

# Exploring a Curriculum Model for the Smart Manufacturing Program in Vocational Bachelor's Degree Programs

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**Abstract:** The continuous advancement of intelligent manufacturing technology has placed higher demands on the knowledge structure and professional competencies of technical personnel. However, the existing vocational undergraduate curriculum system exhibits deficiencies in course content, practical teaching, and industry–academia integration, making it difficult to meet the needs of modern industrial development. To improve the alignment between talent cultivation and job requirements, this study investigates enterprise job demands in the field of intelligent manufacturing, conducts enterprise surveys and typical task analyses, constructs a professional competency map, and examines the main issues in the current vocational undergraduate curriculum system. Following the principles of industry–academia integration, progressive competency development, and practice-oriented education, a “two-platform, three-module” curriculum framework is established. The framework clarifies the curriculum structure and course content and proposes an implementation pathway integrating jobs, courses, competitions, and certificates. The study aims to promote the effective alignment of course content with competency requirements, enhance students’ engineering practice and career development capabilities, and provide a reference for curriculum development and technical talent cultivation in intelligent manufacturing-related vocational undergraduate programs.

**Keywords:** Smart Manufacturing; Vocational Bachelor's Degree; Curriculum Restructuring; Integration of Job Roles, Courses, Competitions, and Certifications; Talent Development.

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## 1. Introduction

With the advancement of intelligent manufacturing technology and the ongoing transformation and upgrading of the manufacturing industry, the demand structure for talent in the manufacturing sector is undergoing profound changes. Vocational undergraduate education is responsible for cultivating high-level technical and skilled professionals, and its talent cultivation model and curriculum system must adapt to the evolving requirements of industrial and technological development [1]. As a key discipline supporting the equipment manufacturing industry, the scientific design and adaptability of the curriculum system for the intelligent manufacturing major directly influence the quality of technical and skilled talent cultivation in the field of intelligent manufacturing.

At present, the curriculum system of vocational undergraduate programs in intelligent manufacturing still exhibits certain limitations. Some programs continue to follow the framework of higher vocational education or adopt the training model of traditional undergraduate programs, resulting in an insufficient reflection of the characteristics of vocational education and an unclear undergraduate-level orientation [1]. On the one hand, course content remains relatively outdated, with limited integration of intelligent manufacturing technologies and typical industrial applications, making it difficult to respond effectively to industry needs. On the other hand, practical teaching is insufficiently aligned with actual enterprise production, and the development of students’ comprehensive practical competencies for complex engineering scenarios requires further enhancement. In this context, reconstructing the vocational undergraduate curriculum system for intelligent

manufacturing to meet the demands of intelligent manufacturing development has become an important task for improving the quality of talent cultivation.

## 2. New Competency Requirements for Professionals in Smart Manufacturing

### 2.1. Characteristics of the Smart Manufacturing Industry and Shifts in Talent Demand

Intelligent manufacturing is based on cyber-physical systems and integrates information technology with manufacturing technology to achieve the digitalization, networking, and intelligentization of manufacturing processes. At present, intelligent manufacturing exhibits significant transformation characteristics in terms of technological systems, production organization models, and job competency requirements. Technologically, manufacturing activities have evolved from reliance on a single mechanical discipline to the integration of multiple fields, including mechanics, electronics, information technology, and artificial intelligence. In terms of production organization, manufacturing has shifted from standardized assembly-line production to flexible and personalized production. Regarding workforce competencies, practitioners are required not only to master equipment operation and production processes but also to possess systems integration capabilities, data analysis and processing skills, and the ability to optimize production processes [2]. These changes have imposed new requirements on the knowledge structure and competency profile of technical and skilled personnel.

