a strong manufacturing country. The continuous iteration of digital technology promotes vocational education to form the evolution mechanism of “demand perception - intelligent response - dynamic optimization”. The continuous improvement system supported by intelligent technology establishes a dynamic monitoring system for the quality of talent cultivation through the collection of graduates' career development data. The career development prediction model constructed by digital portrait technology increases the response speed of professional adjustment.

The ecological reconstruction of vocational education empowered by technology is essentially the adaptive evolution of the education system through digital technology. This evolution not only contains the explicit embedding of technological elements, but also involves deeper changes in educational concepts, organizational forms, and institutional systems. When digital technology is deeply integrated into the value creation process of vocational education, vocational education is evolving from a technical tool adapted to industrial needs to an innovation engine leading industrial change, and this two-way empowerment interaction is reshaping the ontological value and practice form of vocational education.

(4) Educational transformation: Digital transformation is reconfiguring the vocational education system to meet the needs of the times and create a new competitive advantage for the future.

The promulgation and implementation of the Vocational Education Law of the People's Republic of China (Revised in 2022) marks the entry of vocational education in China into a new era of digital transformation and development. Against the background of accelerating digital transformation of global industries, vocational education is facing the strategic opportunity of “double-phase superposition”: not only do we need to complete the transformation and upgrading from scale expansion to quality and excellence, but also respond to the change of education form triggered by digital technology. This dual demand determines that the digital transformation is not a simple superimposition of technology, but through digital thinking to reconstruct the educational ecology, to achieve the concept of education, organizational form, and the operation mechanism of the system innovation. Specifically, one is to drive the innovation of the education paradigm. Based on digital technology to reconstruct the value chain of education, promote the role of teachers to the “digital education designer” transformation, promote the concept of “Internet + vocational education” and the “type of education” positioning of the deep integration, and the formation of a learner-oriented education. Promote the deep integration of the concept of “Internet+Vocational Education” and the positioning of “type education”, and form a learner-centered personalized training paradigm. Secondly, it is to reconstruct the integration system of production and education. The digital twin technology breaks the time and space boundaries of traditional education, builds a virtual and real training field, and forms a cross-regional and inter-school network for sharing high-quality educational resources. At the same time, relying on the industrial Internet platform to establish a school-enterprise collaborative education mechanism, realizing the dynamic adaptation of the supply side of talent training and the demand side of industry. Third, an innovative governance model. Use education big data to build an intelligent decision-making system, optimize the efficiency of resource allocation through data-driven optimization, establish an accurate management model based on digital portraits, and improve the scientific level of vocational education governance. Fourth, building a diversified evaluation ecology. Using learning analytics to establish a dynamic evaluation mechanism for the whole process, integrating the evaluation dimensions of educational institutions, industrial enterprises, employers, and other multiple subjects, forming a competency-based digital certification system, and realizing visual tracking and value-added evaluation of vocational competency development.

4. Realistic Challenges of Digital Transformation of Vocational Education

In the wave of digital transformation of global education, vocational education, as a type of education most closely linked to the industrial economy, has a direct impact on the quality of national human resources and the effectiveness of industrial upgrading. Based on the perspective of system analysis, this study constructs a systematic analysis framework of "cognition-resources-implementation-feedback" from five dimensions, namely, cognition, resources, talents, industry-teaching integration, and evaluation, to analyze the current realities of digital transformation of vocational education.

(1) Cognitive bias and delayed application of technology in digital transformation.

Digital transformation of vocational education is essentially a two-way empowerment process between digital technology and the vocational education system, the core of which lies in reconstructing the education ecology, optimizing the education process, and enhancing the effectiveness of education through digital technology. However, there is a triple cognitive misunderstanding in practice: first, there is a structural lack of policy understanding, and the relevant subjects do not have a good grasp of the essence of the National Vocational Education Reform Implementation Plan and the Vocational Education Law of the People's Republic of China, the Outline of the Plan for the Construction of a Stronger State of Education (2024-2035), and the Opinions on Accelerating the Advancement of Education Digitization and other policy documents. There is a lag in the policy response; secondly, the technical cognition stays at the tool level, according to the survey, 63% of vocational colleges and universities still equate the digital transformation with the application of multimedia teaching tools, and there is insufficient cognition of the educational application of artificial intelligence, virtual reality and other emerging technologies, and the utilization rate of intelligent educational equipment is only 17.3%; thirdly, there is a resistance mentality of the application of educational technology, and some educators are worried about digital transformation increase the management cost, exclude the construction of digital application platform, resulting in the average underutilization of intelligent educational equipment. This cognitive bias has led to the "siloization" of technology applications, and there is an urgent need to build a cognitive correction mechanism based on digital technology.

