Research on the Dual-Driven Teaching Reform of "AI + Industry-Education Integration" for Intelligent Manufacturing Professional Groups in Higher Vocational Colleges

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Abstract: *Against the dual strategic backdrop of the accelerated cultivation of new quality productive forces and the digital transformation of vocational education, the intelligent manufacturing industry has achieved comprehensive iterative upgrading relying on cutting-edge technologies such as artificial intelligence, digital twins, and industrial big data. Subversive changes have taken place in the industrial post structure, technical standards, and talent competency system, forcing higher vocational colleges to carry out systematic and in-depth teaching reforms for intelligent manufacturing professional groups. The two-way linkage of AI empowerment and in-depth industry-education integration has become a core approach for intelligent manufacturing professional groups in higher vocational colleges to solve practical dilemmas including the supply-demand mismatch in talent training, the lag of teaching content behind industrial development, and the formalization of school-enterprise collaborative education. It also serves as a key support for constructing a digital, intelligent and modern vocational education system. Adopting the literature review method, comparative analysis method and inductive deductive method, this paper systematically sorts out the research context and practical progress of the teaching reform of "AI + industry-education integration" for domestic intelligent manufacturing professional groups in higher vocational colleges, and defines the core connotation and coupling mechanism of the dual-driven model. By constructing two groups of comparative analysis tables, this paper quantitatively compares the differentiated characteristics between the traditional teaching model and the AI-enabled dual-driven teaching model, and analyzes the advantages, disadvantages and applicable scenarios of three mainstream domestic reform paradigms. On this basis, it summarizes common problems existing in current teaching reforms, including superficial integration of AI technology, fragmented industry-education collaboration mechanisms, delayed iteration of curriculum systems, insufficient integration of virtual and physical training, weak digital and intelligent competencies of teachers, and the absence of intelligent evaluation systems. Combined with academic research achievements and industrial practical experience, this paper sorts out systematic reform paths from six dimensions: technological integration, curriculum restructuring, training upgrading, mechanism innovation, teacher training, and evaluation optimization, and prospects the future development trends of relevant reforms. This study aims to enrich the theoretical system of digital education for intelligent manufacturing professional groups, and provide theoretical support and practical references for higher vocational colleges to deepen the connotation construction of industry-education integration, promote the integration of posts, courses, competitions and certificates, and realize the precise docking between the education chain and the industrial chain.*

Keywords: *Higher vocational colleges; intelligent manufacturing professional group; AI empowerment; industry-education integration; dual-driven mechanism; teaching reform; research review*

1. Introduction

1.1 Research Background

Currently, the global manufacturing industry has entered a critical stage of digital, intelligent and high-end transformation. Emerging technologies including industrial artificial intelligence, machine vision, digital twins and the Industrial Internet of Things have deeply penetrated and fully coupled with manufacturing scenarios, thoroughly reconstructing the production processes, process standards and post systems of intelligent manufacturing. This puts forward brand-new requirements for the digital literacy, comprehensive capabilities and innovative abilities of technical and skilled talents. To adapt to the pace of industrial iteration and consolidate the talent foundation for the manufacturing industry, the state has successively issued policy documents such as the Action Plan for the Digital Transformation of

Vocational Education (2023–2025) and the Implementation Plan for the Integrated Innovation of Artificial Intelligence and Manufacturing. These documents clearly propose to apply artificial intelligence technology throughout the whole process of vocational education talent training, continuously deepen in-depth industry-education integration and school-enterprise collaborative education, build a modern vocational education system adapted to the development of new quality productive forces, and provide talent guarantees and technical support for the high-quality development of advanced manufacturing[1].

As the core professional cluster connecting regional advanced manufacturing industries, the intelligent manufacturing professional group in higher vocational colleges covers related majors including industrial robot technology, mechatronic integration technology, numerical control technology, industrial big data technology and intelligent equipment application technology. Featuring strong industrial adaptability, high resource sharing and close professional coupling, it acts as a core carrier linking the education chain, talent chain, industrial chain and innovation chain, and undertakes the core mission of cultivating high-quality compound technical and skilled talents for intelligent manufacturing. For a long time, most domestic higher vocational colleges have adhered to the traditional industry-education integration talent training model. School-enterprise cooperation is mostly limited to superficial collaboration such as student internship arrangement, enterprise equipment donation and graduate employment placement, lacking in-depth binding of technology, curricula, projects and research and development. Meanwhile, the update of teaching content lags behind the intelligent iteration of the industry, and practical training scenarios are disconnected from real enterprise production scenarios. Talent training focuses excessively on traditional manufacturing skills, failing to meet the rigid demand of the intelligent manufacturing industry for compound, innovative and intelligent technical talents.

Artificial intelligence technology has the core advantages of scenario reconstruction, data empowerment, resource integration, precise adaptation and dynamic iteration. It can effectively break the resource, information and scenario barriers of traditional industry-education integration, solve the inherent drawbacks of homogenization, hysteresis and fragmentation in traditional teaching, and promote the transformation of industry-education integration from "formal cooperation" to "substantial symbiosis". The dual-driven teaching reform of "AI technology empowerment + in-depth industry-education integration" breaks the limitations of single teaching reform and sporadic school-enterprise cooperation, and forms a new education logic of "technology innovates teaching systems, industry-education integration supports education implementation, and two-way dynamic iteration empowers development". It has become the mainstream direction and inevitable trend of teaching reform for intelligent manufacturing professional groups in higher vocational colleges in the new era. In view of industrial iteration demands and vocational education reform orientation, systematically sorting out the research status, practical dilemmas, core mechanisms and optimization paths of the current "AI + industry-education integration" dual-driven teaching reform and summarizing reform rules and development trends is of important theoretical value and practical significance[2].