## 2.2. Developing a Competency Framework Based on Job Analysis

This study is based on enterprise job requirements and selects companies in related fields such as automotive parts, industrial robots, and intelligent agricultural equipment to conduct job competency surveys and determine training

objectives. On this basis, the typical task analysis method is applied to organize the job responsibilities and competency requirements associated with positions related to the intelligent manufacturing major, and to summarize four core job groups along with their corresponding competency requirements (Fig 1).

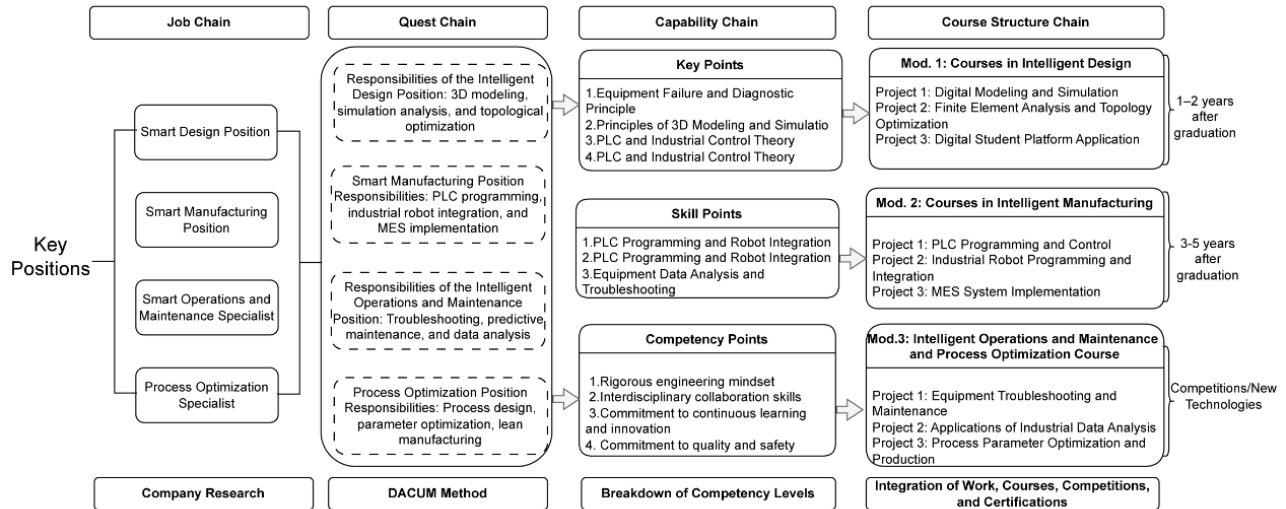


Figure 1. The Four Core Job Categories in the Mechanical Design, Manufacturing, and Automation Program and Their Competency Requirements

## 3. The Adaptability Challenges of the Current Curriculum System

### 3.1. Course content lags behind technological advancements

The pace at which course content for current vocational undergraduate programs in smart manufacturing is being updated lags behind technological developments, making it difficult to meet the practical demands arising from advancements in smart manufacturing technology; in some institutions, the update cycle for teaching materials is relatively long, and course content continues to focus primarily on traditional mechanical design and manufacturing processes, with limited integration of smart manufacturing-related technologies, particularly in areas such as the Industrial Internet and intelligent control [3]; Taking PLC course teaching as an example, most institutions currently still use basic models such as the Mitsubishi FX series and Siemens S7-200 as the primary teaching focus, whilst content relating to the Siemens S7-1500 control system—which is more widely used in smart factories—and industrial Internet of Things (IIoT) communication technologies based on the OPC UA protocol has not yet been incorporated into the curriculum.

### 3.2. The disconnect between practical instruction and real-world production

The practical training component currently exhibits certain structural shortcomings, primarily in three aspects. First, experimental projects are largely limited to basic operational tasks, such as controlling the forward and reverse rotation of electric motors or programming traffic light logic, and comprehensive training in complex engineering scenarios remains insufficient. Second, the updating of practical training equipment lags; some institutions still use equipment

purchased a decade ago, resulting in a significant gap compared with the automated production lines in smart factories. Third, corporate internships tend to be perfunctory in practice; after entering enterprises, students are often assigned auxiliary tasks and rarely have opportunities to participate in core production projects.

