

Construction of a Craftsmanship-Oriented Talent Cultivation System for Vocational Undergraduate Education Serving Intelligent Manufacturing in China

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Abstract: China's manufacturing sector is shifting toward intelligent manufacturing under national policy guidance. This shift increases the demand for advanced technical talent with strong judgment and system understanding. However, many vocational undergraduate training models remain skill-centered. This study examines how vocational undergraduate education can better serve intelligent manufacturing in China. It proposes a craftsmanship-oriented talent cultivation system. Craftsmanship is defined as a capability structure rather than a cultural concept. The study analyzes system design and implementation conditions. It shows that coordinated reform across objectives, curriculum, practice, and evaluation is necessary. It also shows that such a system is feasible under existing institutional conditions. This study provides a system-oriented framework for improving advanced technical talent cultivation in vocational undergraduate education.

Keywords: Vocational undergraduate education; China Intelligent manufacturing; Craftsmanship-oriented talent; Talent cultivation system

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1. Introduction

China's manufacturing sector is shifting toward intelligent manufacturing. This direction has been clearly stated in national policies such as "Made in China 2025" and "the 14th Five-Year Plan for Intelligent Manufacturing Development." These policies emphasize digitalization, system integration, and high-quality production. This policy shift has changed the demand for technical talent. Enterprises now need workers who can understand production systems and make technical judgments. Operational skills alone are no longer sufficient. However, many existing training models remain skill-centered. Vocational undergraduate education has been positioned as an important part of the modern vocational education system. Recent national policy documents call for

strengthening high-level technical talent cultivation and improving the connection between education and industry. Yet current cultivation models still struggle to respond to the complexity of intelligent manufacturing. This study addresses this gap. It proposes a craftsmanship-oriented talent cultivation system. Craftsmanship is defined as a capability structure rather than a cultural slogan. The focus is on judgment, responsibility, and system understanding. The study analyzes system design and implementation conditions. It aims to explain how vocational undergraduate education can better serve intelligent manufacturing in China.

2. Connotation and theoretical foundations of the craftsmanship-oriented talent cultivation system

2.1. Connotation of the Craftsmanship-Oriented Talent Cultivation System

China's intelligent manufacturing sector is developing rapidly and placing new demands on talent. In 2024, the industry's equipment manufacturing scale reached approximately CNY 3.6 trillion, and it is expected to grow to about CNY 5.8 trillion by 2026. Job opportunities are expanding, and demand for high-level technical talent continues to rise.

A craftsmanship-oriented talent cultivation system is not a simple training of skills, nor is it the use of a single teaching method. It is a systematic arrangement that integrates cultivation goals, curriculum content, practical activities, assessment mechanisms, and educational actors. At its core, the system aims to develop students' ability to make sound technical judgments and perform tasks in complex environments.

Unlike traditional talent cultivation models, a craftsmanship-oriented system emphasizes holistic capability development rather than proficiency in a specific skill. It requires students to engage in repeated practice in real or highly simulated production scenarios and to gradually build professional judgment and practical experience. In intelligent manufacturing environments, technical systems are complex and highly integrated. Job roles involve not only operations, but also data analysis, process optimization, and cross-team collaboration. This requires talents to have system thinking, continuous learning ability, and a sense of responsibility for quality and efficiency.

Therefore, the craftsmanship-oriented talent cultivation system is a structured arrangement aimed at long-term career development. By aligning key elements of talent cultivation, it supports vocational undergraduate education in better serving the development of China's intelligent manufacturing sector.

2.2. Talent cultivation transformation under China's intelligent manufacturing context

China's manufacturing sector is advancing into a stage of high-quality development, with intelligent manufacturing as a core driver of industrial upgrading. In 2024, total R&D investment in the manufacturing industry reached about CNY 2.16 trillion, an increase of roughly 13% from the prior year, with notable growth in intelligent manufacturing technologies. These shifts have accelerated the adoption of smart equipment and digital processes in factories. At the same time, the proportion of the working-age population (ages 15–59) declined to 64.2% by the end of 2024, shrinking the available labor pool. These dynamics are intensifying industry competition for high-skilled talent.

