

Research on the Reconfiguration of Digital Twin-Driven Intelligent Manufacturing Courses and the Mechanism of Industry-Education Collaboration

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Abstract

The transformation and upgrading of the intelligent manufacturing industry demands more complex, digital and innovative technical and skilled personnel. The traditional curriculum system has problems such as outdated content, professional isolation, and separation between industry and education. However, digital twin technology possesses the characteristics of virtual-real correspondence, two-way interaction, and physical consistency, making it a new technological approach to reshape the curriculum system and innovate the mode of industry-education integration. This article, from the perspective of the policy orientation of industry-education integration and the cultivation laws of intelligent manufacturing talents, analyzes the current situation and existing problems of the intelligent manufacturing curriculum system and industry-education collaboration. Through curriculum system reconstruction, innovation of practical teaching methods, and shaping of collaborative mechanisms, it explores the transformation paths of intelligent manufacturing courses driven by digital twin technology, so as to achieve deep integration of the education chain, industry chain, innovation chain, and talent chain, and provide theoretical support and implementation paths for the cultivation of high-level technical and skilled talents in the intelligent manufacturing field.

Key words: Digital Twin, Intelligent Manufacturing, Curriculum Reconstruction, Industry-Education Collaboration, Collaborative Education

I. Introduction

With the deep implementation of "Made in China 2025", China's manufacturing industry [1]-[8] is moving towards digitalization, networking, and intelligence, entering a new stage of high-quality development. Intelligent manufacturing is the main

direction for the transformation and development of the manufacturing industry, reshaping the industrial landscape and redefining job forms. New technologies such as industrial robots, intelligent production lines, and digital twins are rapidly integrated into the jobs, with job operation scenarios changing from on-site manual operations to

remote centralized control, job decision-making methods shifting from experience-based judgment to data-based analysis, and job operation modes evolving from manual inspection to intelligent prediction. This profound transformation has raised new requirements for technical and skilled personnel, no longer being simply proficient in operating a certain equipment, but requiring a full-chain collaborative ability, digital analysis skills, and comprehensive innovation capabilities.

However, at present, there is still a significant lag in the relevant professional courses for intelligent manufacturing and the collaboration between industry and education. The intelligent elements in the courses are scarce, and the fragmented nature of the specialties makes students lack a comprehensive understanding of the entire industrial chain. The iteration speed of the courses is far slower than the speed of industrial technology updates. Moreover, the majority of the collaboration between industry and education is at a shallow level, and there is no stable interest connection or institutionalized communication and interaction mechanism established between schools and enterprises. How to re-construct courses and innovate collaboration using digital twin technology is the key to solving the bottleneck in intelligent manufacturing talent cultivation.

Digital twin technology maps physical systems into a virtual space, enabling interaction between the virtual and the real worlds while maintaining physical consistency. This approach provides a technological support for the cultivation of intelligent manufacturing talents. By re-constructing course content using digital twin technology and collaborating with the

industry, this can not only solve the problem of insufficient training resources and the separation of practical teaching from production reality, but also transform the course system from static knowledge transmission to a dynamic process of generating capabilities, allowing the integration of industry and education to develop in a more institutionalized, normalized, and in-depth direction.

II. Current Challenges in the Curriculum System of Intelligent Manufacturing and the Integration of Industry and Education

(1) Lack of Intelligent Content in the Curriculum System and Disconnection from Industrial Demand

At present, the specialized courses related to intelligent manufacturing are still limited to traditional mechanical processing techniques, ordinary machine tool operations, and classic electrical control, lacking integration of new things such as industrial internet, digital twin, intelligent scheduling, and edge computing. In the course "Electrical Control and PLC", the textbook still uses traditional PLC programming, and there is no mention of emerging technologies such as remote monitoring and fault diagnosis based on the industrial internet. The update cycle of intelligent manufacturing technology is 6 - 12 months, so the update speed of the course content is far behind the demand of industrial development.

The lag in curriculum setting is reflected in the fragmentation of courses. The knowledge of mechatronics engineering covers many aspects such as mechanics, electrical engineering, and control, but the

existing courses divide these knowledge into different courses, making the knowledge students learn fragmented and their abilities single. When students engage in actual production work, they cannot integrate various aspects of knowledge and lack systematic thinking and collaborative capabilities across the entire industry chain.