(2) Structural contradictions in digital education resources.

Resource constraints are the fundamental problem of the digital transformation of vocational education, although the national vocational education wisdom education platform has brought together 12,000 professional teaching resources. From the perspective of economic geography, the distribution of digital resources in vocational education in China presents a significant spatial imbalance. The average student digital equipment investment in the eastern region is 2.3 times that of the western region, forming an "east-west" digital divide, and the "Matthew effect" of resource allocation has led to a triple imbalance. First, infrastructure allocation imbalance. According to the survey, the digital transformation of institutions to increase the average cost of training 18% -25%, but the increase in financial allocations is only 9.7%, the formation of "input - output" structural contradiction, the central and western colleges and universities in general, "insufficient advanced equipment" and The paradox of "insufficient advanced equipment" and "high idle rate of equipment" coexist in central and western institutions. Secondly, there is an imbalance in the supply of digital educational resources. The cross-regional resource sharing mechanism has not yet matured, and the coverage rate of the national professional teaching resource base is only 64.3%, so the radiation effect of high-quality resources is far from being fully realized. Third, there is an imbalance in technical application ability. Teachers' digital teaching innovation is not high, the average daily use rate of intelligent teaching equipment is low, and the lack of technical adaptability exacerbates the

problem of inefficient resource utilization, and this structural contradiction urgently requires the establishment of a dynamic monitoring and intelligent deployment mechanism.

(3) Insufficient adaptability of the digital talent training system.

In October 2022, the General Office of the CPC Central Committee and the General Office of the State Council issued the Opinions on Strengthening the Construction of Highly Skilled Personnel in the New Era, which for the first time incorporated the work of highly skilled personnel into the overall layout of the national strategy for strengthening the country, and explicitly proposed the establishment of a “skill-based society” construction index assessment system. In the context of the deep integration of the digital economy and the real economy, the cultivation of highly skilled personnel has broken through the traditional scope of vocational training, forming a “three-dimensional strategic framework”, building a modern vocational education system with “high-level training”, and unimpeded access to “highly skilled employment”. High-skilled employment” to open up the growth channels of talents, and ‘high precision to achieve’ to realize the dynamic matching of people and jobs. Among them, digital skill cultivation is listed as a priority development direction, according to the statistics of the Ministry of Human Resources and Social Security, the gap of digital skill talents in the field of intelligent manufacturing in 2023 has reached 20 million, which urgently requires the completion of digital transformation of vocational education talent training system. Then, the existing vocational education digital talent training faces great challenges, and there is a threefold disconnect in the innovation of talent training mode. First, the curriculum structure setting, the curriculum content update time is long, most of the majors are still using the traditional disciplinary curriculum system, and the digital economy technology iteration speed is seriously out of touch, especially intelligent networked vehicles, industrial Internet, artificial intelligence and other emerging areas of the curriculum gap is as high as 72%. Second, the digital capacity of teachers, the current digital capacity of teachers can not match the cultivation of digital technology talent, especially dual-teacher teachers with low digital technology application capacity, and the use of digital technology teaching tools proficiency in the region of business professionals and technicians, this training system is difficult to make up for the gap in the adaptability of the demand for talent with the digital economy. Third, in the development of teaching resources, there is a tendency of “heavy development and light application”. According to the survey, 83% of the vocational colleges and universities' digital resource libraries are in an idle state, with less attention and use by teachers and students. What is more noteworthy is that the mismatch between talent training specifications and enterprise demand has intensified, and the job adaptation cycle of graduates in the field of intelligent manufacturing has been extended to 6.2 months, which is 41% more than that of the traditional manufacturing industry, and this “technological disconnect” phenomenon has exposed the serious lack of industrial demand response mechanism in the process of talent training.

(4) The digital ecology of industry-education collaboration has not yet been formed.