The requirements for technical personnel in intelligent manufacturing have moved beyond singular operational skills to demand a range of integrated competencies. Recent labor market reports indicate that the need for "multi-skilled technical professionals" in smart manufacturing jobs has risen by nearly 60% over the past three years, and this trend is expected to continue. Key employer priorities now include data analysis,

intelligent equipment configuration, system collaboration, and production process optimization.

Traditional talent cultivation models have focused primarily on mastery of discrete skills and standardized procedures. However, in highly integrated intelligent manufacturing systems, such an approach falls short of meeting complex production requirements. Employers increasingly expect graduates to understand the interconnections among system components and to make sound decisions in the face of on-site anomalies. This demands a shift in education from a skill-centric focus toward the formation of systemic professional capabilities.

Thus, the development of intelligent manufacturing in China is driving a shift in talent cultivation from “quantity of skills” toward “quality of competence.” This shift is not only a response to current industrial needs but also a strategic orientation toward future competitiveness. Vocational undergraduate education plays a critical role in this transition and must build a system to support the development of integrated technical professionals rather than simply producing isolated skill sets.

2.3. The role of vocational undergraduate education in cultivating craftsmanship-oriented talent

Within China’s higher education system, vocational undergraduate education represents a distinct institutional type with clear characteristics. It differs from academically oriented undergraduate programs that prioritize research, and it is also distinct from vocational colleges that focus primarily on short-term skill training. Its positioning is oriented toward addressing talent development in complex technical contexts, which makes it a suitable institutional foundation for cultivating craftsmanship-oriented talent.

In terms of cultivation objectives, vocational undergraduate education emphasizes the parallel development of technical competence and theoretical understanding. Students are expected not only to perform operations but also to comprehend technical principles, process logic, and system structures. This objective aligns closely with the requirements of intelligent manufacturing, where technical challenges are rarely isolated and are often embedded within integrated systems. The ability to understand system operations and make informed judgments in practice is a defining feature of craftsmanship-oriented talent.

Regarding the cultivation process, vocational undergraduate education provides institutional conditions for long-term and progressive practice-based learning. Compared with short-cycle, task-oriented training models, vocational undergraduate programs place greater emphasis on the accumulation of practical experience and the gradual formation of capability structures^[1]. This process-oriented approach allows students to repeatedly test their judgments in real or highly simulated production environments and to refine their behavioral patterns through reflective practice.

From a functional perspective, vocational undergraduate education plays a bridging role between the education system and industrial practice. It ensures systematic cultivation through structured curricula and degree programs, while maintaining close alignment with industry needs through practical training and university–enterprise collaboration. This dual characteristic enables vocational undergraduate education to support craftsmanship-oriented talent development without detaching from real production conditions or being constrained by short-term job requirements.

Therefore, from the perspective of type positioning, vocational undergraduate education should not be viewed as a simple extension of vocational college education, nor as an imitation of general undergraduate programs. Rather, it constitutes an independent educational type oriented toward industrial upgrading and technological advancement. Under the context of China’s intelligent manufacturing development, this positioning provides a solid institutional foundation for constructing a craftsmanship-oriented talent cultivation system.

2.4. Theoretical foundations supporting the craftsmanship-oriented talent cultivation system

The craftsmanship-oriented talent cultivation system is not an experiential proposal detached from educational theory. Rather, it is grounded in well-established learning theories that address how professional competence is formed in real contexts, rather than how knowledge is merely transmitted.

Situated learning theory suggests that professional competence does not emerge in abstract settings but is gradually internalized through sustained participation in specific practice contexts. Core attributes of craftsmanship-oriented talent, such as quality awareness, technical judgment, and professional responsibility, cannot be acquired through classroom instruction alone. They must be cultivated within real or highly simulated production environments. This provides a theoretical foundation for positioning practical scenarios at the center of the talent cultivation system.