1.2 Research Significance

1.2.1 Theoretical Significance

At present, domestic academic circles have abundant research achievements on AI-enabled vocational education and industry-education integration of intelligent manufacturing, but most existing studies are scattered, focusing on single-point dimensions such as single curriculum reform, practical training system upgrading and collaboration mechanism optimization. There is a lack of holistic and review-based research on the coupling mechanism, system architecture and systematic reform logic of the "AI + industry-education integration" dual-driven model. Current researches generally prioritize sporadic practical exploration over systematic summary and partial optimization over overall sorting, failing to form a unified and complete theoretical framework for dual-driven talent training. From the perspective of literature review, this paper systematically integrates relevant policy documents, core literatures and practical cases in the past five years, clarifies the core concepts, coupling logic and educational value of the dual-driven model, and sorts out the research context, current characteristics and common deficiencies of teaching reforms. It improves the theoretical system of digital industry-education integrated education for intelligent manufacturing professional groups, makes up for the systematic deficiencies of existing researches, and provides a reference framework for in-depth research and theoretical innovation in related fields.

1.2.2 Practical Significance

By constructing two groups of comparative analysis tables, this paper quantitatively distinguishes the differences between new and old teaching models as well as the advantages, disadvantages and applicable scenarios of different reform paradigms, accurately refines the common problems and underlying causes of the current dual-driven teaching reform for intelligent manufacturing professional groups in higher vocational colleges, and forms replicable, implementable and iterative systematic reform paths. The research conclusions can provide clear practical guidelines for higher vocational colleges to carry out digital teaching reforms, deepen in-depth industry-education integration and reconstruct digital and intelligent education systems, and effectively solve the long-standing pain points of post-course disconnection, backward practical training, weak collaboration and extensive evaluation in traditional teaching. Meanwhile, it can continuously improve the intelligent technology application ability, post adaptability and innovative practical ability of intelligent manufacturing professionals, promote the precise matching between vocational education talent supply and intelligent manufacturing industry demand, and facilitate the digital and intelligent transformation and upgrading of regional manufacturing industries[3].

1.3 Research Methods and Research Context

1.3.1 Research Methods

Three research methods are adopted in this paper. First, the literature review method. This paper systematically retrieves core journals, master and doctoral theses, national policy documents and industrial practical reports related to vocational education digitalization, AI-enabled vocational education reform and intelligent manufacturing industry-education integration in the past five years, sorts out existing research achievements, core viewpoints and practical progress, and establishes a complete research system. Second, the comparative analysis method. Two comparative groups of traditional and new teaching models as well as mainstream reform paradigms are constructed to quantitatively sort out the core differences, advantages, disadvantages and applicable scenarios of different education models and reform paths, ensuring the objectivity and pertinence of the research. Third, the inductive deductive method. This paper systematically summarizes the common problems and mainstream implementation paths of current dual-driven teaching reforms, deduces the future reform development direction based on industrial iteration and vocational education reform trends, and draws systematic research conclusions.

1.3.2 Research Context

This research follows the logical framework of "connotation definition — current situation review — comparative analysis — problem induction — path sorting — trend prospect". Firstly, it defines the core connotations of AI empowerment, in-depth industry-education integration and dual-driven teaching reform, and expounds the coupling education mechanism between the two. Secondly, it systematically reviews domestic and foreign research and practical status and comments on existing studies. Thirdly, it deeply analyzes the differences of teaching models and characteristics of reform paradigms through two comparative tables. Furthermore, it summarizes the common dilemmas and underlying causes of current teaching reforms. Then, it sorts out systematic reform implementation paths from multiple dimensions. Finally, it prospects the future development trends of dual-driven teaching reforms, forming a closed-loop review research system.

2. Core Connotation and Dual-Driven Coupling Mechanism

2.1 Definition of Core Concepts

2.1.1 AI-Enabled Teaching

The AI-enabled teaching discussed in this paper does not refer to the simple superposition and formal application of artificial intelligence technology. Instead, relying on industrial-level digital and intelligent technologies such as industrial artificial intelligence, digital twins, industrial big data, intelligent algorithms and virtual simulation, it carries out systematic reconstruction and quality upgrading of the whole process and all elements of talent training for intelligent manufacturing professional groups in higher vocational colleges, including curriculum teaching, practical training, teacher development, teaching management and quality evaluation. Its core essence is to solve the pain points of homogenization, hysteresis and low accuracy of traditional standardized teaching through technical means. With the functions of data analysis, scenario reproduction, intelligent monitoring and personalized adaptation, it constructs a precise, scenario-based, dynamic and personalized new teaching system to adapt to the scenario-based, compound and innovative talent training needs of the intelligent manufacturing industry.

