

# Practical Application of Innovation and Entrepreneurship Education for Undergraduates in the Intelligent Manufacturing Engineering Program Based on the OBE Approach

Xiaoyuan Zhang \*, Mengmeng Pei

School of Intelligent Engineering, Jinzhong College of Information, Jinzhong, Shanxi, China

\* Corresponding author: Xiaoyuan Zhang

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**Abstract:** Driven by the “Industry 4.0” and “Made in China 2025” strategies, the intelligent manufacturing industry increasingly demands composite talents integrating “technology, innovation, and entrepreneurship.” However, innovation and entrepreneurship education in university intelligent manufacturing engineering programs faces challenges such as curriculum-industry disconnect, single-dimensional evaluation, and lack of practical application. The OBE approach, centered on “student learning outcomes,” offers a scientific methodology to overcome these limitations. This paper, grounded in the core tenets of OBE, integrates the disciplinary characteristics of intelligent manufacturing engineering with industry demands. It constructs a training objective framework centered on “three-dimensional foundational qualities and three core competencies,” designs a three-tiered curriculum system comprising “general education foundation layer+professional core layer+innovation and entrepreneurship specialty layer,” and establishes an extracurricular scientific and technological innovation activity system driven by competitions, supported by platforms, and led by projects. Reform pathways are proposed across dimensions of teaching content, modes, and methods. This research aims to achieve deep integration between innovation and entrepreneurship education and professional education, providing practical solutions for optimizing and upgrading innovation and entrepreneurship education in university intelligent manufacturing engineering programs. It contributes to cultivating innovative and entrepreneurial talents suited to industrial development.

**Keywords:** Intelligent Manufacturing; Innovation and Entrepreneurship; OBE; Curriculum System.

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## 1. Introduction

At the convergence of a new wave of technological revolution and industrial transformation, smart manufacturing-as the core engine driving the transformation and upgrading of the manufacturing sector-is reshaping the global industrial competitive landscape through strategic initiatives such as “Industry 4.0” and “Made in China 2025” [1]. As the key bridge connecting advanced manufacturing technologies with talent development, the quality of graduates from smart manufacturing engineering programs directly determines China's core competitiveness in this field. Currently, industry demand for smart manufacturing talent has shifted from traditional technical application to composite “technology+ innovation+ entrepreneurship” capabilities. Practitioners must not only master core technologies like industrial robotics, intelligent sensing, and digital twins but also possess innovative thinking to overcome technical bottlenecks and entrepreneurial skills to translate technology into tangible value [2-4]. However, innovation and entrepreneurship education in China's smart manufacturing engineering programs still faces significant challenges: Curriculum design remains disconnected from industry needs, often prioritizing theoretical instruction over practical engineering scenarios; Teaching evaluations focus on knowledge acquisition while inadequately assessing core competencies like innovation commercialization and teamwork; Extracurricular innovation activities remain disconnected from classroom instruction, preventing the formation of a closed-loop system integrating “knowledge

acquisition-skill development-outcome implementation.” Consequently, graduates often “understand technology but lack creativity, possess ideas but struggle with implementation,” failing to meet the practical demands of high-quality industrial development [5].

Outcome-Based Education (OBE), an internationally recognized advanced educational philosophy, centers on “student learning outcomes.” By reverse-engineering instructional objectives, restructuring teaching systems, and innovating pedagogical models, it achieves a closed-loop talent cultivation process that “starts with the end in mind.” This approach provides a scientific methodological foundation for overcoming the challenges in innovation and entrepreneurship education within the Intelligent Manufacturing Engineering discipline. Unlike traditional educational approaches, OBE emphasizes that educational activities must revolve around core competencies and competency goals students should possess. It translates industry demands and student development needs into specific learning outcomes, using these as the basis for designing curricula, organizing teaching processes, and implementing diverse assessments. Integrating OBE into innovation and entrepreneurship education for the Intelligent Manufacturing Engineering program not only shifts the educational focus from “what to teach” to “what to learn and what to be able to do,” but also achieves deep integration between innovation/entrepreneurship education and professional education. This ensures that the cultivation of innovative thinking and entrepreneurial skills permeates the entire learning process of intelligent manufacturing technologies.