(2) Outstanding professional barriers and lack of comprehensive understanding of the entire industry chain

The traditional professional division is too detailed, and students know very little about other aspects of their own profession. Through the investigation of the steel intelligent metallurgical technology professional group, it was learned that the main problem of traditional courses is "professional block division, and students do not know the entire industry chain". Intelligent manufacturing is the intelligence of the entire manufacturing process, and practitioners not only need to master the skills of their own position but also need to understand how the upstream and downstream processes are connected, how data flows, and how different systems collaborate. However, the current courses cannot achieve full-chain cognition.

(3) Weak Practical Teaching Conditions and Severe Disconnection between Virtual and Real

The training equipment for intelligent manufacturing-related majors is relatively expensive, and vocational colleges cannot afford to purchase so many at once. According to the investigation, among the more than thirty vocational schools in Fujian Province, nearly half have related majors in intelligent manufacturing, but the

penetration rate of intelligent training equipment is less than 20%. Some schools want to offer courses such as digital twin, but they lack sufficient training equipment and can only use virtual software to replace real projects for teaching. Such simulation teaching cannot truly replace the real operating environment and cannot effectively cultivate safety awareness when using equipment.

(4) Incomplete Industry-Education Integration Mechanism and Cooperation That Is Only Formal

The current industry-education integration is shallow and superficial. Both the school and the enterprise have no clear cooperation purpose and interest relationship. The school focuses on cultivating people, and the enterprise focuses on production. It is difficult to reach consensus on issues such as the formulation of talent training plans, course development, and training arrangements. The collaborative education of enterprises is a short-term behavior, and there is no long-term investment motivation. Without an effective communication and coordination mechanism and guarantee mechanism, school-enterprise cooperation often relies on personal relationships and lacks fixed communication channels.

(5) Insufficient Practical Ability of the Teaching Staff and Shortage of "Dual-Teacher" Personnel

The course teachers of intelligent manufacturing-related majors mostly come from ordinary universities' engineering-related majors and lack sufficient production experience. They have little knowledge of recent production practices and new production technology in enterprises. The

technical experts within enterprises may have more practical experience and skills, but they do not have teaching experience and knowledge of educational psychology. If they rush into the classroom, they may not be suitable. There are difficulties in teacher training and mutual recruitment between the school and the enterprise. The shortage of "Dual-Teacher" personnel is extremely severe, and those who have strong theoretical literacy and rich practical experience are extremely scarce.

III. The Theoretical Logic of Digital Twin Driving Curriculum Reconstruction

(1) Core Technical Characteristics of Digital Twin

Digital twin is to collect data through sensors, then create a digital equivalent of the physical object in the information space, and also implement automatic interaction through two-way data flow, "mirroring the virtual to the real" and "controlling the real with the virtual". Its main technical characteristics include three aspects: the first is virtual-real mapping, that is, all the geometric parameters, optical properties, sensor responses, and error degradation processes of the real system are projected into the virtual space; the second is the formation of physical consistency, which requires both visual similarity and the imitation of key physical factors that affect the system performance; the third is two-way interaction, where the data of the real system can be continuously fed back to the virtual model, and at the same time, the virtual model can also guide the operation of the real system.

(2) The Inner Mechanism of Digital Twin Enabling Curriculum Reconstruction

Integrating digital twin into the reconstruction of intelligent manufacturing courses mainly brings about three-level changes. Firstly, it transforms static knowledge education into dynamic ability generation; secondly, it transforms the training of individual skills into comprehensive thinking development; thirdly, it transforms the simulated operation within the campus into an operation that integrates virtual and reality.

First, digital twin can replicate the real production scenarios of enterprises into the virtual space, allowing students in school to access real equipment, actual processes, and job tasks. Through virtual scanning, algorithm verification, parameter adjustment, and other methods, through repeated operations, boldly try, and continuously improve their own abilities in the virtual environment. This can alleviate the phenomenon of the separation between practical teaching and production reality caused by limited training resources within the school.

Digital twin can achieve modeling at multiple levels such as single machines to production lines, equipment to systems, which is conducive to cultivating students' system thinking from the equipment layer, production line layer to factory layer. It simulates different positions and different processes of cooperation in the virtual space, allowing students to intuitively understand how the intelligent manufacturing system operates and how each part cooperates with each other.

Second, digital twin has the characteristics of adjustable parameters and expandable scenarios. It can adjust equipment

parameters, process conditions, and fault forms according to teaching requirements, providing students with multiple learning environments. The virtual system can reveal the role of improvement, parameter search, and rehearsal measurement methods, enabling students to deeply understand the improvement methods and decision-making thinking of the intelligent manufacturing system.

