

A Study on the Construction and Practice of Diversified Collaborative Education Model for Automation Specialty in the Context of New Engineering—Digital Intelligence Empowerment and Industry-Education Integration

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Abstract: Faced with the urgent demand for high-quality engineering talents in the context of new engineering education development and national innovation-driven strategies, traditional talent cultivation models in local universities encounter practical challenges such as "cooperation without integration" between industry and education, insufficient practical innovation capabilities among students, and weak engineering backgrounds among faculty members. Taking the Automation program at Qilu University of Technology (Shandong Academy of Sciences) as a case study, this paper proposes and implements a "Digital Intelligence Empowerment-Industry-Education Integration" collaborative talent cultivation model. Guided by industrial demands, the model achieves deep integration of education, research, and industry through three core pathways: restructuring the "AI+" curriculum system, establishing multidimensional innovation practice platforms, and building a "dual-qualified" faculty team. Practical implementation demonstrates that this model effectively enhances the alignment between talent cultivation and industrial needs, significantly improving students' engineering practice and innovation capabilities. It provides a replicable paradigm for upgrading new engineering disciplines in local universities.

1. Introduction

The report of the 20th National Congress of the Communist China has integrated education, science and technology, and talent development into a "trinity" framework, emphasizing the advancement of industry-education integration and the convergence of science and education to cultivate top-tier innovative talents. [1] As a strategic initiative for higher education to proactively respond to the new wave of technological revolution and industrial transformation, [2] the core of New Engineering Education lies in innovating talent cultivation models to resolve structural contradictions between talent supply and industrial demands. However, many local universities face

common challenges in advancing New Engineering Education, including ineffective industry-education collaboration mechanisms, curriculum systems disconnected from industrial development, single-function practical teaching platforms, and insufficient engineering practice capabilities among faculty members, all of which hinder the profound self-reform of the education supply side.

The Automation program at the School of Electronics, Electrical Engineering and Control, Qilu University of Technology (Shandong Academy of Sciences) leverages its unique "academy-institute integration" framework to pioneer a collaborative education model that seamlessly integrates digital intelligence technologies while bridging industrial and academic ecosystems. Building on the program's teaching innovation practices, this study has developed and implemented a diversified collaborative education model centered on "digital empowerment and industry-education integration," providing theoretical references and practical case studies for engineering education reforms in similar institutions.

2. The construction logic and core framework of multi-collaborative education model

The multi-stakeholder collaborative education model proposed in this study emerges from the interaction between educational systems, research institutions, industrial sectors, and social environments. By dismantling organizational, personnel, resource, and cultural barriers across subsystems, it adopts a systems theory-based approach and engineering education principles to restructure the framework. This creates an internally coherent logic of "demand-driven development, technology empowerment, and mechanism coordination," establishing a clear, goal-oriented core framework with well-defined pathways. [3]

2.1 Model construction logic

2.1.1 The external traction of industrial demand and the endogenous driving force of education supply-side reform

The "path dependence" in traditional talent cultivation has created structural misalignment between educational supply and industrial demand. This model positions industry needs as both the fundamental starting point and ultimate destination, shifting the paradigm from "what can I cultivate" to "what society needs." By establishing institutionalized mechanisms like the "Social Evaluation Feedback System" and "Graduate Tracking Survey System," it dynamically captures employers' requirements for graduates' knowledge, skills, and qualities. These insights serve as authoritative input for revising training objectives, graduation standards, and curriculum systems. This "external driving force" fundamentally ensures the accuracy of educational orientation, propelling profound self-reform in the education supply side.

2.1.2 Digital and intelligent technology enables all aspects and processes

Digital and intelligent empowerment in practical education is a key element for cultivating innovative talents. This approach accelerates the development of innovative professionals through digital and intelligent empowerment in practical education, playing a vital role in talent cultivation and reflecting the intrinsic requirements of talent development. [4] With clear educational objectives, this model positions digital and intelligent technologies as the core driving force for transforming talent cultivation systems, aiming to systematically address the bottlenecks in traditional education at the levels of content, methodology, and governance.

At the content level, we promote the integration of cutting-edge technologies with professional expertise. By systematically incorporating key technologies like artificial intelligence, big data, and industrial internet into the core knowledge framework of automation majors, we upgrade existing

curricula through the development of "AI+" course clusters. This initiative equips students with intelligent tools and theories aligned with future industrial demands. In pedagogical approaches, we transition from experience-based to data-driven methodologies. Leveraging AI-powered platforms and virtual simulation projects, we enable comprehensive data collection and intelligent analysis of student interactions during practical training. This evolution shifts evaluation mechanisms from result-focused "summative assessments" to process-oriented "formative assessments," providing a foundation for precision teaching and personalized learning support. At the governance level, we establish data-driven decision-making models. Through creating "professional competency maps" and "issue maps," we visualize knowledge logic and competency structures. These visualizations offer objective data support for curriculum optimization and efficient cross-disciplinary team coordination, ultimately enhancing the professionalism and scientific rigor of educational management systems.

