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Research on the Construction of an Artificial Intelligence Curriculum System for the Integrated Undergraduate–Graduate Intelligent Manufacturing Program Cluster

Haiwei Zhang*, Chunping Liu, Yunlong Li, Qiming Fan, Huapeng Zeng

Tianjin Sino-German University of Applied Sciences, Tianjin, 300350, China

Abstract: *In response to the transformation and upgrading of the intelligent manufacturing industry and the demand for applied talent cultivation in universities, this study addresses the major problems existing in artificial intelligence (AI) courses across undergraduate and graduate education, including content duplication, weak articulation between educational stages, and fragmented practical projects. Guided by the Outcome-Based Education (OBE) philosophy and grounded in the development of the intelligent manufacturing program cluster and emerging technologies, a spiral progressive AI curriculum system is proposed, consisting of four levels: foundational cognition, technology application, system integration, and innovative research and development. A two-way enabling mechanism integrating curricula, projects, and industry–education collaboration is also established. The proposed model is expected to enhance students' engineering application, system integration, and innovative practice capabilities, providing theoretical and practical value for the reform of applied AI curriculum clusters.*

Keywords: *Emerging Engineering Education; Intelligent Manufacturing; Integrated Undergraduate–Graduate Education; Artificial Intelligence Curriculum System; Industry–Education Integration*

1. Introduction

The new round of scientific and technological revolution and industrial transformation is accelerating, and artificial intelligence (AI) is becoming an important technological foundation for the digital, networked, and intelligent transformation of manufacturing. The State Council and relevant ministries have successively issued policy documents such as the New Generation Artificial Intelligence Development Plan and the Action Plan for Artificial Intelligence Innovation in Higher Education, emphasizing the importance of developing fundamental AI theories, key common technologies, and interdisciplinary talent. In 2025, the State Council issued the Opinions on In-Depth Implementation of the "Artificial Intelligence Plus" Initiative, further promoting the extensive and deep integration of AI with various sectors of the economy and society and fostering new forms of an intelligent economy and intelligent society. The Central Education Work Leading Group issued the Action Plan for Adjusting and Optimizing the Discipline and Program Structure of Higher Education (2025–2027), making systematic arrangements for further optimizing academic disciplines and programs and strengthening the empowerment of education and teaching through AI. Against this backdrop, reconstructing AI curricula around the intelligent manufacturing industry chain has become an important requirement for applied universities to serve regional industrial development and improve talent cultivation quality.

As AI technologies evolve rapidly, the demand for qualified professionals is also increasing. Consequently, the development of AI courses within an integrated undergraduate–graduate program cluster has become an important issue in talent cultivation. In 2024, Nanjing University took the lead in establishing a core general-education curriculum system for AI, followed by Zhejiang University, Central China Normal University, and other universities that successively introduced AI general-education courses [1]. The "3+1+3" model of South China University of Technology, the "Four Links" model of Beijing Jiaotong University, and the "3+1+1+X" flexible training model of East China University of Technology have systematically demonstrated, from different disciplinary perspectives, the foundational, coherent, and progressive characteristics of integrated undergraduate–graduate curricula [2–5]. To address the major problems of lagging undergraduate–graduate AI curriculum

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systems and weak research and innovation practice systems, scholars have also proposed integrated and interconnected talent cultivation models [6–7]. In recent years, AI curriculum reform has gradually matured. Chen Zhonghou proposed a "three-dimensional integration" curriculum system based on the rapid growth of industrial robot density and structural changes in occupational competency requirements [8]. Zhang Chunling et al. designed a curriculum system in reverse according to enterprise needs, using AI to empower program development and promoting the upgrading of theoretical teaching through practical innovation [9]. Li Nan et al. reconstructed an AI general-education curriculum system from the perspectives of cultivation systems, diversified and integrated teaching models, and cross-domain collaborative innovation [10].

This study focuses on the demand for applied talent along the intelligent manufacturing industry chain in the context of Emerging Engineering Education. Guided by the OBE philosophy and following the cognitive progression from theoretical foundations to system integration, technology application, and innovative practice, it constructs an AI curriculum system with coordinated articulation between undergraduate and professional master's education and explores the connotation and implementation of an integrated undergraduate–graduate talent cultivation model for AI courses.

