

# Construction Logic and Practice Path of Digital Advanced Manufacturing Training Room-Based on the Perspective of Industry-Education Integration in Higher Vocational Education

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**Abstract:** Addressing challenges in vocational manufacturing education such as disconnection between training programs and industry demands, inefficient training management, and inadequate talent cultivation, this study examines the "Digital Advanced Manufacturing Training Lab Development" project at Wenzhou Vocational and Technical College Ruian Campus. Through systematic analysis of global digital manufacturing training base frameworks, the research establishes a five-in-one platform comprising "system architecture, equipment management, instructional design, supervision mechanisms, and optimization protocols". Key components include digital management platform design, intelligent equipment monitoring systems, and restructured training methodologies. Through phased implementation and data-driven optimization, the lab's effectiveness in enhancing teaching quality, deepening industry-education integration, and cultivating interdisciplinary talents is validated. The findings demonstrate that this innovative training model effectively addresses pedagogical pain points in vocational manufacturing education, providing theoretical foundations and practical models for similar institutions. This approach holds significant implications for aligning vocational education with the digital transformation of manufacturing industries.

**Keywords:** Digital Advanced Manufacturing, Training Base Construction, Higher Vocational Education, Industry-Education Integration, Management Platform, Teaching Optimization.

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## 1. Problem Statement

The digital transformation of manufacturing stands as the cornerstone of China's "Manufacturing Powerhouse" strategy. At its core, this initiative integrates industrial internet, artificial intelligence, and IoT technologies with production processes to achieve intelligent workflows, refined management systems, and premium product services<sup>[1]</sup>. This transformation demands updated competencies from technical professionals, requiring not only solid expertise in mechanical engineering and CNC technology but also cross-disciplinary capabilities in digital equipment maintenance, production data analytics, and collaborative innovation. However, vocational training programs in manufacturing currently face three critical challenges: First, a technological gap persists between training equipment and industry standards. Most labs still rely on outdated CNC lathes and conventional machinery, lacking modern digital tools that create a skills gap between classroom learning and workplace requirements. Second, outdated management practices rely on manual tracking of equipment status, student attendance, and training progress, hindering real-time monitoring and resource optimization. Third, training content remains disconnected from industry standards, with programs focusing narrowly on isolated skill drills rather than authentic production scenarios and digital workflows, resulting in a mismatch between talent development and market needs<sup>[2]</sup>.

Against this backdrop, Zhejiang Province's university laboratory research project "Digital Advanced Manufacturing Training Lab Development" has selected Ruian College of Wenzhou Vocational and Technical College as its implementation base. The initiative focuses on building a digital training system and innovating teaching models,

aiming to systematically address the challenges of traditional practical training. Through this systematic approach, it seeks to provide industry-aligned solutions for cultivating manufacturing professionals in vocational colleges.

## 2. Research Status of Digital Advanced Manufacturing Training Laboratory at Home and Abroad

### 2.1. International Research and Practice Progress

As the birthplace of Industry 4.0, Germany's digital manufacturing training system features a tripartite approach: technology R&D, educational transformation, and industrial application. The Fraunhofer Institute's Industry 4.0 Training Module integrates smart sensors, industrial robots, and digital twin technology to simulate real-world production scenarios. Students master digital production process control and equipment collaboration through hands-on practice on virtual production lines and physical equipment<sup>[3]</sup>. Furthermore, in Germany's dual vocational education system, industry leaders like Siemens and Bosch actively participate in training base development, embedding cutting-edge manufacturing technologies and job standards into curricula to ensure seamless integration between academic learning and corporate practice.

The United States, Japan, and South Korea emphasize interdisciplinary technology integration and innovative training models. At MIT's Digital Manufacturing Lab, big data analytics and CNC machining technologies are combined to develop a data-driven training evaluation system that collects real-time student operation data and generates personalized skill enhancement plans through algorithms.

Japan's Toyota Institute of Technology Affiliated Vocational School has established a virtual factory training platform using VR technology to simulate the entire digital production process of automotive components, reducing training costs while enhancing students' risk management capabilities. In South Korea, Samsung TECHWIN collaborates with universities to build an intelligent equipment training center, focusing on the integration of industrial robots and IoT technologies to cultivate students' skills in digital equipment debugging and system integration<sup>[4]</sup>.