Constructivist learning theory further emphasizes that learning is an active process of meaning construction rather than passive knowledge reception ^[2]. In craftsmanship-oriented talent development, learners form understanding through repeated trial, reflection, and adjustment. This requires a cultivation system that offers open problem contexts and continuous feedback, allowing learning activities themselves to become a key mechanism of capability formation.

From the perspective of cognitive science, distributed cognition theory offers important insights into competence development in intelligent manufacturing environments. In modern manufacturing systems, cognitive activities are distributed across individuals, tools, and environments. Craftsmanship-oriented talent relies not only on personal experience but also on digital tools, system interfaces, and collaborative networks to make judgments and decisions. This characteristic necessitates a cultivation system that pays close attention to the interaction between humans and technical systems.

In addition, practice-based learning theories help explain the long-term and progressive nature of craftsmanship-oriented talent development. Competence is not formed instantaneously; it stabilizes through repeated practice over time. Vocational undergraduate education, with its extended training cycle and structured practical arrangements, provides an institutional space that aligns well with this developmental pathway.

Taken together, the craftsmanship-oriented talent cultivation system does not seek to establish a new theoretical paradigm. Instead, it represents an integrative application of established learning theories within the context of intelligent manufacturing. This theoretical grounding ensures its academic legitimacy and offers a stable foundation for the system construction discussed in subsequent sections.

3. Construction of the craftsmanship-oriented talent cultivation system

3.1. Reconstructing cultivation objectives: Re-defining competency structures for intelligent manufacturing

Within a craftsmanship-oriented talent cultivation system, cultivation objectives are not limited to answering what skills should be taught. Rather, they address a more fundamental question: how technical competence is formed and stabilized within intelligent manufacturing contexts. This shift implies that cultivation objectives must move beyond task-based job requirements toward a systematic definition of competency structures.

Under traditional manufacturing conditions, job boundaries were relatively clear and skill requirements were decomposable. Talent cultivation typically focuses on operational procedures and proficiency, emphasizing whether tasks can be performed correctly and efficiently. In contrast, intelligent manufacturing systems are highly

integrated, with equipment, data, and processes deeply intertwined. Job responsibilities are no longer centered on isolated tasks but continuously adjusted according to system states. As a result, skill-based objectives alone are insufficient to meet real workplace demands.

In this context, the core of craftsmanship-oriented talent is not reflected in the accumulation of multiple skills, but in the stability of competency structures. Such structures generally involve three interrelated dimensions. First is the ability to understand technical principles and system logic, enabling individuals to identify underlying causes beyond surface-level operations. Second is the capacity to make technical decisions under uncertain conditions and to assume responsibility for their consequences—an ability that is both scarce and difficult to cultivate through short-term training. Third is the ability to maintain quality standards and process discipline within collaborative production systems, which determines the long-term reliability of technical performance.

Accordingly, the reconstruction of cultivation objectives does not involve adding more competency indicators. Instead, it redefines the hierarchical relationships and developmental sequence among competencies. The craftsmanship-oriented system emphasizes a progression from instruction-dependent execution, to judgment based on understanding and ultimately to accountability for system outcomes^[3]. This progression requires sustained time and structured experience, and cannot be achieved through compressed training or fragmented curricula.

The unique value of vocational undergraduate education lies in its capacity to accommodate such long-term, structured competency formation. Compared with training models oriented toward immediate job readiness, competency-structure-oriented objectives prioritize learners' adaptability to future technological change. Rather than matching specific job roles, these objectives aim to establish stable competency structures that enable professional judgment and technical responsibility across evolving work contexts.

Therefore, the reconstruction of cultivation objectives within a craftsmanship-oriented talent cultivation system represents an institutional response to system complexity. It provides a unified competency reference for subsequent curriculum design, practical arrangements, and evaluation mechanisms, and serves as the logical starting point for the entire cultivation system.

3.2. Reorganizing curriculum and practice structures: An organizational logic for competency formation

Within a craftsmanship-oriented talent cultivation system, the organization of curriculum and practice directly determines whether competence can genuinely develop. Once cultivation objectives move beyond the accumulation of skills toward the formation of stable competency structures, curriculum design that remains focused on fragmented knowledge or task lists becomes a critical weak point.

