Journal of Electronic Research and Application, 2026, Volume 10, Issue 8
http://ojs.bbwpublisher.com/index.php/JERA
Online ISSN: 2208-3510
Print ISSN: 2208-3502

Research and Practice on Construction Pathways of Emerging Engineering Programs for the Intelligent Manufacturing Industry

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Abstract: Driven by the new round of the industrial revolution, the intelligent manufacturing industry is undergoing rapid iteration. As a national key strategic industry, its transformation and upgrading generate an urgent demand for compound and application-oriented emerging engineering talents, posing new requirements for the engineering education reform of local universities. Newly built undergraduate universities generally suffer from weak disciplinary accumulation, insufficient interdisciplinary integration of curriculum, lack of teachers' engineering practical experience, and superficial industry-education integration. Taking five intelligent manufacturing-related undergraduate majors in Qilu Institute of Technology as the research sample, this study constructs a professional construction system of "one core, two wings, and four dimensions" based on the emerging engineering education philosophy. Through optimizing talent training schemes, building interdisciplinary curriculum modules, cultivating dual-qualified teachers, and constructing industry-education integrated practical platforms, this paper explores a distinctive path for emerging engineering major construction in newly-built undergraduate universities. Practical verification indicates that the proposed system effectively solves the problems of disconnection between talent training and industrial demands and homogenized talent cultivation, improves the quality of application-oriented innovative talents, and provides practical demonstration and reference for emerging engineering construction in peer universities.

Keywords: Intelligent manufacturing; Emerging engineering education; Specialty construction; Industry-education integration; OBE concept

Online publication: Sept 3, 2026

1. Introduction

Currently, a new round of scientific and technological revolution and industrial transformation is accelerating at an unprecedented pace. Emerging technologies, including artificial intelligence, big data, and the industrial Internet, are deeply empowering the manufacturing sector. Leveraging initiatives such as the

Intelligent Manufacturing Engineering program and the "AI + Manufacturing" special action plan, the nation is cultivating new quality productive forces, advancing new-type industrialization, and driving the comprehensive digital, intelligent, and green transformation of manufacturing [1].

Intelligent manufacturing has emerged as the core lever for manufacturing upgrading. The rapid iteration of the industry has triggered a surging demand for compound engineering talents equipped with interdisciplinary knowledge, hands-on engineering capabilities, and innovative literacy, posing new and higher requirements for the reform of local higher engineering education. As a pivotal initiative aligned with national industrial strategies and responsive to industrial transformation, Emerging Engineering Education (EEE) focuses on breaking down the silos of traditional engineering education through interdisciplinary integration and deep industry–education collaboration [2]. Its core objective is to precisely cultivate application-oriented, innovative engineering talents tailored to the future intelligent manufacturing industry.

Newly established undergraduate institutions serve as the core providers of regional intelligent manufacturing talent. However, constrained by limited educational heritage, they face systemic challenges: weak disciplinary foundations, outdated curricula, a shortage of dual-qualified faculty, and shallow university-enterprise collaboration. The traditional, siloed engineering education model is ill-suited to meet the occupational demands of the intelligent manufacturing industry, where computing, communication, and control technologies converge, resulting in a pronounced industry-education disconnect.

Against this backdrop, this paper takes five intelligent manufacturing-related undergraduate programs at Qilu Institute of Technology as its practical foundation. It addresses the pain points of EEE construction in newly established undergraduate institutions through systematic pedagogical reform. Specifically, it builds an integrated education ecosystem uniting industry, academia, research, and application, and explores distinctive program-development pathways tailored to regional industrial needs. The ultimate goal is to provide a replicable practical paradigm for EEE advancement in local universities and the high-quality development of the regional intelligent manufacturing sector.

2. Research status and significance

2.1. Research status

The construction of EEE and the cultivation of intelligent manufacturing talents represent current research frontiers in global engineering education reform. Chinese academia has conducted extensive systematic research on the connotation, construction pathways, and talent cultivation models of EEE.

Professor Lin Jian from Tsinghua University systematically reviewed the core connotation, defining features, construction objectives, and overall framework of EEE. He clarified the priorities and development directions of EEE construction for different types of higher education institutions, providing a theoretical foundation for engineering program reform [3]. Lyngdorf et al. provided a systematic overview of digital transformation frameworks in engineering education, demonstrating how interdisciplinary fusion between emerging technologies and traditional engineering disciplines underpins the development of future-oriented engineering programs [4]. As highlighted in both the 2026 Global Future Higher Education Summit, universities must address the new talent cultivation requirements brought by industrial transformation through three key pathways: interdisciplinary integration, industrial alignment, and collaborative education [5]. Together, these strategies enable the development of EEE talent cultivation models characterized by sustainable competitiveness and practical relevance. At present, domestic research predominantly focuses on EEE construction in key universities, while studies on targeted program development in newly established undergraduate institutions serving the regional intelligent manufacturing industry remain relatively scarce.