## 2.2. Domestic Research and Practice Status

The development of digital advanced manufacturing training laboratories in China is advancing rapidly, driven by both policy incentives and industrial demands. The Ministry of Education's "Vocational Education Specialty Catalog (2024)" explicitly requires manufacturing programs to "establish digital training systems and strengthen core competencies in intelligent equipment operation and production data processing." Furthermore, the Ministry of Industry and Information Technology (MIIT) and the Ministry of Education jointly issued the "Manufacturing Talent Development Plan Guidelines," mandating universities to collaborate with enterprises in establishing digital training bases and promoting the integration of industry-education partnerships, job-course-competition-certification systems<sup>[5]</sup>.

In practice, domestic universities have developed two typical construction models: the first is the "enterprise co-construction type," such as Shenzhen Polytechnic's collaboration with Huawei and Han's Laser to jointly establish a "Smart Manufacturing Training Center," introducing digital production equipment and management systems from enterprises, and transforming real production projects into training tasks; the second is the "virtual simulation type," such as Wuxi Polytechnic's development of a "CNC Machining Virtual Simulation Training Platform," which uses 3D modeling to recreate CNC machine operation scenarios, allowing students to complete high-risk, high-cost training projects in a virtual environment<sup>[6]</sup>. Additionally, Ma Changhui (2022) pointed out that the construction of digital training laboratories should focus on "synchronized advancement of hardware equipment updates and software platform development," achieving full-process digital control of equipment, teaching, and students through a management platform<sup>[1]</sup>; Luo Mingxia et al. (2018) proposed that CNC training laboratories should establish a closed-loop system of "theoretical teaching-virtual simulation-practical training-assessment and evaluation" to enhance the systematicness of training education<sup>[2]</sup>.

## 2.3. Research Review

Research and practice from both domestic and international sources reveal that the development of digital advanced manufacturing training laboratories has evolved into a core trend characterized by "interdisciplinary integration, industry-education collaboration, and data-driven approaches." However, two key areas require improvement: First, the international model of "deep corporate involvement in teaching" needs localization to fit the realities of China's vocational education. Second, some domestic laboratories overemphasize hardware procurement while neglecting software development, resulting in digital management platforms with limited functionality that fail to achieve deep integration with teaching, supervision, and optimization. To

address these issues, this study focuses on the "digital management platform" as the core, establishing an integrated framework encompassing "hardware, software, teaching, and management" for training laboratory development. This approach fills the research gap in China's vocational education by addressing the prevalent issue of prioritizing construction over operational management in digital training bases.

## 3. Core Construction Contents of Digital Advanced Manufacturing Training Laboratory

This project aims to "meet industry demands, enhance teaching effectiveness, and optimize management models" by establishing an integrated framework encompassing "platform, equipment, teaching, supervision, and optimization". The specific components are as follows:

### 3.1. Architecture Design of Digital Management Platform

Based on the principles of "demand-oriented, modular functionality, and scalability," the WIS (Workshop Intelligent System) digital management platform was designed. The platform adopts a B/S architecture, consisting of three layers: the core function layer, the data support layer, and the application layer.

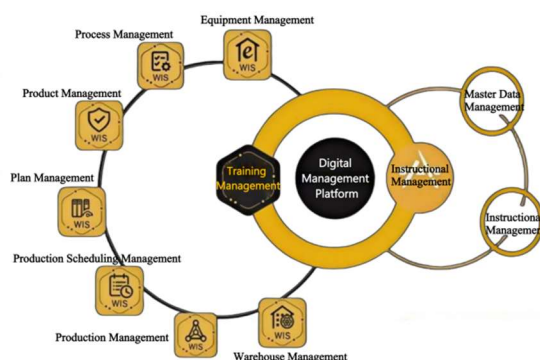


Figure 1. Architecture of the Digital Management Platform

As shown in Figure 1, the system enables end-to-end digital management of equipment, instruction, students, and safety, with customized interfaces for different users. Teachers can schedule courses and evaluate practical training, while enterprises can publish real-world projects.