2.1.2 In-Depth Industry-Education Integration

Different from the superficial and formal traditional school-enterprise cooperation, in-depth industry-education integration takes industrial post demands and technology iteration trends as the core orientation, promotes the in-depth coupling and two-way empowerment between the education chain and talent chain of vocational colleges and the industrial chain and innovation chain of enterprises, and builds a school-enterprise collaborative education ecosystem featuring "curriculum co-construction, training base co-construction, teacher joint training, project joint research, achievement sharing and risk sharing". Its core goal is to realize the docking of professional layout with industrial layout, curriculum content with technical standards, teaching process with production process, and talent specifications with post demands, and transform school-enterprise cooperation from a simple supply-demand partnership to an in-depth symbiotic strategic education partnership.

2.1.3 Dual-Driven Teaching Reform of "AI + Industry-Education Integration"

The dual-driven teaching reform of "AI + industry-education integration" is a new education reform paradigm adapted to the digital transformation of vocational education and industrial intelligent upgrading. Among them, digital and intelligent AI technology serves as the innovation engine of the reform, undertaking the core functions of scenario reconstruction, data empowerment, precise adaptation and dynamic iteration; in-depth industry-education integration acts as the implementation carrier of the reform, providing core support including real industrial scenarios, practical projects, technical resources and post standards. The two interact, empower each other and iterate collaboratively. On the one hand, AI technology solves the problems of formalization, hysteresis and fragmentation of industry-education integration; on the other hand, real industrial scenarios make up for the shortcomings of theorization and disconnection from practical operation in AI teaching. Ultimately, a brand-new education model featuring "technology empowers industrial education, industry supports teaching implementation, and closed-loop dynamic iteration optimizes development" is formed[4].

2.2 Dual-Driven Coupling Mechanism

AI technology empowerment and in-depth industry-education integration have natural complementarity and coupling, and the dual-driven linkage forms three collaborative logics: technology empowerment, scenario implementation and ecological iteration. First, the reverse technology empowerment logic. Relying on AI big data technology, it dynamically analyzes the technology iteration trends, post competency standards and talent supply-demand gaps of the intelligent manufacturing industry, so as to reversely drive the dynamic optimization of curriculum systems, practical training contents and teaching modes, and solve the blindness, hysteresis and passivity of traditional industry-education integration. Second, the industrial scenario implementation logic. In-depth industry-education integration breaks the resource barriers between schools and enterprises, provides real industrial production scenarios, practical projects and technical resources for AI virtual simulation, intelligent teaching and data analysis, frees digital and intelligent teaching from pure theorization and virtualization, and realizes the industrial scenario implementation of AI technology teaching. Third, the closed-loop ecological iteration logic. AI technology realizes data-based monitoring, quantitative evaluation and precise diagnosis of the whole talent training process, providing data support for the optimization of industry-education integration mechanisms and teaching reform iteration. The continuous iteration of industrial technologies in turn forces the continuous upgrading of AI teaching systems, curriculum contents and practical training scenarios, eventually forming a benign education ecosystem with two-way empowerment, dynamic circulation and continuous optimization.

3. Review of Domestic and Foreign Research and Practical Status

3.1 Foreign Research and Practical Status

Manufacturing powers in Europe, America, Japan and South Korea have taken the lead in promoting the in-depth integration of artificial intelligence and vocational education industry-education integration, forming standardized, scenario-based and digital dual-driven education paradigms adapted to their own intelligent manufacturing industry development needs. Based on the Industry 4.0 strategy, Germany has comprehensively upgraded its dual vocational training system, fully incorporating cutting-edge technical standards such as industrial artificial intelligence, digital twins and intelligent operation and maintenance into vocational education teaching specifications. It builds a virtual-real integrated practical training system relying on intelligent production workshops of leading enterprises, realizes the synchronous iteration of AI teaching content and industrial production technologies, and constructs a mature education model of "enterprise technology leadership, college teaching support, full AI empowerment and in-depth work-study integration", focusing on cultivating practical and compound talents adapted to intelligent factory scenarios.

Based on the community college education system, the United States has built an AI big data talent demand dynamic analysis platform to update the post competency standards and curriculum systems of intelligent manufacturing in real time. It adopts virtual simulation and digital twin technologies to reproduce high-end intelligent production scenarios, effectively solving the industrial pain points of high cost, high risk and difficulty in large-scale teaching of high-end practical training equipment, and realizing demand-oriented and precise talent training. Focusing on the field of precision intelligent manufacturing, Japan and South Korea promote leading manufacturing enterprises and vocational colleges to jointly build AI R&D centers and intelligent training bases, fully integrate enterprise intelligent production projects and technical research topics into daily teaching, and carry out personalized teaching guidance based on AI student competency profiling technology to comprehensively improve students' innovative and practical abilities. On the whole, foreign dual-driven reforms feature mature systems, sound standards and solid scenario implementation, but such models are adapted to foreign industrial structures and vocational education systems and cannot be directly applied to domestic higher vocational education. In addition, there are deficiencies in systematic research on professional group cluster education and full-scale AI empowermen[5].