For a long time, curricula have been organized around what content should be taught. This approach worked reasonably well when knowledge was stable and job boundaries were clear. In intelligent manufacturing contexts, however, learners are not confronted with isolated tasks but with continuously changing system conditions. When learning content lacks internal connection, students may complete operations successfully yet struggle to identify problems or explain their own decisions.

Craftsmanship-oriented cultivation places different demands on curriculum structure. Courses should no longer function as collections of content but be organized according to the sequence through which competence develops. Certain capabilities must be established before others can meaningfully emerge. Without an initial understanding of system structure and technical principles, complex practice often turns into imitation rather than

learning. Similarly, practice without opportunities for judgment rarely leads to stable professional competence.

From this perspective, modularization is not a matter of formal course division. Its value lies in whether it reflects the staged nature of competency formation. Early modules are better suited for building an understanding of how systems operate. Intermediate modules should expose learners to uncertainty and require decision-making. Advanced modules, through more demanding collaborative tasks, gradually make learners aware of the consequences and responsibilities attached to technical decisions. These modules are sequential rather than parallel.

Practice occupies a central position in this structure, but it must also be carefully organized. Tasks that are too simple fail to reveal the importance of judgment, while overly complex tasks introduced too early tend to result in superficial compliance. Effective practice maintains a balance between challenge and feasibility, allowing learners to develop judgment through repeated engagement.

Vocational undergraduate education offers favorable conditions for such reorganization. Its extended training cycle avoids excessive compression of developmental processes, while the institutional emphasis on both theory and practice allows adjustments in learning focus across stages. This makes curriculum restructuring based on competency formation a realistic option rather than a theoretical ideal.

In this sense, reorganizing curriculum and practice structures is not merely a change in teaching form. It is a systemic response to the question of how competence can be gradually supported and stabilized. Only when curriculum content, practice tasks, and time arrangements work together can a craftsmanship-oriented talent cultivation system function as intended.

3.3. Reconstructing evaluation and feedback mechanisms: Making competency formation observable and adjustable

Within a craftsmanship-oriented talent cultivation system, evaluation is not a peripheral component. It directly affects whether the cultivation logic can function as intended. If evaluation remains focused solely on outcome verification, adjustments in curriculum and practice structure may fail to translate into genuine competency development.

Traditional evaluation methods typically emphasize task completion and operational correctness. Such approaches are workable when skill objectives are clear, and procedures are stable. In intelligent manufacturing contexts, however, many critical competencies are embedded in processes rather than final results. How learners identify problems, adjust strategies, and assume responsibility in collaborative settings often cannot be captured through one-time assessments.

Craftsmanship-oriented cultivation demands a different evaluation orientation^[4]. Evaluation should move beyond confirming results and toward revealing the trajectory of competency formation. This requires attention to learners' reasoning processes, decision logic, and behavioral changes during practice, rather than focusing solely on whether an answer is correct. Only when these process-related aspects become visible can the cultivation system remain adjustable.

Within this framework, feedback mechanisms become particularly important. When evaluation provides only summative conclusions at the end of a stage, learners often struggle to understand where their capabilities fall short. Continuous feedback, by contrast, enables learners to revise their judgments during practice, allowing competence to stabilize through iterative adjustment. Such feedback does not rely on frequent scoring but on timely identification of critical deviations.

Vocational undergraduate education offers practical conditions for reconstructing evaluation and feedback

mechanisms. Its relatively high proportion of practice-based learning generates abundant process-related information, while stable instructional arrangements make phased feedback feasible during learning activities. As a result, evaluation does not need to be compressed into a single outcome but can function as part of the competency formation process.

In this sense, reconstructing evaluation and feedback mechanisms is not about increasing assessment complexity. It is about making the process of competency development visible, understandable, and adjustable. Only when evaluation serves this function can a craftsmanship-oriented talent cultivation system avoid becoming merely formalistic.