Manufacturing Curriculum System

(1) Construct a "five-level progressive, modular combination" curriculum system

According to the requirements of the job capability map, with "basic general ability - professional common ability - core specialized ability - expansion and improvement ability - comprehensive empowerment ability" as the growth progressive logic, a five-level structure curriculum system is built. The public foundation layer is open to everyone, and it will incorporate some concepts of artificial intelligence and green low-carbon; the professional group sharing layer is consistent, connecting the cognition of the entire industrial chain; the professional core layer is specifically cultivated for different positions, and will incorporate intelligent centralized control and data analysis technologies; the specialized expansion layer can freely select courses across different majors, thus enabling the cultivation of multi-skilled capabilities for one position; the comprehensive practice layer transforms technological renovations and quality problems into training projects through actual enterprise scenarios.

Regarding the curriculum content, timely supplement and absorb the latest

technologies and vocational standards in the intelligent manufacturing industry, such as the integration of new technologies like offline programming for industrial robots, digital twin, and intelligent scheduling, and the deletion of outdated content. It is necessary to pay attention to how the contents are connected and combined, achieving the combination of imparting knowledge, teaching skills, and cultivating morality and character. When teaching "digital processing technology", also convey ideas such as safety, teamwork, and improvement, so that technical learning and character shaping can be advanced simultaneously.

(2) Build a digital twin virtual simulation training platform

Based on digital twin technology, a corresponding virtual simulation training platform is constructed. This platform has three functions: the first is virtual scanning and data generation, which relies on the actual parameters of the intelligent manufacturing system for mapping, thereby shaping physical-consistent virtual observation data; the second is to test and improve algorithms and parameters; previously, different control schemes can be tried in the virtual environment, and relevant process parameters can be optimized; the third is to achieve the integration of virtual and reality and enable remote control operations, forming a two-way data exchange and association between the virtual system and the actual equipment.

The platform construction follows the principles of "geometric uniformity, optical uniformity, sensor uniformity, and task uniformity". Geometric uniformity means that the parameters of devices such as

cameras, projectors, and robotic arms in the virtual system should be consistent with the actual system; optical uniformity means that the virtual system can reproduce the physical phenomena in the imaging chain, such as light transmission, material reflection, and noise attenuation; sensor uniformity concerns the response characteristics of virtual sensors should be consistent with the actual ones; task uniformity includes the display results of phases, perspective differences, depth, etc. generated by the virtual system, which should be related to the actual operation tasks.

(3) Develop modular and reconfigurable curriculum resources

Based on the job capability map, the curriculum content is divided into freely spliced small blocks. Each block contains three levels: knowledge points, skill points, and project points. Students of different majors can select the blocks they like according to their own preferences. The module design should have gradation and selectivity. Basic modules are for all students and focus on cultivating common abilities; core modules focus on each position and enhance individual abilities; expansion modules cross professional boundaries and are conducive to exercising comprehensive abilities.

The development of curriculum resources should use actual enterprise cases and production data. Collaborate with enterprise technical experts to write textbooks and teaching outlines, integrating the production process, technical standards, and position requirements of the enterprise into the curriculum. Update the content of the textbooks in a timely manner, incorporate new technologies and new processes in the

mechanical industry, so that the knowledge students learn can meet the needs of enterprise positions. At the same time, implant enterprise technical standards and jointly compile loose-leaf textbooks, effectively solving the problem of previous teaching and industry disconnection.

(4) Innovate the "project-driven, virtual-real integration" teaching mode

The teaching method adopted is a hybrid approach combining "online self-study, offline discussion and project practice". Online, through a virtual simulation experiment platform, pre-reading tasks, operation demonstrations, and supplementary reading are arranged for students to complete independently; offline, mainly problem discussions and case analyses are conducted, with teachers providing explanations of algorithms and demonstrations of algorithms, and also posing some open-ended questions for students to apply their knowledge to analyze the actual situation of scheduling.

Project practice is an important part of the teaching reform. Some 智能制造 projects similar to real engineering situations should be arranged, such as improving the scheduling of intelligent production lines, debugging the programs of industrial robots, and building the digital twin system. These activities should be assigned to project teams of 4 to 5 people to complete. The entire project operation process includes problem analysis and model formation, scheme planning and hands-on execution, result analysis and improvement, project presentation and defense, etc. This project operation form is used to optimize students' theoretical understanding, stimulate their enthusiasm for participating in engineering

operation activities, and improve teamwork skills.

