Practice and Research on the "Five-Gold" Linkage Education Model Led by Digital Twin Technology Courses in Vocational Education

Jieqiong Zeng*, Renxuan Fu

College of Electrical and Mechanical Engineering, Guangdong Polytechnic of Industry and Commerce, Guangzhou, China.

*email: 123682131@qq.com

Abstract. To address structural challenges in smart manufacturing training—specifically prohibitive equipment costs and high operational risks—this study utilizes the "Digital Twin Technology" course as a strategic hub. It spearheads the collaborative reconfiguration of key educational elements, including specialties, courses, and textbooks. By enabling the seamless transformation of industry-standard scenarios into high-fidelity digital resources, this model establishes a closed-loop education system synchronized with industrial needs. This approach effectively bridges the gap between talent supply and rapid technological iteration, providing a highly replicable blueprint for digital and intelligent transformation in vocational education.

Keywords: Vocational Education; Digital Twin Technology; Virtual-Real Coupling

1 Introduction

Vocational education is currently undergoing a paradigm shift from traditional knowledge transmission to comprehensive capability enhancement. Aligning with the Ministry of Education's "2026 No. 1" directive, the systematic reform of the "Five Golds"—encompassing Gold Specialties, Gold Courses, Gold Textbooks, Gold Teachers, and Gold Training Bases—is essential for resolving the disconnect between industry requirements and educational output.

Addressing the "technical gap" caused by the inherent difficulties of smart manufacturing training (often characterized by high costs, high risks, and high maintenance requirements), this study establishes the "Digital Twin Technology" course as the logical starting point for the digital reconstruction of all educational elements[1]. This paper summarizes the innovative practices at Guangdong Industry Polytechnic, detailing how "Gold Courses" serve as a focal point to drive the systematic upgrading of specialty frameworks and faculty expertise. Ultimately, this provides a practical, industry-aligned model for cultivating talent suited for "New Quality Productive Forces".

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This teaching model focuses on online resource reconstruction and offline teaching implementation, which are closely corresponding and logically consistent: online, through the "Inspiration-Practice-Elevation" approach, it deconstructs industrial pain points, carries out virtual-real mapping training, refines values based on digital intelligence portraits, and cultivates a "zero-error" mindset; offline, it synchronously conducts theoretical practice, virtual-real joint debugging training and enterprise technical problem solving through the "Learning-Training-Innovation" model, and performs value-added evaluation in combination with the Progress Coefficient Δ to achieve precise profiling of students' abilities and improvement of their engineering literacy.

1.1 Virtual-Real Integration and Three-Stage Progression: Constructing a Hybrid Education Model Synergizing Online "Inspiration-Action-Elevation" and Offline "Learning-Training-Creation"

Using the "Digital Twin Technology" course as a strategic anchor, this research spearheads the systematic and collaborative reconstruction of the "Five-Gold" infrastructure (Specialties, Courses, Textbooks, Teachers, and Bases) in vocational education. By leveraging NX MCD to overcome virtual-real synchronization bottlenecks—maintaining latency below 50ms even under high-load conditions—the study establishes a "Virtual-First, Physical-Second" debugging paradigm. This approach effectively mitigates the "Three Highs and Three Difficulties" (high cost, high risk, high difficulty; hard to observe, enter, or replicate) inherent in traditional industrial training.

The curriculum adopts a dual-track model, integrating online resource-driven "Inspiration, Action, and Elevation" (Qi-Xing-Sheng) with offline practice-oriented "Learning, Training, and Creation" (Xue-Xun-Chuang). This framework facilitates the transformation of industrial processes from leading enterprises into digital pedagogical assets. By dynamically coupling educational elements with production factors, the model provides targeted empowerment for cultivating talent suited to "New Quality Productive Forces"[2].

1.2 Online Resource Reconstruction: A Cloud-Based Curriculum Framework Linked by the "Inspiration-Action-Elevation" Logic

Utilizing the "Smart Vocational Education" online platform, the research team restructured the Digital Twin Technology course resources into digital assets across three dimensions—Inspiration (Qi), Action (Xing), and Elevation (Sheng). This reconstruction follows a pedagogical logic of "problem-orientation, task-driven, and literacy refinement".

Phase 1: "Inspiration" (Qi). This stage centers on fostering engineering awareness and deconstructing industrial "pain points". The team transformed industry-leading scenarios, such as CATL battery production lines and Siemens multi-model adhesive application systems, into high-fidelity introductory resources to provide students with authentic learning contexts.