### 3.3. Superficial Implementation of Industry-Education Collaboration Mechanisms

Industry-university collaboration is a key pillar of vocational undergraduate education; however, at present, the level of collaboration remains relatively superficial. Most enterprises are involved only in areas such as the provision of equipment and the organisation of work placements, whilst their in-depth participation in curriculum development, teaching content, the creation of a repository of typical teaching cases, and the evaluation of educational outcomes remains insufficient [3]. The limited integration of industry needs into the teaching process has, to some extent, slowed the pace at which the curriculum adapts to technological changes within the industry, thereby hindering the effective alignment of talent development with the skills required for specific roles.

### 3.4. The curriculum lacks the distinctive features of a vocational bachelor's degree program

At present, some institutions have a misalignment in the construction of vocational undergraduate curriculum systems. One type of institutions still bases their curriculum design on the training model of vocational colleges, focusing more on skill training and neglecting the construction of theoretical knowledge systems and the cultivation of innovation capabilities; the other type of institutions tend to follow the model of ordinary undergraduate education, overly

emphasizing the systematicness and theoretical depth of the disciplinary knowledge system, but paying insufficient attention to the practical orientation of vocational education [4]. These deviations have weakened the uniqueness of the vocational undergraduate curriculum system to varying degrees and are not conducive to fulfilling the requirements of the coordinated development of the "vocational nature" and "higher nature" of vocational undergraduate education.

## 4. Principles and Framework for Curriculum Restructuring

### 4.1. Refactoring Principles

Based on the positioning of vocational undergraduate programmes and the needs of the smart manufacturing industry, the curriculum has been restructured in accordance with three key principles: competence-based learning, industry-education integration, and dynamic adaptation. Taking the job competency framework as the logical starting point, real-world corporate projects, technical standards, and production processes have been deeply integrated into the course content. Course modules have been redesigned to establish a curriculum update mechanism that evolves in tandem with technological advancements in the industry.

### 4.2. The “Two Platforms, Three Modules” Curriculum Framework

Based on the job competency requirements in the intelligent manufacturing field that this project is targeting, a "two platforms and three modules" curriculum system

framework has been formed (Fig 2), which focuses on the coordinated development of students' general ability, professional knowledge, and innovative qualities as the fundamental principle.

The public basic platform mainly reflects the cultivation of basic abilities at the undergraduate level, including advanced mathematics, engineering mechanics, college English, information technology, etc. It emphasizes consolidating theoretical foundations and tool capabilities in areas such as mathematical modeling and numerical analysis of engineering problems, reflecting the ability requirements of vocational undergraduate education for understanding and applying technical principles.

The professional group platform is oriented towards the common knowledge and technical needs of intelligent manufacturing-related majors. This platform sets courses such as Introduction to Intelligent Manufacturing, Foundation of Industrial Robots, Sensors and Detection Technology, and Foundation of Industrial Internet, thereby forming a set of shared technical basic systems that help enhance students' knowledge application ability across different majors.

The basic skills module focuses on the necessary professional basic theoretical knowledge and basic skills of the major, including courses such as Mechanical Drawing and CAD, Electrical and Electronic Technology, Mechanical Design Foundation, and Mechanical Manufacturing Foundation. It adopts a teaching method combining classroom instruction with virtual and real-world integration to improve students' learning effectiveness and mastery of professional basic courses.