Based on this, this paper anchors its exploration in the core tenets of the Outcome-Based Education (OBE) philosophy. By integrating the disciplinary characteristics of the Intelligent Manufacturing Engineering program with industry demands, it systematically investigates practical pathways for innovation and entrepreneurship education. Through defining the competency requirements for interdisciplinary talent in intelligent manufacturing, it constructs a trinity-based innovation and entrepreneurship teaching system comprising "Curriculum Framework -extracurricular practice-outcome transformation." It advances teaching reform across three dimensions-curriculum content, teaching models, and pedagogical methods-aiming to integrate the talent development chain of "knowledge transmission-capability cultivation-value shaping." This study provides a practical framework for optimizing innovation and entrepreneurship education in university smart manufacturing engineering programs, fostering more innovative and entrepreneurial talents who meet the evolving demands of the smart manufacturing industry.

## **2. Core Principles and Characteristics of the Obe Approach**

Originating from American educational reform practices in the 1980s, OBE has evolved over decades into one of the core guiding principles for enhancing global higher education quality. Its fundamental logic lies in "starting with the end in mind," positioning student learning outcomes as both the starting point and ultimate goal of educational activities. Through backward design, it achieves precision and efficiency in talent cultivation[6]. Compared to traditional educational philosophies, OBE exhibits distinct characteristics: First, a return to student agency, shifting the educational focus from "how teachers teach" to "how students learn," emphasizing active student participation and competency development throughout the learning process. Second, a practical orientation, closely aligning with industry demands to ensure learning outcomes directly serve career advancement and societal needs. Third, it adopts diversified assessment, moving beyond single-exam models to combine formative and summative evaluations that comprehensively measure knowledge acquisition, competency development, and overall growth. Fourth, it emphasizes systemic reconstruction, focusing on holistic optimization of teaching systems to achieve organic integration between courses, theory and practice, and in-class/out-of-class activities, thereby preventing fragmented educational processes. These characteristics enable the OBE philosophy to effectively address the challenges of "disconnect between teaching and learning, and separation between learning and application" in higher education, providing a solid theoretical foundation for integrating professional education with innovation and entrepreneurship education.

## **3. The Intrinsic Compatibility between Obe Principles and Innovation-Entrepreneurship Education in the Intelligent Manufacturing Engineering Program**

As an interdisciplinary field integrating knowledge from mechanical engineering, electronic technology, computer

science, artificial intelligence, and other disciplines, innovation- entrepreneurship education in Intelligent Manufacturing Engineering transcends a simple combination of "technical expertise+entrepreneurial skills." Instead, it constitutes a composite educational approach anchored in core intelligent manufacturing technologies, guided by innovative thinking, and centered on entrepreneurial capabilities. The OBE philosophy and innovation-entrepreneurship education in the Intelligent Manufacturing Engineering program exhibit a high degree of intrinsic alignment in their objectives, logic, and implementation pathways. This alignment provides both feasibility and inevitability for their deep integration. Regarding objective alignment: OBE aims to cultivate high-caliber talent meeting societal needs, while the core objective of innovation and entrepreneurship education in Intelligent Manufacturing Engineering is to develop versatile professionals equipped with "technology+innovation+entrepreneurship" skills tailored to industrial demands. Both emphasize precise alignment between talent development and practical needs, preventing waste of educational resources and mismatched talent cultivation. In terms of logical alignment, the "backward design" logic of OBE aligns closely with the "demand-driven" logic of innovation and entrepreneurship education in the Intelligent Manufacturing Engineering program. The former requires designing teaching components based on learning outcomes, while the latter sets training objectives according to industrial needs. Both follow a reverse construction approach of "demand-objective-pathway," ensuring the relevance and effectiveness of educational activities. In terms of path alignment, the implementation approach emphasized by OBE-integrating theory with practice, bridging classroom and extracurricular activities, and linking assessment with improvement-highly matches the requirements of innovation and entrepreneurship education in the Intelligent Manufacturing Engineering program. This includes establishing technical practice platforms, innovation incubation vehicles, and diversified evaluation systems, providing systematic support for the implementation of innovation and entrepreneurship education.