The core module functions of the platform are designed as follows: Equipment Management Module: This module connects CNC machines, 3D printers, and industrial robots in the training lab via IoT technology. It collects real-time operational parameters (e.g., rotational speed, temperature, machining accuracy) and generates equipment status dashboards. By setting fault warning thresholds, the system automatically sends maintenance work orders to the administrator's terminal when parameters exceed normal ranges, while recording repair history to form a complete lifecycle management archive for each device<sup>[7]</sup>.

Teaching Management Module: Supports teachers in creating an integrated teaching plan covering "curriculum standards-practical training tasks-assessment and evaluation," and uploading resources such as training manuals and operation videos. It automatically assigns personalized practical training tasks based on students' major

and skill levels, while tracking their task completion progress and operational compliance in real time.

**Student Management Module:** Enables student information archiving, attendance tracking (with facial recognition and RFID card options), and learning progress monitoring. Through the "Practice Log" feature, students can document daily operational insights and issues, while teachers can view and provide targeted guidance in real time.

**Security Management Module:** Configures tiered access permissions (e.g., "Basic Operation" vs. "Advanced Debugging") to prevent unauthorized personnel from operating critical equipment. The system integrates with platform-linked smoke detectors and emergency lighting, automatically triggering audiovisual alarms and deploying emergency response protocols to faculty and student terminals when safety incidents occur<sup>[8]</sup>.

**Data Analysis Module:** Using Python data analysis tools, it performs statistical analysis on equipment utilization, student training duration, and skill mastery levels, generating "Equipment Operation Reports" and "Teaching Quality Reports". Based on the analysis results, it automatically optimizes equipment scheduling and training course arrangements, achieving "data-driven teaching improvement".

### 3.2. Development of Intelligent Equipment Supervision System

To address the issues of low equipment utilization and slow fault response in traditional training laboratories, an intelligent equipment monitoring system was developed based on the WIS platform, which consists of three core components:

**Hardware-aware layer:** Smart sensors (e.g., current and vibration sensors) and data acquisition terminals are installed on each device. The operational data is transmitted to the platform in real time via 5G Ethernet. Edge computing technology is employed to preprocess the data, thereby reducing the platform's data processing load.

**Intelligent Scheduling Algorithm:** The algorithm is designed based on dual dimensions of "practical training priority and equipment load rate". For example, when multiple classes simultaneously request CNC machine tool usage, the algorithm prioritizes equipment with load rates below 60%, and matches equipment models according to task complexity (e.g., simple machining vs. complex surface machining) to enhance equipment utilization efficiency.

**Fault Diagnosis System:** Develops a comprehensive equipment fault knowledge base that integrates common issues (e.g., spindle failures, nozzle clogging) and their solutions for CNC machine tools, 3D printers, and similar devices. By leveraging machine learning algorithms to analyze real-time operational data and historical fault records, the system enables proactive early warnings and automated diagnostics, reducing equipment failure rates by over 30%.

### 3.3. Reconstruction of the Practical Training Teaching System

Guided by the integration of "post-course-competition-certification", the practical training system is restructured into three levels:

**Basic Skills Level:** Through the virtual simulation module, students undergo "Digital Equipment Awareness-Basic Operation Training". Using VR devices, they learn the structure and operation of CNC machine tools and industrial robots, completing simple machining tasks (e.g., drilling and

milling) in a virtual environment to minimize practical risks.

**Core Competency Layer:** Students work in teams to complete a full-cycle training program covering product design, process planning, equipment debugging, production processing, and quality inspection, using real-world enterprise projects (e.g., digital manufacturing for automotive parts in Ruian). The WIS platform integrates with the enterprise's MES system to simulate digital production management workflows, developing students' collaborative production capabilities.

The Comprehensive Innovation Layer integrates competitions such as the "Internet+" College Student Innovation and Entrepreneurship Competition and the National Vocational College Skills Competition, featuring innovation projects like "Digital Production Process Optimization" and "Intelligent Equipment System Integration". Student teams leverage training room equipment and platforms to tackle technical challenges and develop projects, thereby enhancing their innovation capabilities.