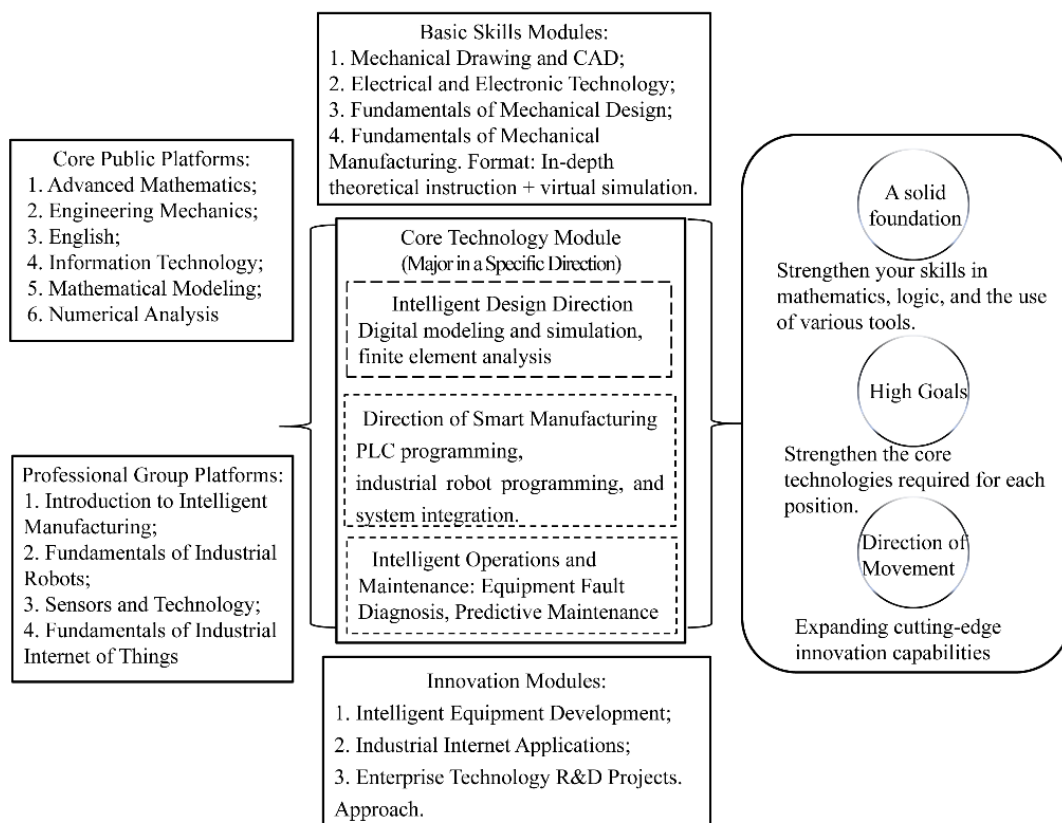


Figure 2. Framework for the Reconstruction of the “Two Platforms, Three Modules” Curriculum System

The core technology module is set up based on the cultivation of core job competencies. This module is divided into three directions: intelligent design, intelligent production, and intelligent operation and maintenance. The intelligent

design direction includes digital modeling and simulation, finite element analysis, etc. The intelligent production direction includes PLC programming, industrial robot programming and integration, etc. The intelligent operation

and maintenance direction includes equipment fault diagnosis and predictive maintenance, etc. Students can choose the corresponding direction according to their career development needs and conduct more in-depth learning activities in this direction.

The expansion and innovation module meets the needs of both industrial technology development and innovation ability cultivation. New contents, such as intelligent equipment development, industrial internet application, and enterprise technical project training are added, and a project-based teaching mode is adopted to enhance their ability to solve complex engineering problems.

Within the curriculum framework, the distribution of teaching hours is as follows: General Foundation Platform 25%, Specialised Cluster Platform 15%, Basic Skills Module 20%, Core Technology Module 25%, and Expansion and Innovation Module 15%; practical teaching accounts for  $\geq 50\%$ , meeting the requirements for practical teaching in vocational undergraduate programmes.