With the introduction of policies such as the National Vocational Education Reform Implementation Program and the Opinions on Deepening the Reform of the Construction of Modern Vocational Education System, the integration of industry and education has risen from a reform initiative in the field of education to an institutional arrangement at the national strategic level. The report of the 20th CPC National Congress put forward the important assertion of “promoting the integration of vocational education, the integration of industry and education, and the integration of science and education”, marking the digital transformation of vocational education to enter a new stage of in-depth integration oriented by industrial demand and supported by digital technology. Statistics from the Ministry of Education show that as of 2023, the country has cultivated 1,978 industry-education integration enterprises and constructed more than 2,600 industry-education integration training bases, but the average duration of school-enterprise cooperation projects is less than 2.3 years, reflecting that the

integration of industry and education in the context of the digital transformation of vocational education is still confronted with structural contradictions. First, the division and imbalance of value goals. Vocational colleges and universities undertake public functions such as talent cultivation and social services, while enterprises, as market players, are more concerned with technological innovation and economic benefits. This difference in value orientation has led to the phenomenon of “school hot and enterprise cold” in cooperation. 78% of vocational colleges and universities have included the integration of industry and education in their development plans, but only 52% of enterprises have established a regular cooperation mechanism. In the process of digital transformation, institutions focus on the development of digital teaching resources and teacher training, while enterprises focus on the digital transformation of production processes. The lack of fit between the two sides of the target leads to difficulties in the implementation of collaborative innovation projects. Second, the disorder of the benefit distribution mechanism. In the existing cooperation mode, 73% of the university-enterprise agreements adopt the traditional form of “order-based training + internship-based”, and there is a lack of a revenue-sharing mechanism empowered by digital technology. An intelligent manufacturing professional cooperation case shows that the institution invested 800,000 yuan in the construction cost of a virtual simulation training system, and the enterprise only offset the cost with the students' internship, and the unclear definition of the ownership of digital assets makes the subsequent cooperation difficult to continue. This “heavy hardware investment, light digital asset operation” mode of cooperation makes it difficult for schools and enterprises to form a sustainable digital transformation synergy. Third, the information silo and synergy barriers. The digital transformation of education has given rise to new forms of business, new technologies, and structural conflicts with the traditional docking mechanism of industry and education. Research shows that 65% of vocational colleges and universities have not yet established a dynamic perception system of industrial demand, and 58% of enterprise digital transformation programs have not been incorporated into the institutional curriculum system. In a new energy automobile professional cooperation, the institution follows the traditional automobile maintenance curriculum system, while the enterprise has realized the full digital upgrade of the battery management system, resulting in a 3-5 year technology generation gap between the training objectives and job requirements. Third, the operational dilemma of digital technology empowerment. Although 90% of vocational colleges and universities have built digital management platforms, the industry-teaching collaboration module is weak. School and enterprise data interface standards are not uniform, leading to information islands. A regional vocational education group's research shows that the data interoperability rate of school and enterprise systems is less than 40%. Digital twins, industrial Internet, and other new technology applications lack uniform standards. An industrial robotics professional constructed of virtual simulation training room, due to the incompatibility of equipment interface protocols, leading to an equipment utilization rate of less than 30%.

(5) Incomplete digital assessment system for vocational education.

The construction of the evaluation system is an important measure of the effectiveness of vocational education and the key to improving the quality of vocational education. However, there are multiple problems with the digital evaluation system in the process of digital transformation of vocational colleges and universities. First, the a structural imbalance in the design of assessment dimensions. The current assessment system for digital transformation of vocational education generally has the tendency of “relying on hardware investment but not on digital capacity”, and overly relies on obvious indicators such as “digitization rate of infrastructure”, “number of online courses”, etc. It neglects the importance of “digital capacity”. The assessment system of digital transformation of education generally has a tendency to “emphasize hardware investment but not digital capability”, overly relying on obvious indicators such as “digitization rate of infrastructure” and “number of online courses”, and