Engineering education reform in Europe and the United States began earlier and has evolved into a more mature system. The Harvard John A. Paulson School of Engineering and Applied Sciences focuses on frontier challenges in human societal development, prioritizes emerging interdisciplinary fields, dissolves the boundaries of traditional engineering programs, and has established a cross-domain engineering talent cultivation system [6]. American engineering education has developed standardized, systematic models for ethics education and innovation education, widely adopted and highly innovative, that serve as a benchmark for global engineering education reform. The Massachusetts Institute of Technology (MIT) pioneered the vision of engineering education reform for future industries, advocating that the focus of engineering education should shift from adapting to existing industries to anticipating future ones. MIT aims to build a forward-looking, innovative new engineering education system that places strong emphasis on cultivating students' ability to solve complex engineering problems and their creative thinking [7]. Overall, European and American engineering education emphasizes interdisciplinary integration, industry–education collaboration, and innovation empowerment. However, as these studies are grounded in the industrial systems and educational models of developed countries, they cannot be directly applied to the regional industrial characteristics and operational realities of newly established undergraduate institutions in China.

2.2. Research significance

Currently, the development of intelligent manufacturing-related EEE programs in newly established undergraduate institutions still faces systemic shortcomings that constrain the quality of regional industrial talent cultivation.

First, disciplinary support is weak. With limited educational heritage, traditional engineering programs in these institutions are dominated by single manufacturing disciplines, lacking interdisciplinary curricula adapted to intelligent manufacturing development. This makes it difficult to align with the demands of the new-generation information technology and intelligent equipment industries [8].

Second, faculty development lags behind. Most full-time instructors emphasize theoretical instruction and lack hands-on engineering experience. Their insufficient grasp of cutting-edge intelligent manufacturing technologies and industry standards renders them unable to meet the talent cultivation requirements of emerging industry formats [9].

Third, industry–education integration remains superficial. The university–enterprise collaborative education mechanism is underdeveloped, and high-quality enterprise projects and authentic engineering scenarios have not been deeply integrated into teaching. As a result, students' complex engineering problem-solving abilities and innovative literacy are insufficiently cultivated [10].

Against this backdrop, this paper is grounded in the developmental needs of the intelligent manufacturing industry, taking five intelligent manufacturing-related programs at Qilu Institute of Technology as its practical carriers. It implements systematic pedagogical reform across four dimensions: talent cultivation plans, curriculum systems, faculty development, and practical teaching—addressing the gaps in EEE construction at newly established undergraduate institutions. The research findings can precisely match regional industrial talent demands and effectively improve the quality of applied innovative talent cultivation. Concurrently, they provide a referable practical paradigm and replicable model for EEE program construction and transformation upgrading in similar local universities.

This study takes serving the development of the regional intelligent manufacturing industry and cultivating high-quality applied innovative talents as its core objectives. It deeply advances interdisciplinary integration across mechanical engineering, automation, computer science, electronic communication, and related fields, and comprehensively promotes reform and innovation in teaching content, curriculum systems, faculty teams, teaching methodologies, and practical platforms.

Focusing on the core requirements of EEE construction, the study strives to achieve the "Five First-Class" construction objectives:

(1) Building a first-class dual-qualified faculty team.
(2) Establishing a first-class undergraduate education system.
(3) Developing first-class distinctive intelligent manufacturing programs.
(4) Creating first-class interdisciplinary integrated courses and cultivating first-class industry-adapted engineering talents.

Ultimately, this research aims to construct a replicable and scalable EEE program construction paradigm for newly established undergraduate institutions, comprehensively elevating the quality of regional intelligent manufacturing talent cultivation.

3. Reform scheme design and implementation methods

3.1. Overall reform scheme design

Grounded in the educational positioning of newly established undergraduate institutions and the developmental needs of the intelligent manufacturing industry, this study innovatively constructs an EEE program construction reform system defined as "One Core, Two Wings, Four Dimensions".

Taking the EEE construction philosophy as the core guidance and leveraging the university's educational resources and enterprise industrial resources as the two supporting wings, comprehensive reforms are implemented across four dimensions: talent cultivation plans, curriculum system development, faculty team cultivation, and practical innovation platforms. This forms a closed-loop, systematic program construction pathway that fully integrates the education chain, talent chain, industrial chain, and innovation chain—achieving synchronized advancement between EEE program construction and industrial development.