## **5. Implementation Pathways for Curriculum Reform Based on “Positions, Courses, Competitions, and Certificates.”**

The integration of ‘job roles, courses, competitions, and qualifications’ is a key mechanism for implementing the curriculum framework; essentially, it takes job requirements as its starting point, uses courses as a vehicle, and employs competitions and qualifications as evaluation drivers to form a closed-loop educational system.

### **5.1. “Job-Course Alignment”: Using Job Competency Maps to Guide Course Development**

When establishing a “school-enterprise dual-entity” curriculum construction mechanism, a curriculum development team should be formed by combining professional teachers from the institution with technical experts from the enterprise. The specific implementation steps include job analysis, extraction of ability elements, and development of curriculum content. Each year, an enterprise’s job capability survey needs to be completed, and the job capability map should be updated accordingly. The job capability requirements should be decomposed into knowledge points, skill points and quality points, and then these elements should be mapped to relevant curriculum modules. The enterprise should provide real project cases, technical documents and production data as teaching materials, and based on this, project-based textbooks should be compiled [5]. For example, in PLC teaching, the PLC control system of an intelligent inspection line from a certain automotive component enterprise can be introduced as a practical case, and the requirements of the production line, hardware design, software programming and debugging operation can be integrated into the teaching process.

### **5.2. “Integrating Courses and Competitions”: Using Skills Competition Standards to Drive Teaching Innovation**

Establish a three-tier competition training mechanism comprising ‘class-level selection – school-level competitions – provincial or national competitions’, and fully integrate

competition content into daily teaching; in practical implementation, this can be approached from three angles: firstly, transforming competitions into course-based activities, namely converting the processes and technologies from competition categories in the National Vocational Colleges Skills Competition—such as production and control in the smart manufacturing module and industrial robot system integration—into standard practical training projects; secondly, making competition training a regular feature by consciously incorporating competition tasks into practical training sessions and assessing students’ work against competition scoring criteria; thirdly, ensuring competition resources better serve teaching by incorporating past competition questions, outstanding entries and expert commentary into the course resource repository. Taking the course ‘Industrial Robot Programming and Integration’ as an example, a comprehensive practical training project titled ‘Vision-Guided Robot Gripping and Palletising’ could be established independently, drawing on the requirements of the ‘Industrial Robot System Integration’ competition. In this project, students would complete tasks whilst simultaneously carrying out preparatory work for the competition, thereby achieving a deep integration of competition and teaching [6].