2.1.3 Deep coordination and system reconstruction of multiple subjects

The integration of industry and education is a crucial initiative for collaborative cultivation of outstanding engineering talents between universities and enterprises. [5] Currently, the practice of industry-education integration often faces the dilemma of "cooperation without integration," fundamentally due to the long-standing superficial and non-institutionalized nature of collaborative mechanisms. To systematically address this issue, the educational model developed in this study breaks through the limitations of single-subject university operations by integrating three core entities: the college, the Automation Research Institute, and partner enterprises, forming a multi-stakeholder collaborative education community of "university-institute-enterprise." This community achieves deep integration across four dimensions—strategic planning, resource allocation, process management, and outcome sharing—through the "departmental system" and "university-institute integration." The college is responsible for establishing the foundational education system and understanding teaching principles; the research institute handles introducing cutting-edge scientific resources and supporting project-based teaching; enterprises provide real-world engineering scenarios and industry competency feedback. The model also establishes organizational decision-making mechanisms including a joint teaching advisory committee, creates regular deliberation channels, and designs incentive-compatible, risk-sharing benefit coordination mechanisms. This ensures institutionalization and sustainability of collaborative processes, ultimately guaranteeing the deep integration and long-term viability of collaborative education.

2.2 Core framework of the model

Building on this internal logic, the study establishes a comprehensive and well-structured framework for multi-dimensional collaborative education. Centered on a core objective, the framework leverages three supporting systems working in tandem, while a cohesive thread ensures seamless integration throughout the entire process. The overall architecture is illustrated in Figure 1.

Within this framework, a core objective is to cultivate innovative application-oriented talents capable of addressing future industrial transformations and solving complex engineering challenges in automation. This goal also serves as the ultimate destination of the system design. The three supporting systems include the "Intelligent+" curriculum system, the "AI+" practice system, and the "Dual-qualified Teachers" faculty system. The "Intelligent+" curriculum system corresponds to the "Knowledge Construction" dimension, serving as the content carrier of the model. Through "AI+ Curriculum" design and the construction of a "Three-tier Knowledge Graph," it achieves the reconstruction and systematization of digital-intelligent knowledge systems. The "AI+" practice system corresponds to the "Competency Development" dimension. This serves as the competency

refinement arena of the model, transforming theoretical knowledge into practical skills and innovative thinking through a three-tier progressive practice platform: "Basic-Comprehensive-Innovative." The "Dual-qualified Teachers" faculty system corresponds to the "Guidance and Support" dimension. This provides human resource assurance for the efficient operation of the model. Through a "combination of recruitment and cultivation, two-way circulation" mechanism, it builds a high-level teaching team proficient in both theory and industry expertise.