Specifically, this alignment manifests in three aspects: First, regarding talent development objectives, the OBE philosophy requires translating industry demands into concrete learning outcomes. The goal of innovation and entrepreneurship education in the Intelligent Manufacturing Engineering program is precisely to convert the innovation needs of the intelligent manufacturing industry into students' technological innovation capabilities and entrepreneurial practice skills. Both converge toward a competency-based talent development objective. Second, in curriculum design, the OBE approach emphasizes selecting teaching content based on learning outcomes. This drives the innovation and entrepreneurship education in the Intelligent Manufacturing Engineering program to break down disciplinary barriers, integrate multidisciplinary knowledge and industrial resources, and construct a curriculum framework centered on "technical core+innovation modules+entrepreneurial support." Third, in assessment implementation, the OBE-advocated diversified evaluation methods meet the multidimensional assessment needs of innovation and entrepreneurship education in intelligent manufacturing engineering-covering students' innovative achievements, practical abilities, and teamwork skills-while overcoming the limitations of traditional evaluation methods in measuring innovation and

entrepreneurship capabilities. It is precisely this inherent alignment that makes the OBE approach an ideal methodology for guiding the reform of innovation and entrepreneurship education in intelligent manufacturing engineering.

## **4. Building an Innovation and Entrepreneurship Teaching System for the Intelligent Manufacturing Engineering Program**

Guided by the core logic of “outcomes-based education” (OBE), and considering the interdisciplinary nature and practical focus of the Intelligent Manufacturing Engineering program alongside industry demands for versatile professionals, we establish a closed-loop innovation and entrepreneurship teaching system. This system follows a three-step approach: defining competency objectives, constructing a supporting curriculum framework, and strengthening extracurricular practice. This ensures precise alignment between educational outcomes and industry needs.

### **4.1. Competency and Capability Requirements**

Anchored by “learning outcomes” under the OBE framework, and aligned with smart manufacturing industry trends and program objectives, we define core development goals for innovation-entrepreneurship talent across two dimensions: competencies and capabilities. This forms a training framework centered on “three-dimensional foundational qualities and three core capability categories.”

The competency framework centers on a three-dimensional structure of “values, spirit, and ethics,” providing intrinsic support for innovation and entrepreneurship practices. First, value-driven competencies emphasize students' unwavering commitment to serving the nation through engineering and their sense of social responsibility. They must fulfill the mission of building a manufacturing powerhouse through technological innovation in intelligent manufacturing—for instance, prioritizing national industrial security and public welfare needs in smart equipment R&D. Second, innovative spirit cultivates students' pioneering exploration, meticulous craftsmanship, and lifelong learning mindset. This enables them to adapt proactively to the rapid technological evolution of smart manufacturing, confront setbacks during technical breakthroughs, and pursue continuous improvement. Third, ethical and regulatory competence requires students to master relevant laws, regulations, and industry ethics in intelligent manufacturing. They must uphold fundamental principles such as data security, intellectual property protection, and appropriate boundaries for technology application, thereby avoiding ethical and security risks like algorithmic bias and leakage of core technologies.

