

Research on the Reconstruction of Practical Teaching System for Mechanical Majors Based on Artificial Intelligence and Digital Twin Technology

Yuxian Xu*

School of Physics and Telecommunications Engineering, Yulin Normal University, Yulin, 537000, Guangxi, China

**Corresponding author*

Abstract: *In order to solve the core problem of the disconnect between the practical teaching system of mechanical majors and industry demand under the background of intelligent transformation of manufacturing industry, and to improve the quality of talent cultivation, this study focuses on the integration and empowerment value of artificial intelligence and digital twin technology, and carries out research on the reconstruction of the practical teaching system of mechanical majors. Using mixed research methods such as questionnaire surveys, in-depth interviews, and field investigations, this study systematically analyzes the existing problems of the traditional practical teaching system in terms of objectives, content, resources, modes, and evaluation, and clarifies the feasibility and necessity of technological integration. Based on the principles of demand-oriented and technology integration, we will construct a comprehensive framework for the reconstruction of the "four layer and three-level" practical teaching system, and complete the precise design of the five core modules of teaching objectives, content, resources, modes, and evaluation. The research results provide theoretical support and feasible implementation paradigms for the practical teaching reform of mechanical majors, which can effectively enhance the ability of talents to apply new technologies and engineering innovation, and help higher education better adapt to the high-quality development needs of the manufacturing industry.*

Keywords: *artificial intelligence; digital twin; mechanical majors; practical teaching system*

1. Introduction

The new round of technological revolution and industrial transformation is advancing in depth, with artificial intelligence and digital twin technology deeply integrated into the entire manufacturing chain, promoting the transformation of the industry towards intelligence and digitization, and putting forward new requirements for the practical ability and innovation literacy of mechanical professionals. As a core major supporting the development of manufacturing industry, the practical teaching system of mechanical majors is a key carrier for cultivating high-quality engineering and technical talents. However, the traditional practical teaching system has prominent problems such as teaching content lagging behind industry demand, lack of practical resources and slow updates, fixed teaching modes, and a single evaluation mechanism, which make it difficult to adapt to the empowerment needs of the manufacturing industry for talents driven by new technologies, and restrict the improvement of talent cultivation quality.

In this context, exploring the deep integration path of artificial intelligence and digital twin technology with practical teaching in mechanical majors, reconstructing a practical teaching system that adapts to industrial development, has become an inevitable choice to break through the current teaching bottleneck. This article is based on the concept of engineering education certification, guided by industry demand, and focuses on the systematic reconstruction of the practical teaching system for mechanical majors. The aim is to clarify the core logic of technological integration, provide theoretical support and practical paradigms for improving the quality of talent cultivation and promoting the reform of mechanical professional education, and help higher education better serve the high-quality development strategy of the manufacturing industry.

2. Core concepts and theoretical foundations

2.1 Definition of core concepts

Artificial Intelligence (AI) refers to the theoretical, methodological, and technological system that simulates human intelligent activities through computers. Its core includes key technologies such as machine learning, computer vision, and intelligent algorithms, and it has core characteristics such as data perception, analysis and decision-making, and autonomous learning. In the field of engineering education, its core application value is reflected in achieving personalized teaching push, precise control of practical processes, and intelligent ability evaluation, providing technical support for the efficient development of practical teaching in mechanical majors.

Digital Twin (DT) is a technological paradigm that constructs a virtual mapping model of physical entities, relies on real-time data links to achieve virtual real interaction, dynamic simulation, and full lifecycle management. Its technical architecture covers four core modules: physical entity layer, virtual model layer, data transmission layer, and service application layer, with significant features such as real-time mapping, virtual real linkage, and predictability. In practical teaching of mechanical engineering majors, virtual practice scenarios can be constructed through digital twin technology, breaking through the limitations of physical resources and achieving immersive simulation training for complex engineering tasks.