Phase 2: "Action" (Xing). With a focus on practical execution, this phase hones technical skills through intensive virtual-real mapping training. Students engage in cloud-based simulations, independently defining physical properties and motion configurations for mechanism-driven demonstration cases. A critical technical achievement in this phase is the stabilization of mapping latency within 50ms, ensuring seamless virtual-real synchronization during training.

Phase 3: "Elevation" (Sheng). At the highest tier of the digital curriculum, this stage facilitates the digital internalization of professional literacy and the cultivation of a "zero-error" occupational mindset. The framework establishes a value-added system driven by "competency evaluation and digital portraits" to achieve the ultimate goal of professional character development[3].

1.3 Offline Instructional Implementation: Scenario-Based Practice via the "Learning-Training-Creation" Triad

During the "Learning" phase, the curriculum emphasizes a deep grasp of theoretical principles and the rigorous validation of technical schemes. By guiding students to visualize signal flows within physical environments, this stage facilitates a fundamental transition from "superficial cloud-based awareness" to "profound industrial comprehension"[4].

As students progress to the "Training" stage, the core objective pivots toward practice-oriented instruction through the integration of training and research, specifically focusing on virtual-real joint debugging. In the most advanced "Creation" stage, the pedagogical focus shifts toward solving actual technical bottlenecks and fulfilling social service functions.

This tripartite "Learning-Training-Creation" model drives a systemic paradigm shift in the curriculum—from simple knowledge transmission to the cultivation of comprehensive professional competencies. Ultimately, it contributes the "GDIP Model" (Guangdong Industry Polytechnic) to the "Five-Gold" infrastructure of vocational education—a synchronized, digitally empowered, and highly replicable blueprint[3].

2 The "Five-Gold" Collaborative Upgrade Scheme Driven by Course Leadership

Positioning the content of the Digital Twin Technology course as the strategic pivot, this research constructs a virtual-real integrated system architecture based on an "end-network-cloud" framework. The hardware environment utilizes a Siemens S7-1500 PLC (CPU 1512C) as the core controller, integrated with a KTP900 HMI and industrial switches. The software stack employs NX 2015 (MCD) for mechatronics concept design and TIA Portal V17 for logic programming, facilitating seamless cross-platform communication through S7-PLCSIM Advanced V6.0 or the OPC UA protocol. The technical route adheres to a rigorous logical closed loop consisting of "high-fidelity modeling -control logic deconstruction -signal mapping -virtual-real closed-loop debugging". Regarding synchronization accuracy verification, the research team utilized the Runtime Inspector in NX MCD to capture high-fidelity feedback data, performing precise time-stamp comparisons against the I/O status mapping data from the physical PLC. This methodology ensures the operational reliability of the "Virtual-First, Physical-Second" paradigm, effectively bridging the "technical chasm" in smart manufacturing practical training caused by synchronization latency.

This study positions the Digital Twin Technology course as the strategic anchor for the collaborative reconstruction of the "Five-Gold" infrastructure in vocational education. By ensuring that course standards penetrate downward into job specifications and support the requirements for "New Quality Productive Forces", the model compels an intrinsic enhancement of all educational elements.

Gold Specialty: Aligning with the professional standards for "Digital Twin Application Technicians", the course technical standards are deeply embedded into the specialty development path to ensure talent specifications precisely match national strategic needs.

Gold Teachers: Facilitating bilateral mobility through structural innovation teams. Teachers transition from "instructional experts" to "practice experts" by undertaking high-load tasks such as virtual-real joint debugging and resolving enterprise technical bottlenecks.

Gold Textbooks: Leveraging agile development for the "lossless migration" of industrial scenarios. In collaboration with "anchor" enterprises like Siemens, real production logic is transformed into "Four-Real and Three-New" digital resources, supported by a 5TB resource package.

Gold Training Base: Constructing a virtual-real coupling ecosystem. By implementing a "Virtual Trial-and-Error before Physical Implementation" closed loop, students can challenge complex working conditions in a zero-risk environment, significantly reducing equipment loss and operational costs.

3 Enhancing Educational Quality and Social Service through Data-Driven Portraits

Evaluation mechanisms have evolved from retrospective analysis into an endogenous driver for the continuous iteration of the "Five-Gold" infrastructure[5]. Addressing the lack of process data in traditional training, this study utilizes the national "Smart Vocational Education" platform to build a precision evaluation system centered on AI course agents, achieving a paradigm shift from "vague perception" to "multi-dimensional digital portraits".