2. Problems in the Development of AI Curriculum Systems for Talent Cultivation in Intelligent Manufacturing Program Clusters at Applied Universities

2.1 Insufficient Differentiation and Weak Articulation of Undergraduate and Graduate Course Objectives

Intelligent manufacturing program clusters are highly interdisciplinary. Therefore, the design of AI course content must balance the foundations of students from automation, electrical engineering, robotics engineering, and related programs while effectively serving the different training objectives at the undergraduate and graduate stages. In the existing segmented training model, undergraduate courses mainly focus on fundamental concepts and introductory algorithms, whereas graduate courses emphasize advanced theories and system applications. However, the two stages lack a consistent knowledge-point map and competency matrix. As a result, foundational content is repeatedly taught at different stages, reducing the efficiency of teaching resources. The core challenge of an integrated curriculum system is therefore to establish continuity among algorithmic principles, engineering implementation, and system integration, and to provide an effective pathway through which students progress from "being able to use" technologies to "being able to design" systems.

The problems of insufficient differentiation and weak articulation between undergraduate and graduate course objectives cannot be solved simply by adding more courses. They require systematic coordination in terms of objective stratification and content reconstruction, with clear boundaries established for course objectives, teaching content, and assessment standards. This can effectively avoid the dual dilemma in which undergraduate courses become excessively advanced while graduate courses merely repeat previous content.

2.2 Insufficient Integration of Emerging AI Technologies with Intelligent Manufacturing Scenarios

Embodied intelligence, as an emerging direction in AI, is expected to reach an industrial scale of RMB 400 billion by 2030, with a talent gap of approximately one million. However, existing curricula can easily become outdated, while practical training conditions may fail to keep pace with technological development, accompanied by challenges such as gaps in faculty capabilities. Meanwhile, competency requirements for intelligent manufacturing positions are shifting from single-device operation toward a combination of mechanical manufacturing, electronic technology, software development, data analytics, and intelligent decision-making. If AI courses remain limited to isolated algorithm instruction and discrete experiments, they will be insufficient to support practical needs in intelligent manufacturing, including visual perception, digital twins, intelligent control, and robot control.

Therefore, deep integration of emerging AI technologies with intelligent manufacturing scenarios is particularly important in curriculum design. The integration pathway should not only align with technological development trends but also improve the fit between practical teaching activities and the competency requirements of industrial positions.

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2.3 Discontinuous Practical Project Chains and Insufficient Coordination of Industry–Education Resources and Assessment Mechanisms

Applied talent needs strong practical capabilities. However, current experimental activities often remain "stand-alone" and fail to consider the interrelationships and progressive nature of courses within an AI curriculum system. Undergraduate education is mainly based on verification-oriented experiments, whereas graduate education emphasizes research or competition projects. There is a lack of transferable and scalable project chains connecting the two stages. At the same time, university platforms, enterprise projects, and course assessment have not yet formed an effective closed loop, making it difficult to accumulate students' practical achievements continuously.

In accordance with the requirements of Emerging Engineering Education, an integrated undergraduate–graduate practical training framework should be established around a continuous project chain, shifting from "individual course experiments" to "integrated projects." Relying on university–enterprise cooperation and on-campus and off-campus training platforms, enterprises should participate deeply in the design of project-chain activities and jointly address real production problems, thereby establishing a dual-benefit university–enterprise collaborative mechanism.

3. Integrated Undergraduate–Graduate Talent Cultivation Model for Applied AI Courses

To meet the positioning of applied talent cultivation, an industry–education two-way enabling mechanism is established based on the competency requirements for high-level applied professionals in intelligent manufacturing and guided by the OBE philosophy. The curriculum system is designed backward from industrial needs and graduate competencies, deriving training objectives and course content to ensure close alignment between talent cultivation and industrial demand and to promote interdisciplinary integration between AI and intelligent manufacturing. Following a spiral cognitive progression, the articulation logic among prerequisite and subsequent courses is established, and a layered and progressive training pathway is adopted. Course content is updated dynamically to actively respond to technological trends in AI, with emerging technologies continuously incorporated into the curriculum. The overall implementation framework is shown in Figure 1.