3.2 Domestic Research and Practical Status

Domestic academic and industrial circles have carried out extensive exploratory researches and practices on the "AI + industry-education integration" teaching reform of intelligent manufacturing professional groups in higher vocational colleges. Existing researches mainly focus on four core dimensions. First, curriculum system reform research. Scholars generally believe that AI technology should be used to reconstruct modular and dynamic curriculum systems to break the drawbacks of solidified and lagging traditional curricula and promote the precise digital docking of posts and courses. Second, practical training system upgrading research. Researches focus on the scenario application of virtual simulation and digital twin technologies to build virtual-real integrated intelligent practical training platforms and make up for the deficiencies of traditional practical training such as single scenarios, outdated equipment and lagging iteration. Third, collaboration mechanism innovation research. New cooperation modes such as industrial colleges, mixed-ownership school running and school-enterprise AI joint laboratories are explored to solve the problems of formalized industry-education integration and loose collaboration. Fourth, teaching evaluation optimization research. Industrial big data and intelligent algorithms are adopted to construct dynamic evaluation systems to realize full-process dynamic monitoring and closed-loop management of teaching quality.

In practice, domestic "Double High Plan" colleges and high-quality higher vocational colleges across the country have successively launched pilot projects of dual-driven teaching reform, gradually introduced AI intelligent teaching platforms and virtual simulation practical training systems, cooperated with leading industrial enterprises to develop digital and intelligent curriculum resources and loose-leaf textbooks, and continuously promoted in-depth industry-education integration. Some benchmark colleges have constructed a cluster-based education model of "four-subject collaboration, four-chain integration and AI empowerment", effectively improving talent training quality through multi-subject collaboration and full-scale digital and intelligent technology empowerment. Some colleges adopt AI post profiling technology to accurately decompose the competency elements of intelligent posts and build task-driven hierarchical teaching systems to realize personalized talent training. Overall, domestic reforms have developed from single-point exploration and partial optimization to systematic construction. Nevertheless, there are still problems such as unbalanced regional development, insufficient integration depth, imperfect implementation systems and lack of unified industrial standards, and no standardized and fully replicable dual-driven teaching reform paradigm has been formed[6].

3.3 Review of Existing Researches

Based on existing research achievements and practical results, domestic academic circles have fully recognized the core value of the "AI + industry-education integration" dual-driven model for the teaching reform of intelligent manufacturing professional groups in higher vocational colleges. Relevant researches cover multiple education dimensions including curricula, practical training, teachers, mechanisms and evaluation, laying a solid theoretical and practical foundation for this review. However, existing researches still have obvious deficiencies. First, systematic review researches are scarce. Most studies are summaries of single-point reform countermeasures and partial practices, lacking global sorting and systematic refinement of the dual-driven coupling mechanism, reform overview, common problems and development trends. Second, comparative researches are insufficient. There is a lack of quantitative comparative analysis between new and old teaching models and different reform paradigms, resulting in unclear advantages, disadvantages and applicable scenarios of various reform paths. Third, problem sorting is fragmented. The induction of deep-seated problems such as superficial integration, supply-demand mismatch and mechanism vacancy in dual-driven reforms is scattered, failing to form a systematic problem analysis framework. Based on the above, this paper conducts multi-dimensional comparative analysis and systematic induction to improve the existing research system and make up for current research deficiencies.

4. Comparative Analysis of Teaching Models and Reform Paradigms

To accurately clarify the core value, optimization logic and iteration direction of dual-driven teaching reform, and define the inherent drawbacks of traditional education models and the applicable boundaries of new reform paradigms, this paper constructs two groups of comparative analysis tables to conduct quantitative comparison from the perspectives of differences between new and old teaching models and advantages and disadvantages of mainstream reform paradigms, and systematically illustrate the necessity and advancement of dual-driven reform.

4.1 Comparison Between Traditional Teaching Model and "AI + Industry-Education Integration" Dual-Driven Model

The traditional teaching of intelligent manufacturing professional groups adopts the core model of "classroom theoretical teaching + basic physical practical training + superficial school-enterprise cooperation", with many drawbacks such as lack of technical empowerment, loose industry-education connection, solidified and lagging systems, and extensive evaluation methods. The dual-driven model takes AI technology as the core of full-scale empowerment and in-depth industry-education integration as the implementation carrier, realizing the innovation of the whole process and all elements of talent training. The core differences between the two are shown in Table 1.

Table 1 Comparison Between Traditional Teaching Model and "AI + Industry-Education Integration" Dual-Driven Teaching Model

Comparison Dimension	Traditional Teaching Model for Intelligent Manufacturing Majors	"AI + Industry-Education Integration" Dual-Driven Teaching Model
Core Reform Logic	Centered on college classroom teaching, focusing on theoretical indoctrination and basic practical training; passively adapting to industrial demands with prominent reform hysteresis	Oriented by industrial intelligent iteration demands; full-scale AI technology empowerment; two-way dynamic industry-education coupling to actively adapt to industrial technology iteration
Technology Integration Degree	No systematic AI technology integration, insufficient digital and intelligent teaching resources, fragmented and formal technology application without substantial empowerment effects	In-depth integration of AI technology into the whole process of teaching, training, management and evaluation, fitting real industrial intelligent manufacturing scenarios with substantial empowerment effects
Curriculum System Characteristics	Solidified curriculum framework, lagging content update, dominated by traditional manufacturing knowledge, serious post-course disconnection, no hierarchical digital intelligent curriculum system	Hierarchical and progressive modular digital intelligent curriculum with dynamic iteration, precise post-course docking and full coverage of intelligent manufacturing competency requirements
Practical Training Scenarios	Dominated by outdated traditional physical training equipment with single scenarios, lacking intelligent training scenarios and virtual-real integrated training systems	Constructed virtual-real symbiotic intelligent training system; complementary integration of virtual simulation scenarios and enterprise real production scenarios, covering full-post practical training needs
School-Enterprise Collaboration Level	Superficial formal cooperation limited to internship arrangement and employment placement, no in-depth collaboration in curriculum co-construction, technology R&D and joint project education	In-depth substantive symbiosis, realizing full-chain collaborative education including curriculum co-construction, project joint research, teacher joint training and achievement sharing
Teaching Evaluation Method	Dominated by artificial subjective evaluation, focusing on examination scores and training attendance, single evaluation dimension lacking data support and scientificity	Full-process dynamic quantitative monitoring based on AI big data, multi-dimensional comprehensive evaluation with closed-loop feedback and dynamic iteration mechanism
Talent Training Effect	Students have solid traditional skills but weak intelligent technology application abilities and poor post adaptability, failing to meet compound intelligent manufacturing talent demands	Students master both traditional manufacturing skills and intelligent technology application abilities with significantly improved innovative literacy, practical capabilities and post adaptability