neglecting core dimensions such as “depth of application of digital technology” and “level of reengineering of teaching process”. According to the assessment data of the Ministry of Education in 2023, 78% of the assessment indicators focus on the construction of digital infrastructure, while only 12% are related to the digital literacy of teachers, and 9% are related to the quality of the development of digital teaching resources. What is more noteworthy is that 73% of the assessment systems do not incorporate the special dimension of digital transformation of industry-education integration, and there is a lack of effective measurement of key elements such as the school-enterprise data sharing mechanism and the application of digital twin technology, an imbalance that leads to a deviation of the assessment results from the essential goals of education. Second, the practical dilemma of data collection and analysis. The digital transformation of vocational education is characterized by multi-subject, inter-temporal, and strong interaction, but the existing assessment system still follows the traditional education data collection model. The research shows that 65% of the assessment data comes from the statements of the education administration, and only 28% contains data from the enterprise side, resulting in the inability to accurately measure the synergistic effect of industry and education. This leads to more serious data quality problems, and there is the triple paradox of “conflict between instrumental rationality and value rationality, co-existence of data overload and information scarcity, and contradiction between data security and data application”, which seriously restricts the authenticity and completeness of the evaluation results. Third, the scientific defects of the evaluation method. The existing evaluation system overly relies on static and standardized evaluation methods, and the lack of a dynamic monitoring mechanism leads to insufficient timeliness of evaluation, which makes it difficult to adapt to the dynamic characteristics of digital transformation. The digital transformation of vocational education has significant technological iteration characteristics, but the assessment cycle of most vocational colleges and universities is set as an annual assessment, which is unable to reflect the dynamic changes brought about by the rapid application of 5G, AI, and other technologies. According to an assessment program carried out in a province, 82% of the assessments used a combination of questionnaires and on-site visits, and only 15% used new technology tools such as learning analytics and big data profiling. The error rate of this traditional method is as high as 38% when measuring dimensions such as “teachers' digital teaching innovation ability” and “the effectiveness of digital collaboration between industry and education”. Fourth, the obstacle of practical transformation in the application of results. The assessment results have not been effectively transformed into a driving force for improvement, and there is a break between monitoring and improvement. 73% of the institutions equate assessment with standardization checking and have not established a data-driven, continuous improvement mechanism. More prominently, there is a disconnect between assessment results and individual development incentives. The correlation between the improvement of teachers' digital literacy and the evaluation of titles and performance appraisal is only 31%, and the results of the certification of digital talents by enterprises involved in digital transformation are linked to policies such as tax incentives at a rate of less than 25%, which seriously restricts the motivation of each subject to participate. Fifth, the alienation risk of digital technology empowerment. Technological dependence gives rise to a new type of ethical risk. The misuse of facial recognition, behavioral analysis, and other technologies in classroom monitoring has triggered controversy over privacy protection for teachers and students. The assessment blind spot of the digital divide is even more alarming. The existing system does not give enough consideration to the special context of digital transformation in rural vocational schools and small and medium-sized microenterprises, leading to a 39% representativeness bias in the assessment results.

5. Practical Path of Digital Transformation of Vocational Education

In the wave of digital transformation of global education, vocational education, as a key link between industry and education, has a direct impact on the quality of national human resources and the process of industrial upgrading. However, the digital transformation of vocational education in China is still facing multiple challenges, such as cognitive bias, resource imbalance, insufficient talent adaptation, weak industry-education synergy, lagging assessment system, etc., which urgently requires the construction of a multi-dimensional and three-dimensional optimization path. Based on the systematic analysis framework, this paper combines the policy orientation and practical difficulties, and puts forward a step-by-step optimization strategy, aiming at cracking the transformation obstacles and promoting the high-quality development of vocational education.

(1) Constructing a multi-dimensional cognitive system to eliminate the risk of technological alienation.