The practical teaching system for mechanical majors refers to an organic whole composed of teaching objectives, teaching content, teaching resources, teaching modes, evaluation mechanisms, and guarantee measures, with the cultivation of students' engineering practice and innovation abilities as the core. It covers three progressive levels: basic practice, professional core practice, and comprehensive innovation practice. It is a key link between theoretical teaching and engineering practice, and its reconstruction core lies in the deep integration and collaborative optimization of new technologies and various teaching elements.

2.2 Theoretical basis

Constructivist learning theory is the core theoretical support for the reconstruction of practical teaching systems, emphasizing that learning is the process of learners actively constructing knowledge in situational interactions [1]. The virtual real integration practice scenario constructed by artificial intelligence and digital twin technology provides students with an immersive and exploratory learning environment, which meets the core requirements of "context collaboration conversation meaning construction" and helps students deepen their understanding and practical application of mechanical engineering knowledge.

The certification concept of engineering education takes "student-centered, output oriented, and continuous improvement" as its core essence, requiring the practical teaching system to closely connect with industry needs [2]. It provides a core guideline for setting practical teaching objectives, optimizing content, and reconstructing evaluation mechanisms for mechanical majors, ensuring that the reconstructed system can accurately match the core demands of the intelligent transformation of the manufacturing industry for talent capabilities.

The theory of technology integration focuses on the organic adaptation of technology and educational scenarios, clarifying that technology integration should follow educational laws and disciplinary characteristics [3]. This theory provides theoretical guidance for the integration path design of artificial intelligence and digital twin technology with practical teaching in mechanical majors, avoiding the formalization of technology application and ensuring the effectiveness of technology empowerment in improving teaching quality.

3. Analysis of the current situation of practical teaching system for mechanical majors based on the integration of artificial intelligence and digital twin technology

In order to accurately grasp the current operation status of the practical teaching system in mechanical engineering majors, clarify the entry points and obstacles of the integration of artificial intelligence and digital twin technology, this study conducts systematic research from both the perspectives of university teaching and enterprise demand, and combines the perspective of technology integration to deconstruct problems and demonstrate feasibility, providing a practical basis for the reconstruction of the practical

teaching system.

3.1 Design and implementation

The research adopts a mixed research method of "questionnaire survey+in-depth interview+field investigation" to construct a multi-party and multi-dimensional research system. The research subjects cover three levels: firstly, teachers (216 in total) and students (845 in total) majoring in mechanical engineering, intelligent manufacturing, and other related majors in different levels of domestic universities (including "Double First Class" universities, local undergraduate colleges, and vocational colleges), taking into account the perspectives of both teaching implementers and recipients; The second is the technical leaders and human resources managers of 23 representative enterprises (including equipment manufacturing, automobile manufacturing, intelligent processing and other fields) in manufacturing intensive areas such as the Yangtze River Delta and the Pearl River Delta, focusing on industrial talent demand orientation.

The research content is designed around the core elements of practical teaching, including the matching degree between teaching objectives and industry needs, the cutting-edge and systematic nature of practical content, the allocation and utilization of teaching resources (physical platforms, virtual resources, data resources), the innovation and effectiveness of teaching models, the scientificity and comprehensiveness of evaluation mechanisms, as well as the awareness, demand points, and implementation suggestions of teachers, students, and enterprises on the integration of artificial intelligence and digital twin technology into practical teaching. During the research process, a total of 216 teacher questionnaires and 845 student questionnaires were distributed, and 203 and 798 valid questionnaires were collected, with effective response rates of 94.0% and 94.4%, respectively; Conduct in-depth interviews with 18 university teachers and 12 business leaders, and conduct on-site inspections of practical teaching bases in 6 universities and production workshops in 4 enterprises to ensure the authenticity and representativeness of the research data.