The competency requirements center on three core areas—“technological innovation, entrepreneurial practice, and cross-disciplinary integration”—to cultivate practical skills aligned with industry demands. First, technological innovation serves as the foundational core, requiring students to apply expertise in mechanical design, intelligent control, digital twins, and industrial internet to solve real-world problems in smart manufacturing. This includes capabilities in intelligent equipment enhancement, production process innovation, and new technology R&D. Second, entrepreneurial practice acts as the conversion safeguard, focusing on practical skills to transform technological

achievements into commercial value. This encompasses project planning, resource integration, team management, and market development. Third, cross-disciplinary integration is an imperative of our era. Leveraging the interdisciplinary nature of the field, it cultivates students' ability to synthesize knowledge from mechanical engineering, electronics, computer science, and business administration. This enables effective bridging between technology and commerce, theory and practice—for example, designing cost-effective smart production lines by integrating intelligent control technology with cost accounting principles.

### **4.2. Curriculum Framework**

Guided by the OBE “backward design” principle, this framework starts with “competency and capability requirements” as the endpoint. Working backward, it constructs a three-tiered curriculum system comprising the “General Education Foundation Layer+Professional Core Layer+Innovation and Entrepreneurship Specialization Layer.” This ensures precise alignment between course content and educational objectives, forming a closed-loop relationship where “courses support competencies, and competencies yield outcomes.”

The General Education Foundation Layer focuses on “innovation and entrepreneurship awareness and foundational literacy,” laying the groundwork for subsequent development. On one hand, it offers required courses such as “Fundamentals of College Student Innovation and Entrepreneurship” and “Innovative Thinking and Methods,” systematically covering foundational topics like innovation and entrepreneurship policies, innovative thinking tools, and business model design. On the other hand, it offers “Innovative Thinking and Methods,” systematically covering innovation and entrepreneurship policies, innovative thinking tools, and business model design. Simultaneously, courses like “Ideological Ethics and Rule of Law” and “Current Affairs and Policy” reinforce value guidance. Elective courses such as “Business Fundamentals” supplement essential entrepreneurial knowledge and enhance outcome protection capabilities. For instance, business courses guide students in applying for smart technology patents and mastering cost accounting methods for entrepreneurial projects.

The professional core layer emphasizes the integration of specialized knowledge and innovative capabilities, uncovering entrepreneurial and innovative elements within professional courses. Innovation projects and industry case studies are embedded within core curricula to advance knowledge transmission and competency development simultaneously: The “Fundamentals of Mechanical Design” course introduces an “Innovative Design of Intelligent Mechanical Structures” module, requiring students to design novel intelligent fixtures integrating hydraulic transmission knowledge; The “Programmable Controller Principles” course centers on the core task of “Developing PLC Control Systems for Intelligent Production Lines,” cultivating system design and debugging capabilities; the “Digital Twin Technology” course integrates real-world enterprise projects, guiding students to construct shop-floor-level digital twin models and optimize production processes. Simultaneously, elective courses such as “Intelligent Robotics Technology,” “Industrial Internet Applications,” and “Artificial Intelligence and Intelligent Manufacturing” address cutting-edge fields in

smart manufacturing, keeping pace with technological trends to provide knowledge support for innovation.

The Innovation and Entrepreneurship Track emphasizes “Practical Skills and Technology Commercialization” through a flexible “Required+Elective+Project” model. Required courses include “Smart Manufacturing Innovation and Entrepreneurship Practice,” requiring student participation in academic competitions or startup projects to gain hands-on experience. Electives such as “Smart Manufacturing Startup Case Analysis” and “Investment, Financing, and Startup Management” analyze technology commercialization pathways using case studies from companies like Sany Heavy Industry and Gree. Project-based courses focus on “real-world problems,” including projects like “Innovative Design of Intelligent Equipment” and “Optimization of Intelligent Manufacturing Systems.” Students complete the entire process—from conceptual design and prototype development to final presentation—in teams. High-quality projects may be directly linked to corporate needs for commercialization. The three-tiered curriculum uses a “course map” to clarify how each course supports competency development, ensuring progressive and effective achievement of educational objectives.