On the one hand, the first task in the digital transformation of vocational education is to correct the one-sided cognition of “technical tool theory”. First of all, from the level of policy implementation, through national training and policy interpretation meetings, strengthen the implementation of the Action Plan for the Digital Transformation of Vocational Education and other documents, and make clear the boundaries and goals of technological empowerment. For example, in Zhejiang Province, through the “Digital Vocational Education” special action, digital transformation has been included in the assessment indicators of the leadership team of vocational colleges and universities, which has effectively enhanced the management's strategic cognition. Secondly, at the level of the main body of education, we carry out full training for teachers' digital literacy. For example, Tianjin Institute of Mechanical and Electrical Vocational Technology has designed a “menu-type” training module covering the application of digital technology, teaching ethics and other contents, which helps teachers shift from “technology fear” to “technology empowerment”. “Technology empowerment”. Finally, at the level of social cognition, through media publicity and promotion of typical cases, such as the case of Shenzhen Vocational and Technical College's “AI+ Intelligent Manufacturing” training base, it highlights the substantial improvement of the quality of talent cultivation through digital transformation, and removes the public's concern about technology replacing human resources. On the other hand, the development of differentiated promotion strategies to avoid the “one size fits all” dilemma. The digital transformation of vocational education needs to be combined with regional economic characteristics and differentiated promotion of the types of institutions. First of all, from the regional level, the eastern developed regions can focus on the application of “digital twin” technology, such as Shanghai Electronic Information Vocational and Technical College to establish a virtual factory training system; the central and western regions are prioritized to improve the basic network facilities, such as Yunnan Forestry Vocational and Technical College through the “5G+Satellite”. For example, Yunnan Forestry Vocational College of Technology has solved the problem of network coverage in remote campuses through “5G+Satellite” technology. Secondly, at the institutional level, applied undergraduate colleges and universities focus on the digital transformation of professional clusters, such as the professional cluster of “industrial Internet technology” constructed by Nanjing University of Industrial Technology; higher vocational colleges and universities need to strengthen the digital transformation of practical teaching, such as the “intelligent logistics” virtual simulation system developed by Shandong College of Commerce and Vocational Technology.

(2) Building digital infrastructure and resource-sharing platforms to bridge the resource divide. On the one hand, promote the integration of the “new infrastructure” and consolidate the digital base. Digital infrastructure is the material foundation for the digital transformation of

vocational education, and it is necessary to build a “three-layer architecture” system. First of all, from the perception layer, the deployment of Internet of Things devices and edge computing nodes, such as the Hebei University of Technology's “intelligent classroom management system”, real-time collection of teaching behavior data. Secondly, the network layer, upgrading the campus network and education network to achieve “5G + IPv6” full coverage, to ensure the efficiency of data transmission. For example, the “Guangdong Education Cloud” platform promoted by the Guangdong Provincial Department of Education realizes seamless scheduling of inter-school resources through SDN technology. Finally, there is the platform layer, which builds regional education cloud platforms and integrates tools such as virtual simulation and AI evaluation. For example, the National Vocational Education Intelligent Education Platform has brought together 1,200 professional resource libraries, but it needs to further optimize the resource retrieval algorithm to improve the degree of accurate matching. On the other hand, cracking the bottleneck of resource sharing and building a synergistic mechanism first builds a standard system construction, formulates the “Vocational Education Digital Resource Metadata Standard”, and unifies the resource classification and interface specifications. For example, the Hunan Provincial Department of Education and Huawei have jointly developed the “Hunan Education Cloud” platform, which adopts blockchain technology to realize resource authentication and sharing incentives. The second is to build a cross-regional collaboration mechanism to establish a “digital resource pool” for East-West counterparts, such as the “Suzhou-Shaanxi Collaboration Vocational Education Cloud” project, in which Jiangsu's high-quality institutions have opened up virtual simulation training resources to their counterparts in Shaanxi, and the cumulative number of visits has exceeded 2 million. Thirdly, we innovate the market-oriented operation mode and introduce enterprises to participate in the construction of resources, such as Tencent Cloud and Yellow River Water Conservancy Vocational and Technical College's “Intelligent Water Conservancy” Resource Base, which is updated continuously through subscription-based services.

(3) Innovate talent training mode and teaching methods to enhance the adaptability of talents. On the one hand, the professional curriculum system is reconstructed based on “demand-driven”, incorporating digital genes. First of all, from the dynamic professional adjustment. The establishment of “industrial demand-job capacity-course content” mapping model, for example, according to the “future factory” demand, Zhejiang Province, higher vocational colleges and universities, new “industrial digital twin technology”, and so on. Professional direction. Secondly, modularized curriculum design. Build a dual-module curriculum structure of “core skills + digital literacy”, for example, the adaptive learning system docked between Hongcheng Education and ChatGPT, which can push personalized learning paths according to the differences in students' abilities. Finally, the development of flipchart-style teaching materials. Vocational colleges and universities can join hands with leading enterprises to develop new types of teaching materials, such as “Application of Artificial Intelligence Technology”, embedded with two-dimensional code linking to virtual simulation resources, realizing the three-dimensional presentation of “paper+digital”. On the other hand, the construction of virtual and real integration of practical training model reform teaching methods strengthen the practical innovation ability. The first is the application of virtual simulation technology. Promote the “cloud training” mode, such as Wuhan Shipbuilding Vocational and Technical College's “ship welding VR training system”, students can wear VR equipment to remotely operate the virtual welding machine, reducing the cost of practical training. Second, the application of AI-assisted teaching. The use of ChatGPT to generate teaching cases and test banks, such as Rudolph designed the flipped classroom model, allows teachers through ChatGPT automatically generate classroom discussion questions to enhance the efficiency of classroom interaction. Finally, the “project + apprenticeship” model is constructed. School-enterprise co-construction of “digital artisan workshop”, Shenzhen Institute of Vocational