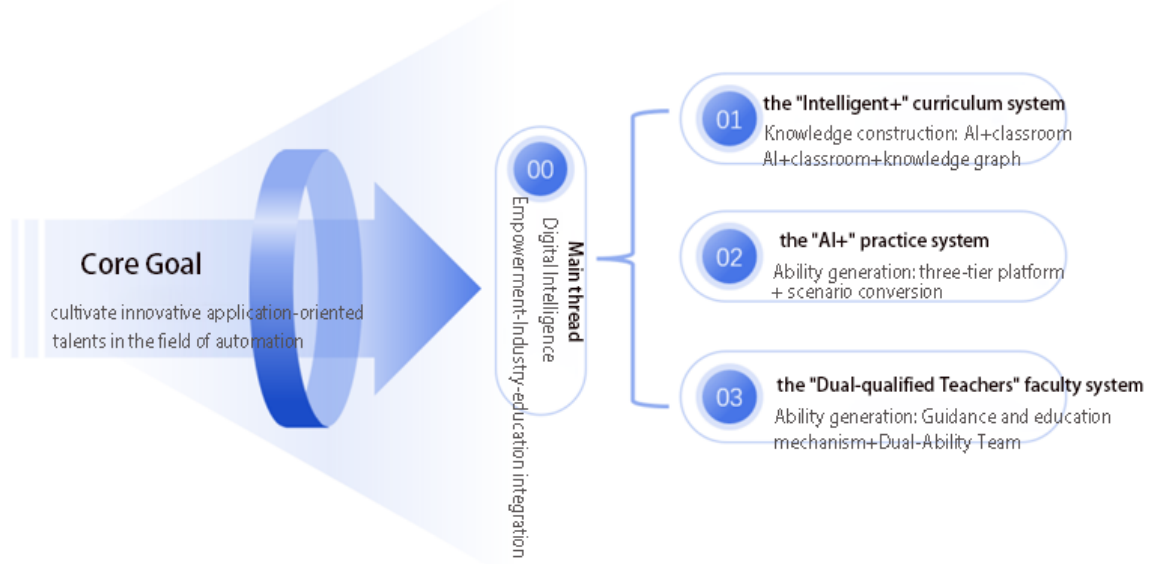


Figure 1: Collaborative education model between science, education and industry

A unified core thread: "Digital Intelligence Empowerment" and "Industry-Education Integration" are not separate components, but two interwoven threads that permeate the three major systems mentioned above. Digital intelligence technology provides new tools and scenarios for industry-education integration (such as remote training and data-sharing platforms), while industry-education integration offers real-world "training grounds" and demand sources for digital intelligence applications. These two elements complement each other, jointly driving the entire model to evolve toward higher levels.

3. Three core paths for model implementation

To ensure the effective implementation of the theoretical framework, this study systematically designs three mutually reinforcing implementation pathways based on the "demand-driven, technology-enabled, and mechanism-coordinated" logic. These pathways focus on three key systems: knowledge construction, capability development, and faculty support, aiming to transform educational philosophies into actionable and assessable concrete practices.

3.1 Reconstruct the "intelligent +" curriculum system to realize digital and intelligent empowerment of knowledge construction

As a vital platform for talent cultivation, the curriculum system serves as a crucial bridge connecting professionals with industry demands. [6] Its modernization constitutes a prerequisite for successful implementation of educational models. This study systematically restructures the original curriculum framework of automation majors under the theme of digital-intelligent empowerment, focusing on three key aspects: 1) Curriculum Content Restructuring: Building an "AI+" course cluster

that retains core content from traditional courses like "Principles of Automatic Control" and "Modern Control Theory," while systematically introducing cutting-edge courses such as "Machine Vision and Intelligent Perception," "Industrial Big Data and Optimization," and "Intelligent Robot Systems." This creates an "Intelligence+" course cluster centered on the "intelligent perception-cognitive decision-making-autonomous execution" axis, ensuring students' knowledge structure closely aligns with industrial intelligentization trends. 2) Knowledge Visualization: Constructing a "three-tier knowledge graph" system. Following a progressive path from "course graph → professional graph → problem graph," we systematically advance knowledge visualization. First, we deconstruct individual course knowledge points to build detailed course graphs. Then, we integrate cross-course knowledge logic to form professional graphs reflecting the overall architecture and competency requirements. Finally, we develop "problem graphs" addressing typical engineering challenges like "intelligent production line scheduling" and "complex system fault diagnosis," integrating multidisciplinary knowledge from control, computer science, and management to systematically cultivate students' interdisciplinary system design and problem-solving capabilities. 3) Mechanism Assurance: Establishing a dynamic optimization mechanism. Based on the Implementation Rules of the Social Evaluation Feedback Mechanism, experts from industry enterprises, key teachers and graduate representatives are regularly organized to participate in the revision of training programs, so as to timely feedback the evolution of industrial technology and the change of job competency requirements to the adjustment of curriculum content and syllabus, and build a closed-loop mechanism of "demand-feedback-optimization" for continuous improvement.

3.2 Establish an "AI+" multidimensional innovation platform to strengthen engineering capability development

To effectively address the disconnect between practical teaching and real-world enterprise scenarios, this study has established a multi-dimensional innovative practice system characterized by "integration of virtual and real, convergence of courses and competitions, and unity of industry and education," encompassing the following three levels. At the foundational level, an AI-enhanced digital experimental platform for professional courses is built. Based on the OBE philosophy, a digital experimental platform integrating virtual simulation and remote real-world experiments is developed. This platform not only simulates high-risk and high-cost industrial scenarios but also automatically collects and analyzes behavioral data from students during operational procedures, parameter settings, and fault diagnosis, providing precise evidence for process evaluation and promoting the shift from "result assessment" to "process optimization" in teaching evaluation. At the enhancement level, a three-dimensional innovation platform integrating courses and competitions is established. The questions and evaluation criteria from high-level academic competitions such as "Internet+" "Siemens Cup" China Intelligent Manufacturing Challenge and "Challenge Cup" are organically incorporated into the teaching content and credit system of courses like "Innovation and Entrepreneurship Practice" and "Professional Comprehensive Experiment." Through "learning through competition, innovation through competition, and convergence of courses and competitions," students' innovative potential is stimulated, and their ability to solve complex engineering problems under multiple constraints and their teamwork skills are enhanced. At the integration level, an industry-university-research collaborative internship and training platform is established. Relying on the "Jinan Industry-Talent Integration Public Training Base" of the Ministry of Industry and Information Technology, in-depth cooperation with enterprises such as Shandong Aotai and Huaqing Yuanjian is implemented to fully execute the "integrated graduation internship and graduation design" training model. In their senior year, students join platforms or enterprises. Under the joint guidance of dual mentors (corporate engineers and university faculty), they conduct graduation

projects by integrating real R&D or engineering tasks, achieving a seamless transition from learning to employment. This process enables a comprehensive understanding of the entire lifecycle of products, systems, and engineering processes.