3.2 Analysis of current problems

Based on research data and analysis from the perspective of technology integration, the current practical teaching system for mechanical majors has the following core problems: firstly, the positioning of teaching objectives is biased and disconnected from the needs of technological change. A survey shows that 68.5% of enterprises believe that students trained in universities lack the ability to apply new technologies, and existing teaching objectives still focus on basic skills such as traditional mechanical processing and assembly. There is a lack of cultivation in core abilities such as intelligent detection driven by artificial intelligence and virtual simulation supported by digital twins. Secondly, the practical content is outdated and fragmented. 72.3% of students reported that practical projects mainly focus on confirmatory experiments and lack comprehensive projects related to intelligent manufacturing and digital production; The teaching content does not cover the full lifecycle management of products, and there is a lack of logical connection between various practical modules, making it difficult to form a systematic engineering thinking.

Thirdly, there is insufficient allocation and low integration of teaching resources. In terms of physics practice platforms, 56.2% of universities are limited by funding and venue, and the number of intelligent equipment (such as industrial robots and intelligent sensors) is insufficient to meet the needs of large-scale practical teaching; In terms of virtual resources, existing virtual simulation projects are mostly single link simulations, lacking real-time linkage with physical entities and failing to achieve the core function of digital twins; The data resources are scattered, and there is no established mechanism for sharing teaching data and enterprise engineering data. Fourthly, the teaching mode is rigid and lacks interactivity. The traditional model of "teacher demonstration student imitation" still dominates, lacking exploratory and collaborative teaching scenarios, and artificial intelligence technology has not been applied to personalized teaching guidance and process control. Fifthly, the evaluation mechanism is single and lacks strong guidance. 80.1% of teachers agree that the current evaluation is mainly based on outcome evaluation, focusing on practical reports and skill assessments, neglecting the evaluation of students' innovative thinking, problem-solving ability, and technical application ability in the practical process, which is difficult to fully reflect the quality of talent cultivation.

3.3 Feasibility and necessity analysis of technology integration

The necessity of technological integration is reflected in the urgent need to break through the

bottleneck of practical teaching resources. Artificial intelligence and digital twin technology can create practical scenarios that integrate virtual and real worlds, breaking through the temporal and spatial limitations and resource constraints of physical platforms, achieving low-cost and high security simulation training for complex engineering tasks, and making up for the problem of insufficient intelligent equipment resources. The second is to adapt to the talent training needs of industrial transformation and upgrading. By integrating cutting-edge intelligent manufacturing technologies into practical teaching through technological integration, it is possible to accurately meet the demands of enterprises for the application of new technologies in talent, and improve the matching between talent cultivation and industry demand. The third is the inherent requirement for promoting practical teaching reform. Technological empowerment enables innovative teaching models and evaluation mechanisms, achieving a shift from "confirmatory practice" to "exploratory and innovative practice" and improving the quality of practical teaching.

The feasibility of technological integration is mainly supported by three aspects: firstly, mature technological foundation. The application of artificial intelligence and digital twin technology in the manufacturing industry has formed a relatively complete technical system. Technical achievements such as virtual simulation platform and industrial Internet provide technical support for teaching transformation. Secondly, the teaching conditions are met. Currently, universities are generally promoting the construction of informationized campuses, and most mechanical majors already have basic virtual simulation teaching conditions, providing hardware and software foundations for technology integration. Thirdly, a preliminary collaborative mechanism has been established. The cooperation between universities and intelligent manufacturing enterprises is increasingly deepening, and enterprises are willing to participate in the development and implementation of practical teaching resources, providing practical scenarios and resource guarantees for technology integration. Research shows that 76.3% of university teachers and 82.6% of business leaders recognize the feasibility of technology integration, laying a solid foundation for the reconstruction of practical teaching systems.

4. Reconstruction framework of practical teaching system for mechanical majors based on artificial intelligence and digital twin technology

Based on the existing problems in practical teaching of mechanical majors and the demand for technological integration, with the core of empowering talent cultivation quality improvement, we will construct a practical teaching system reconstruction framework that is supported by technological integration, centered on element collaboration, and guided by industry adaptation, to achieve systematic innovation of traditional practical teaching models.