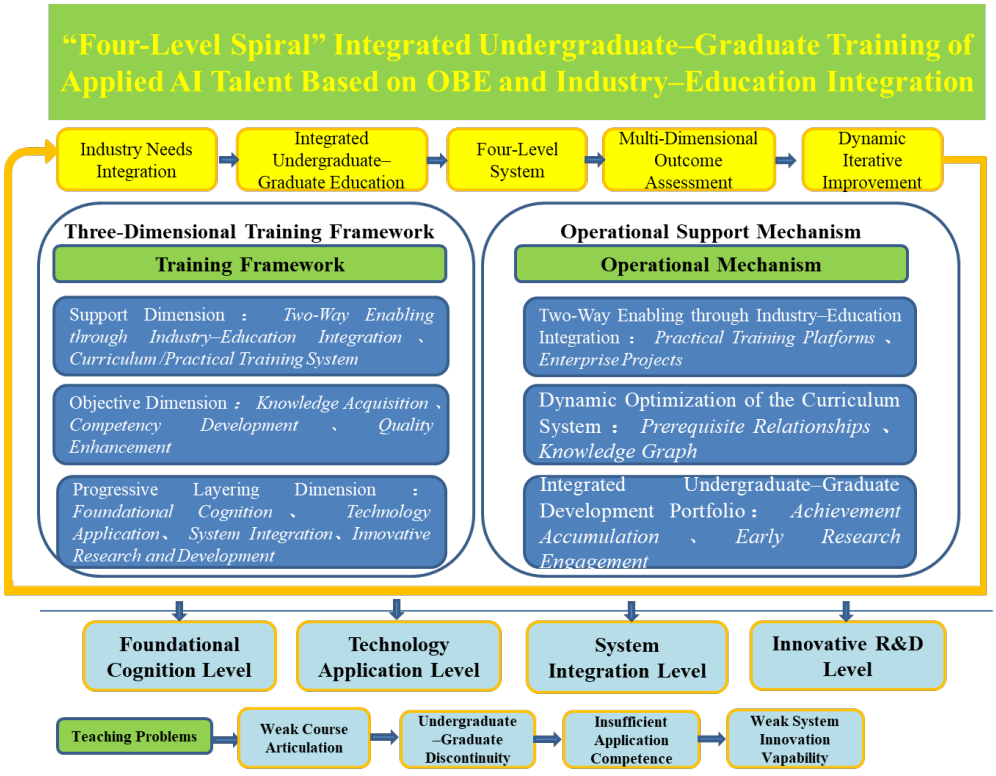


Figure 1. Implementation Framework for Applied AI Talent Cultivation

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3.1 OBE-Oriented "Three-Dimensional" Training Framework

The development of an integrated undergraduate–graduate AI curriculum system follows the OBE philosophy. Starting from an industrial talent competency map, occupational competencies and training objectives are derived, after which the curriculum system is designed backward. Considering the characteristics of the intelligent manufacturing program cluster, a "three-dimensional, four-level" training framework is constructed in which support, objectives, and levels are mutually coupled. The support dimension consists of the two-way enabling mechanism of industry–education integration, the curriculum system, and the practical training system. The training objectives are aligned with the needs of applied industrial talent and specifically include knowledge acquisition, competency development, and quality enhancement. The progressive dimension designs course content according to the cognitive progression of foundational cognition, technology application, system integration, and innovative research and development. Undergraduate education emphasizes principles, application, and implementation, while graduate education emphasizes system integration and innovation. The four levels advance progressively in accordance with cognitive development and form a spiral pathway for competency development, thereby achieving the intended training objectives.

3.2 Operational Mechanism for Undergraduate–Graduate Coordination and Industry–Education Integration

A stable and feasible operational mechanism is the foundation for constructing an integrated undergraduate–graduate AI curriculum system. First, the two-way enabling mechanism of industry–education integration should be improved. By leveraging on-campus and off-campus training platforms, occupational competency requirements, authentic engineering cases, and industrial technology trends should be continuously collected, enabling enterprises to serve simultaneously as providers of competency requirements, participants in practical projects, and evaluators of project outcomes. The model of "building foundations on university platforms, improving capabilities through enterprise scenarios, and cultivating talent through dual mentors" can substantially enhance the practical depth and industrial relevance of integrated undergraduate–graduate education.