4. Implementation conditions and operational guarantees of the craftsmanship-oriented talent cultivation system

4.1. Rebuilding faculty practice capacity through authentic engineering engagement

Within a craftsmanship-oriented talent cultivation system, the effectiveness of practical teaching largely depends on instructors' ability to make sound instructional judgments. When faculty roles remain confined to content delivery or procedural demonstration, even well-equipped practice platforms may lead to task completion without fostering stable technical judgment among students.

In intelligent manufacturing contexts, the core challenge of practical teaching lies not in equipment operation, but in dealing with uncertainty. Whether instructors have encountered real production anomalies and understand how enterprises balance quality, efficiency, and safety directly influences how they design tasks and intervene during practice. As a result, faculty support should shift from static indicators of engineering background toward sustained engagement with authentic engineering processes.

Some vocational undergraduate institutions have explored workable approaches. In intelligent manufacturing and equipment-related programs, several institutions have established faculty engineering participation mechanisms^[5]. Partner enterprises provide contexts such as process optimization, technical upgrades, or production line adjustments, while instructors participate as observers or auxiliary contributors. Faculty members are not responsible for production targets, but they are involved in problem identification, solution discussion, and post-implementation review. Such participation enables instructors to grasp real decision-making logic and translate it into teaching judgment.

This experience directly shapes the teaching organization on campus. In practice-oriented courses, some instructors no longer provide predefined solutions. Instead, they design tasks around possible problem types and guide students to compare the consequences of different responses. These arrangements emphasize reasoning processes rather than task completion, reflecting instructors' familiarity with real engineering contexts.

To support sustained faculty practice capacity, some institutions have adjusted evaluation systems. In intelligent manufacturing programs, practice teaching organization quality has been incorporated into faculty assessment, reducing exclusive reliance on publication counts or classroom hours. Participation in enterprise projects, engineering investigations, and course restructuring is recognized as part of the instructional workload, lowering institutional barriers to faculty engagement.

Overall, enhancing faculty practice capacity does not depend on recruiting a small number of industry experts. It requires establishing routine mechanisms for engineering participation. Only when instructors develop an understanding of real engineering problems can practical teaching shift from operational training toward judgment-oriented learning, providing a stable foundation for a craftsmanship-oriented talent cultivation system.

4.2. Reconstructing practice platforms and authentic scenarios: Enabling continuous exposure to real manufacturing problems

In a craftsmanship-oriented talent cultivation system, the effectiveness of practice platforms is determined not by the sophistication of equipment, but by whether students are repeatedly exposed to real manufacturing problems. When practice environments are dominated by demonstration and verification, learners encounter pre-simplified tasks, limiting the role of practice in competency development.

Some vocational undergraduate institutions have avoided full replication of industrial production lines and instead adopted an approach of embedding key process segments. In intelligent equipment and automation training, campus platforms retain critical elements such as equipment selection, parameter configuration, and quality inspection, while excluding components closely tied to production rhythm or commercial decisions. Within these constrained scenarios, students repeatedly practice judgment and adjustment rather than attempting to operate entire lines. This approach allows core manufacturing problems to be addressed even under limited resources.

Virtual platforms, including manufacturing execution systems (MES) or production simulations, are also used selectively. In practice, these systems serve primarily as decision-making carriers rather than objects of instruction. Teachers design tasks around common scenarios such as equipment anomalies, quality fluctuations, or scheduling conflicts. Students analyze system data, make decisions, and explain their reasoning. Operational fluency with the system is not the evaluation focus; reasoning quality is.

Authentic scenario integration is further constrained by safety and cost considerations. Some institutions have negotiated with local manufacturing firms to embed student practice into trial production or auxiliary roles. During equipment commissioning or process validation phases, students assist with data collection, parameter comparison, and post-task review under engineer supervision. Although these activities do not affect output directly, they expose students to real production constraints related to quality and time. This low-risk embedding approach has proven more sustainable in practice.

Practice platform operation also faces the challenge of underutilization. To address this, some institutions link platform usage directly to course assessment and program evaluation, requiring core practice courses to be conducted through designated platforms. Coordinated maintenance by instructors, technical staff, and enterprise engineers ensures that platform content evolves alongside industrial processes.