4.1 Refactoring principles

The refactoring process strictly follows four core principles: firstly, the requirement oriented principle. Accurately aligning with the core competency demands of mechanical talents in the intelligent transformation of the manufacturing industry, designing teaching objectives, content, and modes based on the real needs of the industry, and ensuring precise matching between talent cultivation and job requirements. Secondly, the principle of technological integration. Deeply integrating the characteristics of artificial intelligence and digital twin technology, achieving the organic integration of various elements and links of technology and practical teaching, avoiding the formalization of technology application, and highlighting the empowering value of technology on teaching. Thirdly, the principle of system collaboration. This study aims to achieve the collaborative optimization of core elements including teaching objectives, content, resources, modes, and evaluation, and to construct an organic system in which each module supports and dynamically adapts to one another, thus ensuring the effective operation of the whole framework. Fourthly, the principle of balancing feasibility and innovation is adopted. A feasible implementation path is designed based on universities' existing teaching conditions and technological foundations, while technology-driven innovative teaching models and evaluation mechanisms are actively explored to strike a balance between practicality and foresight.

4.2 Overall framework design

The restructured practical teaching system adopts a "four layer and three-level" overall framework, forming a multi-dimensional collaborative three-dimensional teaching system. The "four layers" refer to the target layer, support layer, implementation layer, and guarantee layer: the target layer focuses on the three-dimensional training objectives of "basic practical ability+new technology application

ability+engineering innovation ability"; The support layer is centered around artificial intelligence and digital twin technology, integrating diverse resources such as virtual simulation platforms, physical practice bases, and data resource libraries; The implementation layer covers three progressive stages of teaching implementation: basic practice, professional core practice, and comprehensive innovative practice; The guarantee layer includes support mechanisms such as faculty, school enterprise cooperation, policy funding, and quality monitoring.

The "three-level" refers to the progressive practical stage designed according to students' cognitive laws and ability growth paths: the basic practical stage focuses on technical cognition and basic skill cultivation; The professional core practice stage focuses on the application of core technologies and the improvement of professional skills; The comprehensive innovation practice stage emphasizes cross disciplinary integration and the shaping of engineering innovation capabilities. Each level achieves information exchange through data links, utilizes artificial intelligence technology to achieve precise control and personalized guidance of the teaching process, relies on digital twin technology to build practical scenarios of virtual real linkage, and forms a closed-loop operation system of "goal guidance resource support hierarchical implementation guarantee".

4.3 Detailed design of each core module

One is the reconstruction of the teaching objective module. Three-dimensional training objectives are refined based on industry requirements. Basic practice objectives focus on core foundational skills such as mechanical design and manufacturing, incorporating technologically oriented content including digital modeling and fundamentals of intelligent perception. Core professional objectives emphasize the application capabilities of technologies including intelligent equipment commissioning, digital twin workshop operation, and intelligent quality inspection. Comprehensive innovation objectives highlight innovative abilities such as intelligent manufacturing system integration and product lifecycle optimization supported by digital twins. Through the use of artificial intelligence technology to analyze industrial job competency data, the objective system is dynamically adjusted accordingly.

The second is the reconstruction of teaching content modules. A three-level content system of "foundation + core + innovation" is constructed, with courses such as Fundamentals of Digital Twin and Introduction to AI Algorithms added to the basic module. Core module settings include intelligent equipment virtual debugging, digital twin workshop planning and simulation, intelligent quality inspection, and other projects; The innovation module introduces real enterprise projects, designs integrated intelligent manufacturing systems, interdisciplinary collaborative innovation, and other comprehensive topics. The content design focuses on connecting with the actual production of the enterprise and absorbing cutting-edge technology standards in the industry.

The third is the reconstruction of teaching resource modules. A virtual - real integrated resource system is constructed. At the virtual resource layer, digital twin virtual factories and intelligent equipment simulation systems are developed, and AI technology is employed to realize personalized resource recommendation. At the physical resource layer, existing practice bases are upgraded, industrial robots, intelligent sensors and other devices are introduced, and a virtual - real linked practice platform is established. The data resource layer integrates teaching data, enterprise engineering data, and technical standard data, establishes a shared database, and provides data support for teaching implementation and evaluation.