Second, a dynamic curriculum optimization mechanism should be established based on training objectives. Occupational skill requirements in intelligent manufacturing talent competency maps should be analyzed periodically. Using a knowledge-point map for the curriculum cluster as the carrier, courses such as AI Fundamentals, Machine Learning, Deep Learning, and Robot Learning should be organically connected. The prerequisite relationships, core knowledge points, training objectives, and assessment standards of each course should be analyzed to reduce redundant content, incorporate emerging application skills, and strengthen logical progression among courses.

Finally, an integrated project portfolio mechanism should be established across undergraduate and graduate education. Comprehensive practical projects, competition achievements, and enterprise practice outcomes completed during the undergraduate stage should be incorporated into students' development portfolios. Promising undergraduates should also be encouraged to enter graduate supervisors' research groups in advance and participate directly in research activities such as intelligent manufacturing system integration, thereby implementing the goals of "early exposure, early planning, and early advancement."

3.3 Construction of the Four-Level Spiral Progressive System

The overall objective of curriculum development is to cultivate applied professionals who meet the requirements of Emerging Engineering Education and possess both a solid theoretical foundation in AI and proficiency in AI application technologies for intelligent manufacturing. Accordingly, both the theoretical knowledge system and practical training system should follow the spiral cognitive progression of "foundational cognition, technology application, system integration, and innovative research and development." Knowledge maps are used to clarify the logical relationships and continuity among prerequisite and subsequent courses. The practical training system is developed according to the progression from simple to complex tasks, from on-campus to enterprise scenarios, and from application to innovation. In parallel with the knowledge structure, a stepwise project chain is gradually formed. The training objectives, project types, and assessment systems at each level are designed to advance progressively, thereby forming a complete and integrated talent cultivation pathway, as shown in Table 1.

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The foundational cognition and technology application levels correspond to the undergraduate stage. The objective of the foundational cognition level is to enable students to master mathematical foundations, basic AI concepts, and fundamental algorithms, laying a foundation for subsequent interdisciplinary learning. Corresponding practical activities mainly consist of verification-oriented experiments of moderate difficulty, coordinated with AI fundamentals modules. Examples include "Python Fundamentals for Machine Learning" and "Basic AI Visual Recognition," through which students verify and consolidate theoretical knowledge and systematically master basic experimental skills and commonly used tools.

The subsequent technology application level focuses on machine learning, data processing, machine vision, and industrial visual recognition, emphasizing the application of AI technologies in typical intelligent manufacturing scenarios. Corresponding practical activities mainly consist of design-oriented projects, such as industrial robot visual sorting, quality inspection, and basic path planning. Students learn the complete process from requirements analysis and algorithm selection to system implementation. This progression from fundamental theory to algorithm reproduction and then to practical application constitutes the first major transition from theoretical knowledge to practical capability.

The system integration and innovative research and development levels correspond to the graduate stage. The system integration level includes Deep Learning, Reinforcement Learning, Robot Learning, and Introduction to Embodied Intelligence, while the innovative research and development level addresses practical industrial project needs through courses and activities related to system optimization and the digital transformation of intelligent manufacturing. Corresponding practical activities include multi-sensor fusion, robot motion planning, reinforcement learning strategy optimization, and multi-agent collaboration, with an emphasis on developing complex capabilities in multi-agent cooperation and system integration. This promotes the second major transition from technology application to system innovation.

Table 1. Design of the Integrated Undergraduate–Graduate AI Curriculum System

Spiral Level	Course Group	Practical Project	Training Objectives	Assessment
Foundational cognition	AI Fundamentals; Python Programming; Intelligent Sensors and Detection Technology	Basic Python; Machine Learning Experiments	Understand basic AI concepts and master fundamental programming skills	Algorithm understanding; experimental standards; software use
Technology application	Machine Learning (visual recognition experiments); Comprehensive Robotics Course Design	Industrial Robot Visual Sorting	Implement basic algorithms and validate typical tasks in simple engineering scenarios	Engineering implementation; teamwork; problem identification
System integration	Deep Learning; Reinforcement Learning; Robot Learning; Introduction to Embodied Intelligence	ROS- and Reinforcement-Learning-Based Mobile Robot Workpiece Grasping and Handling System	Develop capabilities in multi-sensor integration, system integration, and analysis of complex engineering problems	Complex engineering problem solving; system debugging; solution optimization
Innovative R&D	Intelligent Manufacturing System Integration; ROS and Robotics Projects	Authentic Enterprise Intelligent Manufacturing AI Projects	Develop capabilities in technological innovation, engineering optimization, and industrial problem solving	Innovation; industrial relevance; potential for technology transfer