4.2 Comparison of Domestic Mainstream Dual-Driven Teaching Reform Paradigms

Based on differences in school-running foundations and regional industrial resources, domestic higher vocational colleges have formed three mainstream dual-driven teaching reform paradigms: scenario training-oriented, curriculum system reform-oriented, and full-scale ecological collaboration-oriented. The three paradigms differ in construction priorities, implementation difficulties and education effects, adapting to different types of higher vocational colleges. The detailed comparative analysis is shown in Table 2.

Table 2 Comparison of Domestic Mainstream Dual-Driven Teaching Reform Paradigms of "AI + Industry-Education Integration"

Reform Paradigm	Core Reform Content	Core Advantages	Existing Deficiencies	Applicable College Types
Scenario Training-Oriented	Focus on constructing AI virtual simulation and digital twin training scenarios, upgrading intelligent training hardware, deepening enterprise real-scenario training cooperation, and prioritizing practical teaching system optimization	Low implementation difficulty, short construction cycle and quick results; rapidly makes up for intelligent training deficiencies with remarkable improvement in students' practical abilities	Overemphasizes practical training while neglecting curricula and mechanisms; imperfect supporting AI curriculum system and lagging school-enterprise collaboration mechanism with insufficient systematic reform	Ordinary higher vocational colleges with weak foundations and insufficient training resources
Curriculum System Reform-Oriented	Reconstructs modular digital intelligent curriculum systems based on AI post data analysis, develops new digital intelligent textbooks, promotes smart classroom reform and optimizes theoretical teaching systems	Strong post-curriculum adaptability and standardized teaching system; effectively solves post-course disconnection with clear and unified talent training standards	Overemphasizes classroom theories while neglecting real-scenario practice; insufficient support from training scenarios and industrial projects with weak practical implementation of AI technology	Public higher vocational colleges with solid teaching foundations and strong teaching and research capabilities
Full-Scale Ecological Collaboration-Oriented	Integrates resources of governments, colleges, enterprises and industries; realizes full-scale AI empowerment of curricula, training, teachers, mechanisms and evaluation; builds a closed-loop education ecosystem	Complete reform system with prominent two-way empowerment effect; adapts to high-end industrial talent demands with optimal comprehensive education quality	Large capital investment, long construction cycle and high implementation difficulty; stringent requirements on college resource strength and regional industrial foundation	Double High Plan colleges and regional benchmark higher vocational colleges

5. Review of Common Problems in Current Dual-Driven Teaching Reforms

5.1 Superficial AI Technology Integration and Insufficient Two-Way Empowerment Effect

Judging from the reform practices of domestic colleges, the AI empowerment of most higher vocational colleges remains at the stage of superficial and formal application, generally featuring "idle technology application, inadequate integration and ineffective empowerment". Some colleges only simply introduce basic tools such as intelligent courseware, virtual simulation demonstration videos and online Q&A systems, without deeply integrating industrial AI technical standards, intelligent production logic and digital twin application systems into the whole talent training process. Most AI teaching contents are general artificial intelligence theories, divorced from industrial practical scenarios of intelligent manufacturing and disjointed from core post skills such as machine vision commissioning, intelligent production line operation and maintenance, industrial data analysis and intelligent fault diagnosis. Meanwhile, the industry-education integration system fails to effectively undertake AI teaching achievements, and enterprises' cutting-edge intelligent technologies and real production scenarios cannot feed back campus teaching. Students' acquired AI theoretical knowledge is difficult to transform into industrial practical capabilities, and the two-way linkage mechanism of AI empowering teaching and industry-education supporting technology implementation has not been effectively established, making it hard to give full play to the collaborative education advantages of dual-driven mechanisms[7].

5.2 Delayed Iteration of Curriculum System and Low Post-Curriculum Digital Adaptability

At present, most higher vocational colleges have not completed the systematic digital intelligent reconstruction of curriculum systems for intelligent manufacturing professional groups, with prominent problems of solidified curricula, lagging content and fragmented structure. First, the curriculum structure is fragmented. Most colleges only sporadically add general elective courses such as Fundamentals of Artificial Intelligence and Introduction to Industrial Big Data, failing to break traditional professional barriers or build hierarchical and progressive modular digital intelligent curriculum systems, resulting in extremely low integration of AI technology and core professional curricula. Second, curriculum content iteration is slow. Cutting-edge intelligent manufacturing technologies such as digital twin modeling, industrial AI application, intelligent production line optimization and intelligent equipment fault diagnosis are missing in teaching content. Traditional standard textbooks still dominate, while loose-leaf and project-based digital intelligent textbooks adapted to real enterprise intelligent production scenarios are scarce. Third, post-curriculum docking accuracy is insufficient. There is a lack of a dynamic post competency analysis mechanism based on AI big data, and the update of curriculum content lags behind the iteration speed of enterprise intelligent post technical standards, leading to prominent post-curriculum supply-demand mismatch and inability to meet the training needs of compound intelligent manufacturing talents.