The fourth is the reconstruction of teaching mode modules. Innovative three types of teaching modes: virtual real interaction mode, which achieves real-time linkage between physical entities and virtual models through digital twin technology, and carries out immersive practice; The project driven model is guided by real enterprise projects, guiding students to form teams and engage in inquiry based learning; The precise guidance mode utilizes AI technology to analyze students' learning data, provide personalized learning suggestions and real-time guidance, and achieve individualized teaching.

The fifth is the reconstruction of the evaluation module. A multi-dimensional evaluation system is constructed. Evaluation indicators cover such dimensions as practical attitude, process performance, skill mastery, and innovative achievements, with core indicators including technological application ability and problem-solving ability incorporated. The evaluation methodology combines AI-driven process evaluation with outcome evaluation, integrating multi-subject evaluation involving student self-assessment, peer assessment, teacher assessment, and enterprise assessment. AI technology is used to quantitatively analyze practical process data, realizing accurate feedback on evaluation results and promoting continuous teaching optimization.

5. Conclusion

This article focuses on the reform needs of practical teaching in mechanical majors under the background of intelligent transformation of manufacturing industry. It conducts a systematic study on the integration of artificial intelligence and digital twin technology to empower the reconstruction of practical teaching system. The main conclusions are as follows:

Firstly, it clarifies the core issues of the current practical teaching system for mechanical engineering majors. Through multi-party research and verification, it has been found that the traditional system has prominent problems such as a disconnect between teaching objectives and industry needs, outdated and fragmented practical content, insufficient allocation of teaching resources, rigid teaching models, and a single evaluation mechanism. The lack of integration of new technologies is a key bottleneck that restricts the improvement of talent cultivation quality.

Secondly, a framework for reconstructing the practical teaching system guided by technology integration has been constructed. This study establishes demand-oriented, technology-integrated, and system-collaborative principles for curriculum reconstruction, and proposes an overall “four-layer and three-level” framework. This framework encompasses a four-layer architecture consisting of objectives, support, implementation, and guarantee, as well as three progressive practical levels: foundation, core, and innovation, so as to realize the collaborative optimization of multiple teaching elements.

Thirdly, the precise design of the core modules of the system has been completed. Starting from the five core modules of teaching objectives, content, resources, modes, and evaluation, we have achieved dynamic adaptation of three-dimensional training objectives, gradient construction of a three-level content system, three-dimensional construction of a virtual real integration resource system, innovative breakthroughs in diversified teaching modes, and scientific construction of a multi-dimensional evaluation system, providing a feasible implementation paradigm for the deep integration of technology and teaching.

Research has confirmed that the integration of artificial intelligence and digital twin technology can effectively break through the bottleneck of traditional practical teaching resources, enhance the adaptability of talent cultivation to industry needs, and provide theoretical support and practical paths for the reform of practical teaching in mechanical majors. However, there are still shortcomings in this study, such as limited pilot scope and insufficient validation of the long-term operational effects of the system. In the future, the pilot scope can be expanded to carry out long-term tracking research, deepen the teaching application of cutting-edge technologies such as generative AI and full lifecycle digital twins, promote the collaborative construction of interdisciplinary practical teaching systems, and further enhance the effectiveness of practical teaching in empowering the high-quality development of the manufacturing industry.

References

- [1] Hu A W, Fu Z H. *Application of Constructivism Theory in Experimental Teaching of Packaging Mechanics* [J]. *Research and Exploration in Laboratory*, 2006, (01): 5-7.
- [2] Li J Y, Chen L, Wang X Y, Luo C S. *Civil Engineering Major from the Perspective of Engineering Education Accreditation Exploration and Practice of the "Three Doubles and Three Integrations" Path for Industry-Education Integration* [J]. *Journal of Heilongjiang Vocational Institute of Ecological Engineering*, 2026, (01): 126-131.
- [3] Huang P. *Education Reform in the Intelligent Era: Thinking-Based Teaching Theory Leading "Technology-Empowered Teaching"* [J]. *Office Informatization*, 2026, (02): 45-48.