3.1 The AI-Powered "One Course, Five Dimensions" Full-Link Evaluation Model

The research team adapted the DeepSeek Large Language Model (LLM) to construct the "AI Zhi Mengmeng" assistant system, which covers the entire cycle of course construction, guidance, and evaluation. This agent is deeply embedded in the digital field, utilizing behavioral capture technology to transform operational trajectories into visualized, quantifiable "Digital Portraits". By modeling over 1.02 million experiment logs, the system accurately deconstructs logical efficiencies in industrial-grade training. For instance, in tasks like "0.1mm sensor calibration," the AI provides real-time diagnostics and generates individual reports based on the "Progress Coefficient Δ" mechanism [3].

Table 1. The "Progress Coefficient Δ" Value-Added Evaluation Index System Driven by Digital Twin + AI

Dimension	Observation Points	Data Sources	Learning Outcomes
Engineering Thinking (Δ)	Active discovery of industrial "pain points" (e.g., sorting jams, robotic collisions).	"AI Zhi Mengmeng" behavioral capture and "QiZhi Cloud" digital portraits.	Capability to identify and resolve faults under complex conditions.
Operational Precision (Δ)	Consistency between 28mm pusher plate stroke and 0.1mm sensor calibration.	NX MCD high-fidelity feedback and physical PLC mapping data.	Mastery of synchronization (<50ms) under 1500k high load.
Safety Literacy (Δ)	Rigor of PLC logic interlocks and emergency stop latency under 5G.	5G Industrial Internet communication links.	Internalizing "Zero-Error" responsibility as an instinctive safety reflex.
Innovation Transformation (Δ)	Participation in enterprise technical challenges and patent filings.	Industrial Digital Innovation Center data and institutional research records.	Cultivating artisans capable of solving industry-wide technical problems.

3.2 The "Progress Coefficient Δ" Value-Added Evaluation Mechanism

To measure the shift in students' engineering thinking during virtual-real debugging, the "Progress Coefficient Δ" mechanism focuses on the iteration efficiency of students when resolving unexpected "faults" on the production line. This ensures a systematic leap in training quality, as detailed in Table 1.

The "Progress Coefficient Δ" is derived by weighting multi-dimensional behavioral data within the digital instructional field. The calculation formula is defined as follows:

$$\Delta = \sum_{i=1}^{n} (S_{i1} - S_{i0}) \times W_i \div T$$

Where:

S_{i0}: The pre-test level for dimension (baseline behavioral portrait data).

S_{i1}: The post-test level for dimension (final training task achievement data).

W_i: The weight assigned to the respective dimension.

T: The iteration efficiency of task completion (represented by the frequency of debugging or a duration correction factor required to resolve industrial "pain points").

3.3 Dual Effectiveness: Releasing Educational and Social Service Potential

From a governance perspective, this research leverages the national "Smart Vocational Education" AI-enhanced course platform. Throughout five instructional cycles spanning from 2021 to 2025, the study utilized underlying behavioral capture technology to aggregate and model 1.456 million log entries. This comprehensive behavioral dataset serves as the foundational bedrock for precision digital intelligence evaluation, enabling a profound deconstruction of practical training effectiveness.

Such high-quality educational outcomes have catalyzed a significant, large-scale release of potential within social services. According to university research management systems and feedback reports from partner enterprises, the team secured 50 horizontal research projects via the "Reveal the Rankings" mechanism, with actual research funding received exceeding 12 million RMB.

Furthermore, based on real-time statistical criteria from the national platform, this Digital Twin "Gold Course" and its associated resources have reached over 250 institutions nationwide, with 10,485 registered students and more than 54,727 instructional interaction samples. These achievements have established a highly empirical and influential "GDIP Model" (Guangdong Industry Polytechnic Model), providing a replicable blueprint for the digital transformation of vocational education.

4 Conclusion: Constructing a Digital Ecosystem for the "Five Golds"

By using the Digital Twin course as a hub, this research drives the total reconfiguration of specialties, faculty, and training environments. Technically, the team has overcome the millisecond-level synchronization bottleneck, enabling the transformation of industrial processes into educational resources. In terms of governance, the use of AI-driven digital portraits has resolved the inherent difficulties of traditional training, achieving a paradigm shift from experience-based to value-added evaluation. This practice effectively couples the educational and industrial chains, providing a replicable "GDIP Model" for the manufacturing sector[6].

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