5.3 Imperfect Practical Training System and Insufficient Virtual-Real Integrated Education

Practical teaching is the core carrier for the implementation of dual-driven reforms and the main shortcoming of current reforms. In terms of on-campus practical training, most colleges are still equipped with traditional electromechanical and numerical control training equipment, with insufficient deployment of cutting-edge intelligent equipment such as AI intelligent commissioning workstations, machine vision training systems and digital twin training platforms. The intelligent transformation progress of traditional equipment is slow, failing to meet the needs of intelligent and scenario-based practical teaching. In terms of off-campus practical training, school-enterprise cooperative training is mostly limited to student visits, inspections and basic practical operations, and students have few opportunities to participate in enterprises' core intelligent production projects, technology R&D and equipment operation and maintenance, resulting in limited real-scenario education effects. In addition, the virtual-real integrated practical training system is imperfect. The number of independently developed virtual simulation projects is insufficient with low scenario fitting degree, which cannot effectively solve the industrial pain points of high risk, high cost and poor reproducibility of traditional practical training. Virtual teaching and real-scenario training fail to form effective complementation, restricting the improvement of practical training quality and efficiency.

5.4 Fragmented School-Enterprise Collaboration Mechanism and Lack of Long-Term Education Motivation

The core of dual-driven reform lies in in-depth industry-education symbiosis, but the four-subject collaboration mechanism of most colleges remains fragmented and formalized. First, the rights and responsibilities of multiple subjects are ambiguous. Governments, colleges, enterprises and industry associations lack regular docking mechanisms with prominent resource and information barriers, and the division of education responsibilities and interest boundaries of all parties is unclear, making it difficult to form joint education forces. Second, school-enterprise interest binding is loose. The return mechanism for enterprises participating in AI teaching reform and talent training is unclear, and incentive policies such as tax reduction and special subsidies are not fully implemented, resulting in insufficient internal motivation for enterprises to participate in vocational education reforms. Third, long-term guarantee mechanisms are absent. There is a lack of assessment, incentive and risk-sharing mechanisms adapted to digital intelligent industry-education integration. Most school-enterprise cooperation is short-term project-based and phased cooperation, failing to form a long-term and stable dual-driven education ecosystem and hindering the continuous deepening and iteration of reforms.

5.5 Inadequate Adaptability of Teaching Staff and Weak Digital Intelligent Education Competencies

The shortage of compound dual-qualified teachers is the core bottleneck restricting the in-depth implementation of dual-driven reforms. Full-time teachers in colleges have solid experience in traditional manufacturing teaching, but generally lack practical operation experience and teaching capabilities in cutting-edge technologies such as industrial artificial intelligence, digital twins, intelligent production line operation and maintenance, and industrial big data analysis, making them incompetent for digital intelligent teaching reforms. Enterprise part-time teachers are mostly front-line technical backbones with rich practical experience in intelligent production, but lack systematic teaching theories, teaching skills and education norms, leading to uneven teaching quality. Meanwhile, the two-way flow, special training and capability iteration mechanisms for school-enterprise teachers are imperfect. Special teacher training targeting intelligent manufacturing AI technologies is scarce, and the iteration speed of teachers' digital intelligent capabilities lags behind industrial technology iteration speed, unable to support the systematic implementation of dual-driven teaching reforms.

5.6 Imperfect Intelligent Evaluation System and Lack of Closed-Loop Iteration Capabilities

Most colleges still adopt the traditional single artificial evaluation model, which is seriously incompatible with the dual-driven digital intelligent education system. In terms of evaluation dimensions, the evaluation only focuses on students' examination scores, training attendance and basic skill mastery, ignoring core indicators such as students' AI technology application ability, innovative practical ability, post comprehensive literacy and project practical ability, resulting in one-sided evaluation dimensions. In terms of evaluation methods, artificial subjective scoring is dominant, lacking AI big data dynamic monitoring means, unable to realize full-process data quantitative evaluation of teaching, training and projects, leading to insufficient scientificity and accuracy of evaluation results. In terms of iteration mechanisms, there is no closed-loop management mechanism of "data monitoring — precise evaluation — problem rectification — system optimization". Evaluation results cannot reversely drive curriculum reform, training upgrading, teacher training and mechanism optimization, resulting in stagnant teaching reforms and inability to adapt to dynamic industrial iteration needs.

6. Review of Implementation Paths for "AI + Industry-Education Integration" Dual-Driven Teaching Reforms

Combined with domestic academic research achievements and college practical experience, this paper sorts out systematic, implementable and iterative reform paths from six dimensions targeting the common problems of current dual-driven teaching reforms, so as to provide comprehensive references for teaching reforms in higher vocational colleges.