3.4 Integration of Emerging Technologies such as Embodied Intelligence

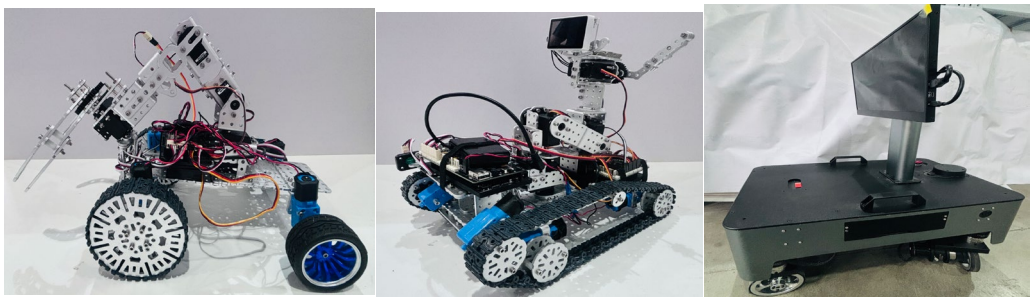
The embodied intelligence industry is expected to exceed RMB 400 billion by 2030, indicating a substantial demand for talent. At present, embodied intelligence has become an important frontier in AI

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and shows broad application prospects in intelligent manufacturing, moving from demonstration-oriented applications toward demand-driven applications. To implement the New Generation Artificial Intelligence Development Plan, the Education Powerhouse Development Plan (2024–2035), and the Action Plan for Adjusting and Optimizing the Discipline and Program Structure of Higher Education (2025–2027), embodied intelligence was formally incorporated into the undergraduate program catalog in 2026, marking the entry of embodied-intelligence talent cultivation in China into a standardized stage. In the dynamic optimization of AI curricula, it is therefore necessary to integrate emerging topics such as embodied perception, environmental interaction, reinforcement learning, and imitation learning into course content.

4. Implementation Outcomes

Over a three-year period, more than 500 student-participations were recorded in scientific and technological innovation activities. A total of 525 student-participations received 89 awards in major competitions, including the Siemens Cup China Intelligent Manufacturing Challenge, the National Undergraduate Electronic Design Contest, the China Undergraduate Robot Competition, and the "Internet Plus" College Student Innovation and Entrepreneurship Competition. These awards included 54 first prizes, 86 second prizes, and 49 third prizes. Students demonstrated strong competitive performance in tracks related to intelligent manufacturing, AI, and the Industrial Internet. Starting from industrial development needs, the integrated undergraduate–graduate AI curriculum architecture arranges courses progressively and links practical activities systematically, providing students with abundant teaching resources and practical platforms. An open and autonomous learning environment enables students to exercise initiative and stimulate their innovative potential, resulting in positive outcomes at different stages of cultivation. Examples of student projects at different stages are shown in Figure 2.



(a) Foundational cognition: Remote-controlled car; *(b) Technology application: Autonomous line following;* *(c) System integration: Intelligent mobile car*

Figure 2. Student Projects at Different Training Levels

5. Conclusions

The era of AI has created new opportunities for the development of intelligent manufacturing while placing higher demands on the talent supply side. Developing an integrated undergraduate–graduate AI curriculum system is therefore of considerable significance for reconstructing the curriculum framework of intelligent manufacturing program clusters. To address the problems of insufficient differentiation of training objectives, discontinuous practical project chains, and inadequate integration of emerging technologies, this study proposes a "three-dimensional, four-level" integrated undergraduate–graduate AI curriculum framework based on the OBE philosophy in the context of Emerging Engineering Education.

The proposed framework establishes an operational mechanism integrating undergraduate–graduate coordination and industry–education collaboration. Through dynamic optimization of course content based on the knowledge-point map of the AI curriculum cluster and the use of a stepwise practical project chain to support competency development, it strengthens the alignment between intelligent manufacturing program clusters and industry needs and effectively improves students' engineering application, system integration, and innovative practice capabilities. In the future, the university will remain student-centered and further investigate curriculum implementation effectiveness, enterprise feedback, and graduates' job fit, so as to continuously optimize the curriculum system and talent cultivation measures.

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