V. Construction of the Digital Twin-driven Collaborative Education Mechanism

(1) Establish a multi-party collaborative governance mechanism involving "government, schools, institutions, and enterprises"

Form a collaborative education leadership group composed of schools, enterprises, the government, and industry associations, clearly defining their respective responsibilities and initiating collaborative education work. Establish a regular communication system between schools and enterprises, arranging a collaborative education meeting once a month to quickly resolve issues arising during the cooperation and ensure that both parties reach consensus on the formulation of talent training plans, course arrangements, and training plan planning, etc.

Refer to the practices of the national smart communication industry industry-academia integration community, and establish a hierarchical governance framework system. Representatives from enterprises, industry-related parties, and university teachers jointly serve as the chairperson of the joint governance body. This can ensure mutual cooperation among the three parties. When the council layer sets up specialized working groups, professional construction teams, curriculum development teams, internship base organizations, teacher training teams, and technology research departments are established to promote the formation of corresponding levels of cooperation. This organizational form design conforms to the operational rules in practice and thus

provides a dependent framework structure for multi-party collaboration.

(2) Improve the interest linkage and sharing mechanism

Based on the interests of both schools and enterprises, establish an "win-win" interest linkage mechanism for school and enterprise. Schools provide services such as employee training, technical research, and product development for enterprises to enhance the core competitiveness of enterprises; enterprises provide training resources, internship positions, and part-time teachers for schools to improve the teaching level of schools; the government introduces some tax reduction and subsidy policies to encourage enterprises to participate in collaborative education.

Explore how to use methods of property rights or equity arrangements to clarify the corresponding rights, responsibilities, and interests of each party in the input-output process. For the material carriers such as jointly built industrial colleges and training bases, the property rights ownership can be defined through a mixed ownership system and a benefit-sharing and risk-sharing interest connection mechanism based on the proportion of investment. Some scholars believe that the relationship between enterprises and schools should be transformed from emotional connection to asset connection to enhance the stability and sustainability of cooperation.

(3) Build a digital twin collaborative education platform

Utilize digital twin technology to build a platform for collaborative education between schools and enterprises. This

platform should have three functions: the first is data sharing, which can immediately collect industry talent demand maps, technological research and development dynamics data, and resource distribution information, thereby eliminating cooperation obstacles caused by information asymmetry; the second is virtual and real integration, where the actual production data of enterprises can be immediately transmitted to the virtual simulation system of the school, and the school's teaching data can also be transmitted back to the enterprise as a reference for employee training; the third is collaborative operation. On this platform, both schools and enterprises can reach consensus at the same place, formulate training plans, jointly develop educational resources, and evaluate training quality.

When creating the platform, the principle of "unified standards, step-by-step implementation, and continuous update" should be followed. Unified data interfaces and exchange standards should be established to enable interconnection between different systems. The platform function creation should be carried out step by step, starting with basic data sharing, and gradually achieving joint work and operation of virtual and reality, and forming a dynamic update mechanism to continuously improve platform functions according to technological development and teaching needs.

(4) Improve the collaborative education evaluation system

Establish multiple evaluation entities and construct an evaluation entity jointly participated by schools, enterprises, industry associations, and students. Improve the

evaluation content and standards, change the evaluation methods that emphasize theory and neglect students' practical skills, problem-solving abilities, professional ethics, and teamwork skills. According to the enterprise position evaluation standards, formulate skill level evaluation standards for front-line operation positions in intelligent manufacturing-related majors.

Establish a feedback and improvement mechanism, and promptly inform students, teachers, and enterprises of the results of these evaluations. This process should also form a repetitive cycle. "Conduct a survey of the technological transformation dynamics and technological innovation of enterprises every three months - after one semester, it becomes usable application - evaluate it on an annual basis" - this continuous update course mechanism has been created: every three months, conduct research on technological transformation dynamics and emerging technologies for cooperative enterprises, so as to promptly improve the technical list; every semester, break down the actual production scenarios of enterprises into knowledge and skills points that can be learned and mastered, to improve the course itself and its training materials; arrange special evaluation work for modular courses each year, and then implement corresponding adjustment operations based on the evaluation results.

(5) Strengthen the construction of "dual-qualified" teacher teams

Establish a mechanism for enhancing teachers' practical capabilities. Teachers go to enterprises for on-the-job training and participate in actual production projects in the enterprises, and regularly hold teacher vocational skills training activities. In this way,

teachers can quickly grasp the latest developments in industry technology. Establish a system where technicians from enterprises come to schools for teaching and some incentive measures are set to encourage outstanding engineers to serve as training tutors or subject teachers at schools.