3.2. Specific reform implementation methods

3.2.1. Interdisciplinary integration empowerment: Optimizing the "five integrations" talent cultivation system

Guided by industrial demands, the talent cultivation plan is optimized through research validation, university–enterprise collaboration, and expert empowerment. By visiting intelligent manufacturing enterprises, investigating peer institutions, and inviting industry experts and enterprise technical backbone to participate in program validation, a four-in-one cultivation framework is reconstructed—comprising general education, disciplinary foundational education, specialized direction education, and practical innovation education.

Five major integration reforms are deeply advanced:

(1) Integrating program characteristics with industry needs.

(2) Cutting-edge technologies with traditional knowledge.
(3) Innovation and entrepreneurship education with specialized education.
(4) Practical education with enterprise resources, and in-class cultivation with extracurricular development.

This thoroughly breaks the homogeneous model of traditional talent cultivation. Focusing on the core competencies of intelligent manufacturing positions, graduation requirements and competency indicators are refined, constructing a new personalized, interdisciplinary, and innovative talent cultivation system that precisely matches the needs of core positions such as intelligent production line operation and maintenance, intelligent equipment R&D, and industrial data processing.

3.2.2. Concurrent recruitment and cultivation: Building a dual-qualified faculty team

Adhering to the faculty construction principle of "rooted in cultivation, focused on recruitment, and shared between university and enterprise", the faculty structure is comprehensively optimized, and overall faculty capabilities are enhanced.

In terms of internal cultivation, a standardized mechanism for faculty enterprise practice is established. Each year, 1–2 professional faculty members are selected to engage in full-time engineering practice at intelligent manufacturing enterprises, accumulating frontline project experience, mastering cutting-edge industry technologies, and addressing gaps in engineering practical experience. Leveraging on-campus research platforms and educational reform projects, faculty are encouraged to conduct EEE pedagogical research and technological R&D, simultaneously improving their teaching and research capabilities.

Adopting flexible recruitment and elastic employment models, highly skilled enterprise talents, master craftsmen, and technical experts are recruited into the part-time faculty team, undertaking teaching tasks such as practical instruction, course lectures, and project guidance—thereby compensating for the insufficient industry experience of on-campus faculty.

Through two-way talent flow between university and enterprise and dual empowerment of teaching and research, a well-structured, highly capable dual-qualified faculty team adapted to EEE talent cultivation is built.

3.2.3. OBE philosophy guidance: Constructing interdisciplinary curriculum modules

Grounded in the Outcome-Based Education (OBE) philosophy, with student competency outcomes as the core, a modular, interdisciplinary, and cutting-edge curriculum system is reconstructed.

Breaking down the disciplinary silos of traditional mechanical, automation, and communication programs, the three core technology systems—computing, communication, and control—are integrated to construct distinctive interdisciplinary curriculum modules. Cutting-edge intelligent manufacturing technologies such as big data analytics, artificial intelligence, machine vision, 5G industrial communication, and the industrial Internet of Things are fully integrated into the curriculum. Nine interdisciplinary and cross-program elective courses, including "Artificial Intelligence Technology and Applications", are added to fill the gap in cutting-edge technologies within traditional curricula.

Research findings, enterprise projects, and industry standards are promoted for conversion into teaching resources, and distinctive textbooks such as "Artificial Intelligence Technology and Applications" are developed. Using real engineering projects as carriers, a progressive project case system is established: "in-class foundational experiments → intensive specialized practice → graduation design innovation". Abandoning traditional theory-cramming pedagogy, project-based, case-based, and inquiry-based teaching models are implemented. Course assessment methods are optimized, and a process-oriented, diversified, and comprehensive evaluation system is constructed—comprehensively enhancing students' ability to apply interdisciplinary knowledge and solve engineering problems.

3.2.4. University–enterprise co-construction: Building a four-in-one practical teaching platform

Leveraging provincial-level research and teaching platforms—including the Shandong Provincial Sino-German Smart Factory Application Engineering Research Center, the Shandong Provincial Key Laboratory of Industrial Big Data and Intelligent Manufacturing, and the Shandong Provincial University International Joint Laboratory of Industrial Internet of Things—university-enterprise strategic cooperation is deepened. On-campus and off-campus practical resources are integrated to build a four-in-one practical innovation teaching system: on-campus training platforms, provincial research platforms, industrial college platforms, and enterprise practice platforms.

Authentic enterprise production scenarios, engineering challenges, cutting-edge equipment, and technical projects are fully integrated into the entire process of practical teaching. Outdated practical content is updated, practical teaching models are innovated, and practical teaching management mechanisms are refined.

Students are organized to participate in phased practical activities: enterprise cognitive internships, on-the-job training, project R&D, and graduation design. A full-chain industry–education integration practice system of "cognition → practice → innovation" is constructed, comprehensively tempering students' engineering practical abilities, teamwork capabilities, and innovative R&D competencies.