### **5.3. “Certification-Course Alignment”: Assessing Learning Outcomes Through Vocational Certification Exams**

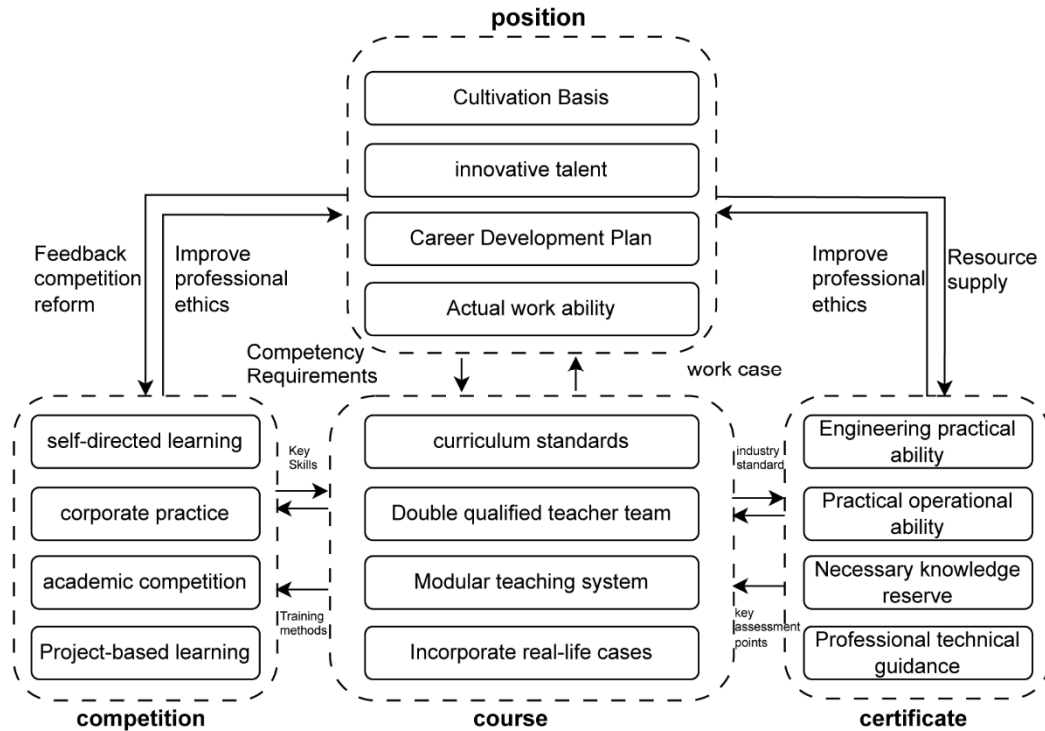
The key to implementing “course-credential integration” lies in structurally integrating the vocational skill level assessment standards of the “1+X” certificates with the existing curriculum system, and establishing a teaching model where course learning and certificate assessment are integrated. First, in terms of standard alignment, the core knowledge points from the assessment standards of “1+X” certificates such as CNC turning and milling processing, and industrial robot operation and maintenance are decomposed into each course; second, in terms of assessment alignment, the final grades of each course consist of theoretical examination and practical assessment, among which the certificate training part is implemented according to the content and standards of the certificate assessment operation; third, in terms of credit recognition, after students obtain the vocational skill level certificate, they can go to the academic affairs office to have their course grades certified and obtain corresponding credits. At the same time, certificate assessment stations are set up in the on-campus industry-academia integration training base to provide one-stop support services for students, such as training, simulation training and certificate examinations, to enhance students’ willingness to take the exams and the pass rate of the certificates.

### **5.4. Implementation Safeguards**

To ensure the effective implementation of the “position–course–competition–certificate” integration, three supporting mechanisms should be established. First, in terms of school–enterprise cooperation, a professional development committee should be jointly established by academic program leaders, enterprise technical supervisors, and competition guidance experts. A curriculum revision seminar should be held each semester to ensure that course content is aligned with job requirements and competition standards. Second, regarding the teaching staff, a rotation and industry practice system for teachers in enterprises should be established. Each

year, a group of core teachers should be selected for enterprise-based practical training, generally for no less than three months, enabling them to gain in-depth understanding of real production environments. At the same time, technical experts from enterprises should be appointed as part-time instructors to promote the integration of teaching and practical training. Third, in terms of resource development, an

integrated teaching resource database for the “position–course–competition–certificate” framework should be established. Digital resources such as job cases, competition materials, and vocational certificate item banks should be collected and integrated, and continuously updated and shared through a smart teaching platform (Fig 3).



**Figure 3.** Implementation Pathway for Talent Development Based on the Integration of “Positions, Courses, Competitions, and Certifications”

## 6. Evaluation of the Effectiveness of Curriculum Reform

A key aspect of evaluating the outcomes of the restructuring and promoting continuous improvement is the assessment of curriculum reform effectiveness. Based on the

mentioned research, a “four-dimensional, three-level” evaluation system has been established, covering four dimensions: student development, teaching quality, employer satisfaction, and social recognition. Within each dimension, both process-oriented and outcome-oriented indicators have been defined (Tab 1).