Carry out joint training of teachers with enterprises. Develop training courses together, conduct job rotation exchanges, etc. College teachers go to enterprise technicians for learning, and enterprise technicians come to college teachers for learning. Everyone progresses together. Through the digital twin platform, teachers can do teaching practice on this platform to improve their own levels, and technicians also learn teaching methods and educational theory knowledge on this platform, thus cultivating a batch of "dual-qualified" teachers capable of undertaking teaching tasks in the integration of production and education.

VI. Conclusion

Digital twin technology brings new possibilities for the reconfiguration of the intelligent manufacturing curriculum and the update of the industry-academia integration mechanism. By building a virtual simulation training platform that combines virtual and real elements, developing reconfigurable modular course resources, and changing the teaching approach driven by projects, it addresses issues such as outdated course content, harsh operating environments, and obvious professional barriers, transforming the course from static knowledge imparting to dynamic ability generation.

From the perspective of industry-academia collaboration, after forming a diversified collaborative governance mechanism,

establishing a mechanism for interest connection and sharing, creating a digital twin collaborative education platform, and improving the evaluation mechanism, it can promote the development of industry-academia collaboration towards institutionalization, normalization, and deepening, achieving deep integration of the education chain, industry chain, innovation chain, and talent chain.

It should be noted that there are still many problems in the course reconfiguration driven by digital twin technology in terms of industry-academia collaboration. For example, developing a high-fidelity virtual simulation experimental platform is costly, and it requires continuous investment to maintain consistency between virtual and real elements. The digital literacy and teaching ability of the teachers need to be improved, and data sharing between schools and enterprises will encounter constraints on security and privacy. Future research should mainly focus on developing methods for building low-cost and fast digital twin platforms, formulating evaluation standards and calibration methods for virtual and real consistency, improving the training system for teachers' digital literacy, and creating a secure and trustworthy data sharing mechanism. Only in this way can it provide more reliable technological support and institutional guarantees for the cultivation of the high-quality technical and skilled talents in the intelligent manufacturing field.

References

1. Lin, Boqiang, Wei Wu, and Malin Song. "Industry 4.0: Driving factors and impacts on firm's performance: An empirical study on China's manufacturing industry." *Annals of Operations Research* 329, no. 1 (2023): 47-67.

- 2.Wen, Huwei, Qiming Zhong, and Chien-Chiang Lee. "Digitalization, competition strategy and corporate innovation: Evidence from Chinese manufacturing listed companies." *International Review of Financial Analysis* 82 (2022): 102166.
- 3.Dou, Qianqian, and Xinwei Gao. "The double-edged role of the digital economy in firm green innovation: Micro-evidence from Chinese manufacturing industry." *Environmental Science and Pollution Research* 29, no. 45 (2022): 67856-67874.
- 4.Wang, Mei Ling. "Effects of the green finance policy on the green innovation efficiency of the manufacturing industry: A difference-in-difference model." *Technological Forecasting and Social Change* 189 (2023): 122333.
- 5.Usman, Favour Oluwadamilare, Emmanuel Chigozie Ani, Wisdom Ebirim, Danny Jose Portillo Montero, Kehinde Andrew Olu-lawal, and Nwakamma Ninduwezuor-Ehiobu. "Integrating renewable energy solutions in the manufacturing industry: challenges and opportunities: a review." *Engineering Science & Technology Journal* 5, no. 3 (2024): 674-703.
- 6.Xu, Jiawei, Yubing Yu, Min Zhang, and Justin Zuopeng Zhang. "Impacts of digital transformation on eco-innovation and sustainable performance: Evidence from Chinese manufacturing companies." *Journal of Cleaner Production* 393 (2023): 136278.
- 7.Yan, Bin, Feng Wang, Tian Chen, Siyu Liu, and Xiaoxuan Bai. "Digital finance, environmental regulation and emission reduction in manufacturing industry: New evidence incorporating dynamic spatial-temporal correlation and competition." *International Review of Economics & Finance* 83 (2023): 750-763.
- 8.Hao, Xiaoli, Xinhui Wang, Haitao Wu, and Yu Hao. "Path to sustainable development: Does digital economy matter in manufacturing green total factor productivity?." *Sustainable Development* 31, no. 1 (2023): 360-378.