4. Reform practice outcomes

4.1. Reform practice achievements

Through systematic and standardized EEE program construction reform practices, the construction quality of five intelligent manufacturing-related undergraduate programs at Qilu Institute of Technology has significantly improved, the adaptability of talent cultivation has been greatly enhanced, and favorable pedagogical reform outcomes have been achieved.

An interdisciplinary curriculum system adapted to the intelligent manufacturing industry has been successfully constructed, breaking down traditional disciplinary silos and forming a new multi-dimensional integrated talent cultivation model. Program characteristics have become more distinctive, and alignment with regional industries has markedly improved.

Through enterprise practice, external recruitment, and internal cultivation, the coverage rate of engineering practical experience among full-time faculty has substantially increased. The proportion of dual-qualified faculty continues to grow, and the part-time faculty team effectively supplements industry teaching resources, resulting in a continuously optimized faculty structure.

The practical teaching system has become more comprehensive, enabling students to deeply engage with authentic engineering scenarios and cutting-edge technologies in intelligent manufacturing. Their complex engineering problem-solving abilities and innovative practical capabilities have significantly improved.

The quantity and quality of student participation in intelligent manufacturing disciplinary competitions and innovation and entrepreneurship projects continue to rise. The proportion of graduation designs aligned with actual enterprise projects has substantially increased. Graduate employment rates, major-job matching rates, and enterprise satisfaction have steadily grown, effectively alleviating the shortage of interdisciplinary talents in the regional intelligent manufacturing industry.

The “One Core, Two Wings, Four Dimensions” EEE program construction system formed by this reform provides practical reference for the transformation and upgrading of EEE programs in similar newly established undergraduate institutions across the province, and possesses strong scalability value.

4.2. Existing issues and reflective improvement

In the phased reform practices, several issues remain that urgently need improvement.

First, the construction of interdisciplinary course teaching teams still requires strengthening. Some interdisciplinary courses place high demands on faculty’s comprehensive knowledge reserves, and faculty’s interdisciplinary teaching capabilities still need continuous enhancement.

Second, there remains room for deepening university–enterprise cooperation. The long-term incentive mechanism for enterprise participation in talent cultivation has not been fully established, and the integration of some enterprise projects into teaching is not sufficiently thorough.

Third, the personalized talent cultivation system still needs refinement. The stratified cultivation model for students with different academic foundations and different career orientations requires further optimization.

Going forward, targeted efforts will be made to address these shortcomings: improving the long-term mechanism of university–enterprise collaborative education, strengthening interdisciplinary faculty cultivation, refining stratified and categorized talent cultivation plans, and continuously deepening EEE pedagogical reform.

5. Conclusion

Advancing EEE program construction in response to the transformation and upgrading needs of the intelligent manufacturing industry represents a core pathway for newly established undergraduate institutions to adapt to regional economic development, improve the quality of applied talent cultivation, and highlight their distinctive educational identity.

Grounded in the educational shortcomings of newly established undergraduate institutions and the pain points of regional industrial talent demand, this paper takes intelligent manufacturing-related programs at Qilu Institute of Technology as practical carriers and innovatively constructs the “One Core, Two Wings, Four Dimensions” EEE program construction system. By optimizing the Five Integrations talent cultivation plan, building interdisciplinary curriculum modules, cultivating a dual-qualified faculty team, and developing a four-in-one industry–education integration practical platform, this study systematically addresses the core challenges facing engineering programs in newly established undergraduate institutions: low industrial adaptability, weak disciplinary integration, insufficient faculty practical experience, and lagging practical education.

Reform practices demonstrate that this construction pathway aligns with the operational realities of newly established undergraduate institutions and precisely meets the demand for interdisciplinary, innovative talents in the intelligent manufacturing industry. It effectively improves talent cultivation quality and supports the intelligent transformation and upgrading of regional manufacturing.

Going forward, the university will continue to deepen EEE construction reform, grounded in the new development trends of Shandong Province's intelligent manufacturing industry. It will dynamically optimize the curriculum system and talent cultivation model, continuously deepen industry–education integration and university–enterprise collaborative education, and strengthen interdisciplinary innovative talent cultivation. The university will steadily refine the EEE program construction system for newly established undergraduate institutions, continuously delivering high-quality applied engineering talents for the high-quality development of the regional intelligent manufacturing industry. Furthermore, it will amplify the demonstrative and spillover effects of educational reform, promoting high-quality development of engineering education in local universities.

Funding

2023 Shandong Provincial Undergraduate Teaching Reform Research Project (Project No.: Z2023209); 2025 Shandong Provincial Undergraduate Teaching Reform Research Project (Project No.: M2025723)

Disclosure statement

The authors declare no conflict of interest.

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