**Table 1.** “Four-Dimensional, Three-Tier” Evaluation System

Evaluation Criteria	Key Metrics	Data Source	Evaluation Cycle
Student Development	Vocational certification attainment rate, competition award rate, and job-major alignment rate	Academic Management System, Competition Records, Employment Statistics	Semester/Academic Year
Quality of Education	Percentage of students receiving high grades on course assessments, practical skills evaluations, and engagement in learning	Grade Analysis, Skills Assessments, Learning Behavior Data	Semester
Corporate Satisfaction	Time to job adaptation, employer evaluations, and percentage of students receiving high grades on internship assessments	Corporate Surveys, Internship Evaluations	Academic Year
Public Recognition	Program enrollment rate, starting salaries for graduates, and career development tracking	Admissions Data, Salary Surveys, Alumni Tracking	Academic Year

## 6.1. Analysis of Expected Outcomes

Based on the practical experience of curriculum reform in similar institutions and related research analysis, the expected outcomes of the curriculum system reform will be positive in terms of vocational ability cultivation, enterprise recognition, and employment quality. By promoting the "integration of courses and certificates", embedding the assessment content of "1+X" vocational skills level certificates into the course teaching, the expected rate of students obtaining vocational skills level certificates is expected to increase from 45% before the reform to over 85%. Among them, the rate of obtaining intermediate certificates will reach 100%, and the rate of obtaining advanced certificates will exceed 30%. At the same time, relying on the "integration of courses and competitions" and the regular skill training mechanism, the proportion of students participating in provincial-level and above skill competitions is expected to increase from less than 30% to over 60%, the winning rate has improved compared to before the reform, and good results have been achieved in competition items such as production and control of intelligent manufacturing units and industrial robot system integration.

With the support of school-enterprise collaborative education and real project-based training, the expected job adaptation period for graduates is reduced from six months to within three months. The overall enterprise satisfaction score is expected to exceed 90 points. Employers' evaluation of students' ability to solve complex engineering problems and teamwork skills is also expected to improve. At the same time, the curriculum reform is expected to have a positive impact on employment quality. The proportion of students obtaining employment aligned with their major is expected to increase from 65% to over 85%. The proportion of graduates entering technical positions such as intelligent design, production line debugging, and process optimization has increased, and the average starting salary is expected to increase by 15%–20% compared with the pre-reform level.

## 6.2. Continuous Improvement Mechanism

To further improve curriculum development, a dynamic management cycle of "assessment–diagnosis–improvement" should be established. At the end of each academic year, the college should conduct a quality analysis of course teaching, comprehensively diagnose teaching implementation, and, based on data from annual enterprise satisfaction surveys and graduate follow-up visits, identify student training outcomes and enterprise needs. Based on the diagnostic results, which serve as an important basis for reforming course content, teaching methods, and teaching resource allocation, continuous improvement of curriculum development should be promoted. In addition, a dynamic course revision system should be established. In line with industrial technological development and changes in job competency requirements, the curriculum system should be systematically revised every two years to ensure that course content maintains dynamic alignment with industrial demands.

## 7. Conclusion

The restructuring of the curriculum system for the

vocational undergraduate major in intelligent manufacturing is an objective necessity driven by the context and emerging requirements of the intelligent manufacturing industry, and it is also an inherent requirement for achieving the training objectives of vocational undergraduate education. This study begins with a competency map, extracts new job competency requirements in the context of intelligent manufacturing, and identifies problems in the traditional curriculum system of the major. On this basis, a curriculum system consisting mainly of "two platforms and three modules" is designed, and curriculum reform is promoted through the integration of "job–course–competition–certificate." At the same time, a corresponding evaluation index system for teaching effectiveness is established. The results indicate that the key to curriculum system restructuring lies in the organic integration of "vocational orientation" and "higher education," and that achieving this integration requires an institutional mechanism of joint participation by schools and enterprises and dynamic adaptation. Future research may further introduce emerging technologies such as digital twin and artificial intelligence into curriculum teaching and conduct coordinated reforms and practices across multiple provinces, cities, and institutions, in order to provide more comprehensive theoretical support and practical references for the high-quality development of vocational undergraduate education.

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