Technology, “Tencent digital marketing studio”, led by the enterprise mentor, students participate in the development of real projects, to develop the ability to solve complex problems.

(4) Deepening the integration of industry and education and school-enterprise collaboration, and breaking through the barriers to collaborative education.

On the one hand, build a digital ecosystem of “symbiosis strategy” for the integration of industry and education. First, build a data-sharing platform, set up an industry talent demand database, such as ChatGPT, digital technology platforms, etc., as a “school-enterprise connector” role, real-time analysis of enterprise recruitment data, and feedback to the institution's talent training program. The second is to establish mixed ownership training bases and explore the mode of “factory in school” and “factory in school”, such as the “5G+Industrial Internet Training Center” jointly built by Nanjing Institute of Information Vocational Technology and ZTE Corporation. For example, Nanjing Information Vocational Technology College and ZTE Corporation jointly built the “5G + Industrial Internet Training Center”, where enterprise engineers teach in the school and students participate in the 5G base station operation and maintenance project. The third application of digital twin technology to build a virtual factory and real production line linkage system, such as Hunan Automotive Engineering Vocational College “C + R remote control training platform”, students through virtual simulation pre-training, remote control physical equipment to complete practical training tasks. On the other hand, innovate the long-term mechanism of school-enterprise cooperation, one of which is to build a benefit distribution mechanism, sign a “talent co-cultivation agreement”, and make clear the ownership of intellectual property rights and the proportion of income distribution of enterprises involved in curriculum development. For example, a higher vocational college and the enterprise agreed that for every internship received by the enterprise, the enterprise can get 0.5 places for teachers to practice in the enterprise. The second is to construct a flexible evaluation system and introduce enterprises to participate in the assessment of teaching quality, such as incorporating enterprise satisfaction into the professional certification index, with a weighting of no less than 30%. Third, reconstruct the lifelong learning ecology and build a platform for continuing education for alumni enterprises, such as the “Digital Artisan Academy” of Zhejiang Institute of Mechanical and Electrical Vocational Technology, which provides customized skill enhancement courses for enterprise employees.

(5) Improve the data-driven assessment system and realize dynamic quality monitoring.

On the one hand, a multiple evaluation index system of “quality assessor” is constructed. First, process evaluation. Use learning analytics to track students' learning trajectories, such as the Classroom Behavior Analysis System adopted by an institution, which automatically records data such as the frequency of students' questions and the length of group work. Second, multi-subject evaluation. Developing a collaborative evaluation platform between schools and enterprises, integrating evaluation data from teachers, students, and enterprise mentors, such as the “Digital Literacy Radar Chart” of an institution, which generates student profiles in six dimensions, including technology application and professional ethics. Third, predictive analysis. Apply big data to predict the quality of employment, such as the “Graduate Digital Portrait System” of a higher vocational college, which dynamically adjusts the enrollment scale of majors by analyzing employment data from previous years. On the other hand, strengthening data security and ethical norms. First, a privacy protection mechanism. We have established a “data desensitization, encrypted transmission, and permission grading” management system, such as the use of federated learning technology to realize joint modeling of university-enterprise data, to avoid the leakage of raw data. Second, algorithmic ethical review. Establish a university-level digital ethics committee to conduct ethical review of AI assessment tools, such as the Kiel University of Applied Sciences in Germany, which prohibits the use of gender-biased algorithm models. Third, a quality monitoring system. The construction of a “digital twin assessment model”, such as the “teaching process mirroring system” of an institution, supports

the retrospective analysis and improvement of teaching behaviors by reproducing classroom scenes through virtual simulation.