Overall, reconstructing practice platforms and authentic scenarios is not a one-time project, but an ongoing process of adjustment. By establishing clear boundaries between virtual and real environments, students can repeatedly engage with genuine manufacturing problems under controlled conditions, enabling practice-based learning to fulfill its role in competency formation.

4.3. Reconstructing university–enterprise collaboration mechanisms: Securing long-term cooperation through institutional boundaries

Within a craftsmanship-oriented talent cultivation system, university–enterprise collaboration is not an optional enhancement, but a prerequisite for the sustained operation of practice-based learning. In practice, cooperation often breaks down not due to lack of willingness, but because of unclear responsibility boundaries and inadequate risk-sharing mechanisms.

In intelligent manufacturing contexts, enterprises are highly sensitive to production stability and risk control. When collaboration is limited to providing internship positions, student practice is often the first activity to be reduced under production or safety pressure^[6]. To address this, some institutions have shifted collaboration from

project-based arrangements to institutional embedding, clarifying boundaries to reduce enterprise concerns.

In concrete terms, several vocational undergraduate institutions explicitly distinguish between “educational practice” and “production operations” in cooperation agreements. Student activities are confined to low-risk tasks such as data collection, process observation, parameter comparison, and problem review, while critical operations remain the responsibility of enterprise staff. Although this limits students’ direct operational involvement, it significantly improves collaboration stability and allows practice arrangements to continue over time.

Regarding responsibility allocation, some institutions have adopted dual-responsibility frameworks. During practice activities, universities assume responsibility for instructional organization and student conduct, while enterprises remain responsible for production safety and equipment operation. Written procedures clarify risk ownership when practice is embedded in real settings, preventing cooperation from collapsing due to liability disputes. These arrangements do not eliminate risk entirely, but make it manageable.

The sustainability of collaboration also depends on the visibility of benefits for enterprises. In some regions, institutions provide technical support, staff training, or data organization services to partner firms. For instance, process records or problem analyses completed by students during practice are consolidated and fed back to enterprises for improvement purposes. While such outputs may not generate direct economic returns, they reduce the hidden costs of participation.

To avoid overreliance on personal relationships, some institutions embed collaboration mechanisms within program and curriculum structures. Partner enterprises engage with academic programs rather than individual instructors, reducing vulnerability to staff turnover and enhancing the stability of practice resources.

Overall, reconstructing university–enterprise collaboration mechanisms is not about increasing the number of cooperative projects. It is about reducing friction through clear institutional boundaries and responsibility allocation. Only when enterprises can participate under manageable risk conditions can a craftsmanship-oriented talent cultivation system operate sustainably.

5. Conclusion

This study examines how vocational undergraduate education in China can support intelligent manufacturing. It focuses on the construction of a craftsmanship-oriented talent cultivation system. In this study, craftsmanship is treated as a capability structure. It is not defined as a value slogan or cultural label. The study shows that skill-centered training models are no longer sufficient. Intelligent manufacturing systems are complex and change frequently. Work tasks involve uncertainty. In this context, technical judgment and responsibility are more important than isolated skills. Effective talent cultivation requires coordinated reform. Cultivation objectives must be clear. Curriculum and practice structures must support capability formation. Evaluation mechanisms must focus on learning processes. Isolated adjustments are not enough. The study also examines implementation conditions. These include faculty engagement in real engineering work. They also include virtual–real integrated practice platforms. Boundary-based university–enterprise collaboration is another key condition. The analysis shows that these measures are feasible under current institutional constraints. The study finds that sustainability does not depend mainly on resource expansion. It depends on a clear role definition. It depends on manageable risk. It also depends on stable organizational arrangements. This study contributes a system-oriented framework. The framework links capability formation with institutional design in vocational undergraduate education. The analysis is mainly conceptual. Future research can use longitudinal data. Comparative studies are also needed.

Disclosure statement

The author declares no conflict of interest.

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