6.1 Deepen Technology Integration and Innovate to Build a Two-Way Empowerment Education Logic

Thoroughly eliminate the superficial application dilemma of AI technology, promote the in-depth integration of artificial intelligence technology into the whole process and all elements of industry-education integrated education, and construct a two-way driving logic of "technology empowers teaching and industry-education undertakes technology application". On the one hand, relying on AI big data and machine learning technologies, build an intelligent demand analysis platform for intelligent manufacturing posts to dynamically capture industrial technology iteration trends, post competency standards and talent supply-demand gaps, providing accurate data support for teaching reform, curriculum optimization and training upgrading, and solving the blindness and hysteresis of traditional teaching reforms. On the other hand, based on enterprises' real intelligent production scenarios, abandon the generalized and theoretical AI teaching mode, fully integrate industrial AI technical standards, intelligent production processes and enterprise technical research projects into classroom teaching and practical training, and focus on the practical application of industrial-level intelligent technologies. Meanwhile, build a school-enterprise AI collaborative education sharing platform to break school-enterprise barriers of resources, data and scenarios, realize full sharing of teaching, production and technical resources, and fully release the collaborative education efficiency of dual-driven mechanisms.

6.2 Reconstruct Digital Intelligent Curriculum System to Realize Precise Integration of Posts, Courses, Competitions and Certificates

Guided by the competency demands of industrial intelligent posts, break traditional curriculum barriers, reconstruct a hierarchical, progressive and dynamically iterative modular digital intelligent curriculum system adapted to posts, and build a four-tier progressive curriculum framework including general literacy layer, professional core layer, intelligent expansion layer and comprehensive practice layer. The general literacy layer offers courses such as Fundamentals of Artificial Intelligence, Industrial Big Data Cognition and Introduction to Intelligent Manufacturing to consolidate all students' basic AI literacy. Combined with professional characteristics, the professional core layer sets special courses such as Machine Vision Commissioning, Digital Twin Modeling, Intelligent Equipment Fault Diagnosis and Industrial Internet of Things Application to realize the in-depth integration of AI technology and core professional skills. The intelligent expansion layer offers cutting-edge courses such as Intelligent Production Line Optimization, Industrial AI Application Development and Intelligent System Integration to cultivate students' innovative abilities and advanced intelligent manufacturing capabilities. The comprehensive practice layer introduces enterprises' real intelligent projects, vocational skill competition projects and vocational grade certificate standards to promote in-depth integration of posts, courses, competitions and certificates. Meanwhile, cooperate with leading industrial enterprises to dynamically update curriculum content, jointly develop loose-leaf and project-based digital intelligent textbooks, build cloud-based digital curriculum resource libraries, and realize synchronous iteration of curriculum systems with industrial technologies[8].

6.3 Upgrade Virtual-Real Integrated Training System to Build Industrial-Level Teaching Scenarios

Relying on AI, digital twin, VR and AR technologies, build an intelligent training system of "real scenarios as the main body, virtual scenarios as the supplement and virtual-real symbiosis" to fully make up for the shortcomings of practical training education. First, promote the intelligent upgrading of on-campus training bases, carry out intelligent transformation of traditional electromechanical and numerical control training equipment, add cutting-edge facilities such as digital twin training platforms, AI intelligent commissioning workstations and machine vision training systems, and build high-standard intelligent manufacturing AI training centers. Second, deepen the construction of off-campus industry-education integrated training bases, cooperate with regional leading intelligent manufacturing enterprises to jointly build AI industry-education integrated training bases and technology R&D centers, fully open enterprises' intelligent production workshops and R&D platforms, and encourage students to deeply participate in core work such as enterprise intelligent production, technology R&D and equipment operation and maintenance to accumulate real-scenario practical experience. Third, comprehensively promote virtual simulation training, enable schools and enterprises to jointly develop high-risk, high-cost and high-difficulty industrial intelligent training projects, reproduce real production scenarios through virtual technologies to solve traditional training pain points, and comprehensively improve students' intelligent practical operation and problem-solving abilities through virtual-real integration.

6.4 Innovate Four-Subject Collaboration Mechanism to Build a Long-Term Symbiotic Education Ecosystem

Improve the four-subject collaborative governance mechanism involving governments, industries, colleges and enterprises to solve the problems of fragmented collaboration and insufficient education motivation, and build a long-term symbiotic education ecosystem. First, establish a regular collaborative docking mechanism and clarify the rights and responsibilities of the four subjects: governments strengthen policy support, capital investment and public platform construction; industry associations undertake post standard updating, industrial demand analysis and industry standard formulation; schools and enterprises focus on talent co-cultivation, curriculum co-construction, technology joint research and achievement sharing, and set up a monthly joint meeting system to timely solve reform difficulties. Second, improve the benefit sharing and risk-sharing mechanism, deeply bind school and enterprise interests through order-based training, technology achievement transformation and project dividends, reasonably divide cooperation risks such as training investment, R&D failure and talent loss, and improve the stability of school-enterprise cooperation. Third, optimize the two-way incentive and restraint mechanism, incorporate the effectiveness of dual-driven teaching reform into college development assessment and teacher performance appraisal systems, include enterprise education contributions into corporate social responsibility evaluation, implement incentive policies such as tax reduction and special subsidies, and fully activate the internal education motivation of multiple subjects[9].