### 3.4. Construction of Security System

In view of the characteristics of digital training room equipment, which is complex and high in technical complexity, a whole-process safety guarantee system of "prevention-monitoring-disposal-review" is constructed.

**Preventive measures:** Develop the "Digital Training Lab Safety Operation Procedures" to specify equipment operation restrictions and emergency response protocols. Conduct safety training and assessments via the WIS platform, where students must pass both a safety knowledge test and virtual operation evaluations to obtain equipment operation authorization.

**Monitoring phase:** Install video surveillance systems and environmental sensors (e.g., temperature/humidity sensors, harmful gas sensors) to monitor lab conditions and equipment status in real time. The platform automatically locks equipment and triggers alerts when safety thresholds are exceeded, such as equipment operation timeouts or abnormal environmental parameters.

**Disposal:** The platform establishes an emergency response mechanism to automatically push disposal plans to administrators and nearby teachers/students when equipment failures or safety incidents occur, while activating emergency equipment in training labs (e.g., fire extinguishers, first-aid kits). An emergency stop button is installed to enable one-touch power cutoff.

**Post-incident review:** Document and analyze security incidents to establish a closed-loop process of 'incident reporting, root cause analysis, and corrective actions', while updating security training materials and platform alert thresholds to continuously enhance security management capabilities<sup>[9]</sup>.

## 4. Research Methods

The project adopts a progressive research method of "theoretical research-practical development-verification and optimization" to ensure the scientificity and feasibility of the construction scheme.

A survey was conducted among 10 automotive parts and equipment manufacturing enterprises in the Ruian area, interviewing their technical directors and workshop supervisors to identify core competency requirements for these roles. Simultaneously, 20 manufacturing faculty members and 200 students from Wenzhou Vocational and

Technical College were interviewed to gather insights on pain points in practical training and platform functionality needs. The WIS digital management platform was developed using agile development methodology in iterative phases. After completing each functional module (e.g., equipment management module), faculty and students were invited to test the platform, with feedback collected and optimizations made to ensure its alignment with teaching requirements.

The practical training room construction achievements are applied to the 2024 cohort of Mechanical Manufacturing and Automation major at Wenzhou Vocational and Technical College. By comparing and analyzing indicators such as the pass rate of students' skill assessments and enterprise satisfaction before and after the construction, the effectiveness of the practical training room construction is verified.

## 5. Research Foundation

Rui'an College is equipped with manufacturing training facilities valued at over 5 million yuan, including CNC lathes and machining centers, providing essential hardware support for this project. The faculty team comprises 2 professors, 3 senior technicians, and 2 engineers. The project leader brings 20 years of CNC training experience and 10 years of training management expertise, having led the university-level key project "Construction of a Mixed Ownership Training Base" and demonstrates strong project coordination capabilities.

The school has established industry-education integration partnerships with 15 manufacturing enterprises in Ruian area, including Zhejiang Ruiming Auto Parts Co., Ltd. and Ruili Group, which provide real production projects and technical support to ensure that the construction of training laboratories keeps pace with industrial demands.

## 6. Conclusion

The development of digital advanced manufacturing training laboratories represents a pivotal initiative for vocational education to align with the digital transformation of manufacturing. Its core value lies in transforming practical training from "single-skill instruction" to "comprehensive competency development" and upgrading from "manual management" to "intelligent control" through the "digital platform + industry projects + data-driven" model. This study, implemented at Wenzhou Vocational and Technical College Ruian Campus, establishes a "five-in-one" construction framework and WIS management platform. These

innovations effectively address the pain points of traditional training methods, providing a new pathway for cultivating talent in manufacturing-related vocational programs.

Going forward, we must further deepen the integration of industry and education by encouraging enterprises to actively participate in the teaching and management of training laboratories. This will enable the real-time incorporation of the latest corporate technologies and job standards into training content. Meanwhile, we should explore a "cross-institutional sharing" model, utilizing cloud platforms to open up training resources. This approach will enhance the outreach capacity of training laboratories, ultimately cultivating more high-quality technical and skilled talents for the digital transformation of manufacturing industries.

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