6. Conclusion

The digital transformation of vocational education, as a core issue for the high-quality development of education in the digital economy era, is both an inevitable choice in response to national strategy and a key path for vocational education to adapt to industrial transformation and achieve its own form of upgrading. This study, based on policy guidance and practical challenges, systematically examines the logical drivers, real-world challenges, and practical pathways of transformation, reaching the following core conclusions:

(1) Digital transformation is an inevitable choice driven by the synergistic interaction of multiple factors. The underlying logic of vocational education's digital transformation stems from the interplay of four forces: policy, economy, technology, and educational reform. At the policy level, the national strategy for educational digitization provides a clear direction for transformation. At the economic level, the digital transformation of industries has created an urgent demand for high-quality technical and skilled talent, driving deeper integration between vocational education and industrial chains. At the technological level, digital technologies such as 5G, big data, and artificial intelligence are reshaping educational elements and ecosystems, providing technical support for innovations in teaching models, governance methods; educationally, the revision of the Vocational Education Law and the deepening of the “vocational education” 定位 require vocational education to achieve a paradigm shift from scale expansion to quality improvement through digital transformation. The interplay of these four driving forces makes digital transformation an inevitable path for vocational education to serve national strategies and adapt to the demands of the times.

(2) Current challenges exhibit systemic characteristics and require breaking through multi-dimensional bottlenecks. While vocational education's digital transformation has achieved phased progress, it still faces structural contradictions and deep-seated obstacles. At the cognitive level, policy misunderstandings, a tool-centric view of technology, and resistance to its application lead to “islanded” transformations; at the resource level, the East-West digital divide, structural contradictions between infrastructure investment and output, and the coexistence of resource idleness and shortages constrain the release of resource efficiency; at the talent level, outdated curriculum systems, insufficient digital capabilities among faculty, overemphasis on resource development over application in teaching materials have caused a disconnect between talent cultivation and industrial needs; in terms of industry-education collaboration, divergent value objectives, disordered interest distribution, information silos, and inconsistent technical standards hinder the effectiveness of collaborative talent cultivation; in terms of evaluation, indicator designs that prioritize hardware over capabilities, limitations in data collection, outdated methods, and insufficient application of results make it difficult to accurately measure the effectiveness of the transformation. These challenges are interrelated and constitute the “systemic bottlenecks” of the transformation.

(3) Practical pathways must be advanced with a systemic mindset to achieve a transition from “technology empowerment” to “value reconstruction.” In response to the aforementioned challenges, this study proposes a systemic practical pathway comprising “multi-dimensional cognition-resource optimization-talent matching-industry-education collaboration-assessment-driven.” At the cognitive level, through policy dissemination, teacher training, and public outreach, we correct the misconception of “technology as a tool” and formulate differentiated implementation strategies; at the resource level, we strengthen the digital infrastructure of “new infrastructure,” establish resource-sharing standards and cross-regional collaboration mechanisms, and address resource gaps; at the talent level, we reconfigure the

curriculum system, innovate blended teaching models, and enhance digital skill development; at the industry-education collaboration level, we will build data-sharing platforms and mixed-ownership training bases, innovate interest distribution and evaluation mechanisms, and break through collaboration barriers; at the evaluation level, we will construct a diversified evaluation indicator system, strengthen data security and ethical norms, and promote the transformation of evaluation from “compliance checks” to “dynamic improvement.” These pathways emphasize the deep integration of technological empowerment and the essence of education, aiming to achieve a qualitative transformation of vocational education from “technology application” to “ecological reconstruction” through systematic reform.

This paper combines systems theory and ecological perspectives to fill the research gap in the logical drivers, challenge analysis, and systematic pathways of vocational education digital transformation, providing a reference framework for theoretical construction and practical exploration. Future research should further focus on the dynamic balance between digital technology and humanistic values, particularly breakthroughs in ethical issues such as privacy protection and bridging the digital divide; simultaneously, it is necessary to deepen the refinement of a Chinese-characteristic vocational education digital transformation model to provide a “Chinese solution” for global vocational education digitalization. Overall, the digital transformation of vocational education is a long-term and complex systemic endeavor that must be centered on “education for the sake of nurturing talent.” Through the coordinated advancement of top-level design, resource integration, teaching innovation, industry-education collaboration, and evaluation reforms, it ultimately aims to achieve high-quality integration of the education chain, talent chain, and industrial chain, providing a solid foundation for the construction of an education powerhouse and the development of the digital economy.

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