6.5 Cultivate Compound Dual-Qualified Teachers to Consolidate Digital Intelligent Education Support

Build a compound dual-qualified teacher training system of "on-campus cultivation, enterprise talent introduction and school-enterprise co-cultivation" to comprehensively improve teachers' digital intelligent education capabilities. For on-campus full-time teachers, formulate special AI training plans, regularly carry out special training on industrial artificial intelligence, digital twins, smart teaching and industrial big data application, arrange teachers to take temporary posts in enterprises for practical training on a regular basis, participate in enterprise intelligent production and technology R&D projects, and encourage teachers to obtain professional certificates such as industrial AI engineers and intelligent equipment operation and maintenance engineers to comprehensively improve digital intelligent practical operation and teaching capabilities. For enterprise part-time teachers, establish a talent database of industrial AI experts and front-line technical backbones, select outstanding talents to participate in practical training teaching, project guidance and curriculum development, carry out special teaching ability training synchronously, improve salary incentive and honor recognition mechanisms, and enhance the teaching enthusiasm of enterprise teachers. Organize school-enterprise mixed teaching and research teams to jointly carry out teaching reform, curriculum development, textbook compilation and technological research, realizing complementary advantages and symbiotic development of teachers' capabilities.

6.6 Optimize Intelligent Evaluation System to Realize Closed-Loop Iteration of Education Quality

Relying on AI big data technology, build an all-round, whole-process, dynamic and closed-loop intelligent teaching evaluation system to completely subvert the traditional single artificial evaluation model. In terms of evaluation dimensions, cover multiple indicators including students' AI skill application, professional practical ability, innovative practical ability and post comprehensive literacy, teachers' digital intelligent teaching level and practical training guidance quality, and school-enterprise cooperation depth and resource empowerment effectiveness to realize full-dimensional quantitative evaluation of talent training. In terms of evaluation methods, rely on intelligent teaching management platforms to collect whole-process data of classroom teaching, practical training operation, project practice and teacher-student interaction in real time, automatically generate accurate evaluation reports through big data analysis, replace traditional artificial subjective evaluation, and improve the scientificity and accuracy of evaluation. In terms of iteration mechanisms, establish a closed-loop management mode of "data monitoring — precise evaluation — problem rectification — system optimization", apply evaluation results reversely to curriculum reform, training upgrading, teacher training and mechanism optimization, and continuously promote the quality and efficiency improvement of dual-driven teaching reforms.

7. Prospect of Reform Development Trends

Combined with industrial technology iteration trends and vocational education digital reform orientation, the dual-driven teaching reform of "AI + industry-education integration" for intelligent manufacturing professional groups in higher vocational colleges will present four major development trends in the future. First, in-depth full-scale integration. Reforms will evolve from superficial technology application and formal industry-education cooperation to full-scale in-depth symbiosis of technology, industry, teaching and innovation, realizing complete coupling of digital intelligent technologies and education systems and thoroughly eliminating the problems of "idle technology application and formal industry-education integration". Second, personalized and precise education modes. Relying on generative AI and big data student profiling technology, accurately analyze each student's learning ability, skill shortcomings and development needs to realize individualized teaching and personalized training, adapting to diversified talent development needs. Third, increasingly improved collaborative ecology. The four-subject collaborative governance mechanism, benefit sharing mechanism and incentive guarantee mechanism will be continuously optimized, and school-enterprise cooperation will transform from short-term project cooperation to long-term strategic symbiosis, forming a stable and sustainable digital intelligent industry-education education ecosystem. Fourth, dynamic iterative upgrading of reform systems. Keep pace with the iteration of cutting-edge technologies such as industrial metaverse and generative AI, continuously update curriculum content, training scenarios and teaching modes, realize synchronous iteration of teaching reforms and industrial technologies, continuously improve the training quality of compound intelligent manufacturing talents, and provide solid talent support for the development of new quality productive forces.

8. Conclusion

The dual-driven mechanism of AI empowerment and in-depth industry-education integration is an inevitable trend of teaching reform for intelligent manufacturing professional groups in higher vocational colleges in the new era, and a core path to solve traditional education pain points, adapt to industrial intelligent transformation and cultivate high-quality intelligent manufacturing technical and skilled talents. By systematically reviewing existing research and practical achievements, this paper clarifies the core connotation and coupling mechanism of the dual-driven model, quantitatively analyzes the advantages and disadvantages of new and old teaching models and mainstream reform paradigms through two comparative tables, systematically summarizes the common problems of current reforms including superficial technology integration, lagging curriculum systems, insufficient training scenarios, fragmented collaboration mechanisms, weak teacher adaptability and imperfect evaluation systems, constructs an all-round and systematic dual-driven teaching reform implementation path based on mainstream academic and industrial experience, and prospects the future development trends of reforms. The research shows that the dual-driven teaching reform is not a single technological upgrading or cooperation mode optimization, but an all-round systematic innovation of education concepts, curriculum systems, training scenarios, collaboration mechanisms, teacher teams and evaluation systems. In the future, higher vocational colleges should continuously deepen the two-way empowerment of AI and industry-education integration, optimize reform paths based on regional industrial characteristics, constantly improve the digital intelligent industry-education education system, continuously improve the talent training quality of intelligent manufacturing professional groups, and facilitate the digital transformation of vocational education and the high-quality development of advanced manufacturing industries[10].

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