### 4.3. Extracurricular Science and Technology Innovation Activities

With the objectives of “extending classroom instruction, strengthening practical application, and promoting the commercialization of research outcomes,” we have established an extracurricular science and technology innovation activity system driven by competitions, supported by platforms, and guided by projects. This system bridges the critical links between classroom learning, extracurricular practice, and the commercialization of research outcomes, enabling the progressive enhancement of innovation and entrepreneurship capabilities.

**Competition-Driven Approach** We establish a dual-track mechanism combining “academic competitions+entrepreneurship contests” to stimulate learning through competition and ignite innovative drive. For academic competitions, we focus on cultivating technological innovation capabilities by organizing student participation in events such as the National College Students Mechanical Innovation Design Competition, Industrial Robot Technology Application Competition, and Intelligent Manufacturing System Simulation Competition. For instance, leveraging knowledge from the Intelligent Control course, teams are formed to compete in the Industrial Robot Path Optimization Contest, honing technological innovation skills through real-world application. For entrepreneurship competitions, the focus is on enhancing technology commercialization capabilities. Students are guided to package technological achievements from courses and research into entrepreneurial projects for competitions like the “Internet Plus” College Student Innovation and Entrepreneurship Competition and the “Challenge Cup.” They undergo comprehensive training covering business plan development and pitch presentations. Competition achievements are incorporated into credit recognition systems to boost student participation.

The platform supports the creation of a dual-track system combining “on-campus training with off-campus collaboration,” providing resource guarantees for practical training. On campus, leveraging facilities such as the Intelligent Manufacturing Laboratory, Industrial Robot

Training Center, and Digital Twin Simulation Platform, an “Innovation and Entrepreneurship Studio” has been established. Equipped with intelligent machinery, development software, and other resources, it supports students in independently undertaking projects like intelligent equipment upgrades and control algorithm research. Off campus, partnerships with intelligent manufacturing enterprises and research institutions have led to the establishment of “Industry-University Joint Innovation Bases” and “Entrepreneurship Incubation Centers” with smart manufacturing enterprises and research institutes, organizing student participation in real-world corporate projects—such as assisting partners in upgrading smart production lines—to accumulate practical experience in authentic settings. Concurrently, corporate resources are leveraged to establish the “Smart Manufacturing Innovation Fund,” providing funding and implementation channels for high-quality student projects.

**Project-Driven Approach** Implementing a three-tier system of “course projects+research projects+independent entrepreneurship projects” to institutionalize practical learning. Course projects integrate with classroom instruction, such as the “Intelligent Manufacturing System Course Design” requiring students to develop small-scale intelligent systems. Research projects leverage faculty research topics, encouraging student participation in studies like “Intelligent Robot Modeling” and “Industrial Big Data Analysis” to cultivate scientific innovation capabilities. Independent entrepreneurship projects empower students to initiate ventures addressing industry pain points, with the program providing technical guidance and policy consultation. For instance, projects like developing low-cost collaborative robots tackle manufacturing's labor shortage challenges. Selected projects may achieve commercialization through the university's entrepreneurial incubation platform. This three-tiered framework establishes a stepwise practical pathway: foundational practice→capability enhancement→outcome transformation.

## 5. Conclusion

Guided by the OBE philosophy, this paper systematically explores reform and implementation pathways for innovation and entrepreneurship education in the field of intelligent manufacturing engineering, addressing its current challenges. The established teaching system breaks down the traditional barriers between professional education and entrepreneurship training: the curriculum achieves an organic integration of general education, specialized knowledge, and innovation/entrepreneurship skills, while the extracurricular activity framework bridges classroom learning to practical outcomes. Together, these components support students' development in technological innovation, entrepreneurial practice, and cross-disciplinary integration. This framework not only addresses the “New Engineering” initiative's demand for cultivating multidisciplinary talents but also provides a talent pool for the intelligent manufacturing industry, demonstrating strong practical guidance value. Future research should further deepen the implementation effectiveness of this system to propel innovation and entrepreneurship education in intelligent manufacturing engineering toward higher-quality development.

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