3.3 Build a "double teacher and double ability" teaching team to ensure the quality of collaborative education

"Teachers are the foundation and source of education." [7] A high-caliber faculty team with dual qualifications and capabilities serves as the cornerstone for the model's effective operation. This study systematically advances faculty structure optimization and competency development through three dimensions: internal integration, external recruitment, and capability enhancement. In terms of internal integration, we deepen the "university-institute integration" mechanism. Leveraging the strengths of the academic department system, we break down organizational barriers between colleges and research institutes. We explicitly require and incentivize researchers from the Automation Research Institute to teach core professional courses and jointly guide graduation projects, systematically transforming cutting-edge research achievements into comprehensive, research-oriented teaching cases to achieve effective feedback of research resources to teaching. Regarding external recruitment, we implement a "two-way circulation" plan between universities and enterprises. On one hand, we strictly enforce the "Teacher Enterprise Training Program," incorporating young teachers' enterprise practice experience (in principle, no less than six months cumulatively every five years) into performance evaluations and promotion criteria to continuously update their engineering capabilities. On the other hand, we establish positions such as "Industry Professors" and "Special Mentors," creating standardized appointment and compensation mechanisms to attract senior technical talents from enterprises to deeply participate in course teaching, specialized lectures, and graduation project guidance, forming a stable human resource sharing channel between universities and enterprises. For capability enhancement, we conduct specialized training programs in digital and intelligent literacy. We regularly organize specialized workshops and training programs focusing on smart teaching tools, AI-assisted instructional design, and online course development. These initiatives systematically enhance teachers' capabilities in applying digital and intelligent technologies to optimize classroom teaching and reform assessment systems, while facilitating their transformation from traditional knowledge transmitters to learning facilitators and innovation catalysts.

4. Practice results and analysis

After four years of systematic practice and exploration, the "Digital Intelligence Empowerment-Industry-Education Integration" multi-stakeholder collaborative education model developed in this study has achieved remarkable results in the Automation program at Qilu University of Technology. In the past two academic years, the coverage rate of students participating in provincial-level or higher academic competitions has increased to 85%, and they have repeatedly won honors in high-level events such as the "Siemens Cup" China Intelligent Manufacturing Challenge, setting a new record in both the number and level of awards. According to the 2025 graduate employment quality tracking survey, corporate satisfaction with graduates' "ability to solve complex engineering problems," "innovative thinking," and "teamwork" reached 95.2%, with the major alignment rate and average starting salary surpassing those of similar institutions in the province. In terms of expanding the depth and breadth of school-enterprise cooperation, three new in-depth industry-education integration practice bases have been added, with enterprises cumulatively investing over 3 million yuan in equipment and funding support. The school and enterprises jointly developed four project-based courses and two new-format textbooks, upgrading the cooperation model from a single "project

collaboration" to a systematic upgrade of "resource co-construction, process co-management, and outcome sharing." The faculty structure and practical teaching capabilities have also been significantly enhanced in practice, with the proportion of teachers with over six months of high-quality enterprise engineering practice experience increasing from 35% initially to 68%. Part-time teachers from industry enterprises undertake an average of more than 400 teaching hours annually. Teachers have won three awards in provincial-level or higher teaching innovation competitions, reflecting the continuous improvement in the vitality of teaching reform.

5. Discussion and reflection

The practical outcomes of this study demonstrate that the "Digital Intelligence Empowerment-Industry-Education Integration" collaborative education model provides a viable pathway for new engineering discipline development in local universities. However, several critical issues require exploration and resolution during the model's refinement and promotion. The sustainability mechanism of collaboration remains underdeveloped. While enterprises prioritize commercial value, current university-industry partnerships often rely on short-term projects and individual relationships, lacking institutionalized mechanisms for shared benefits and risk-sharing. Future efforts should focus on establishing long-term mechanisms such as equitable intellectual property distribution and joint talent cultivation programs to enhance collaboration stability and continuity, preventing disruptions caused by project termination or personnel turnover. Faculty evaluation systems lack sufficient coordination. Existing university promotion and performance evaluations still emphasize research papers and vertical projects, failing to adequately recognize teachers' contributions in industry-education integration, curriculum restructuring, and practical guidance. Institutional reforms should be implemented to establish diversified promotion channels like "teaching-focused" and "social service-oriented" tracks, incentivizing deeper faculty participation in collaborative education. The depth of digital intelligence technology integration and ethical boundaries require clarification. Current applications of digital intelligence in teaching primarily focus on superficial support in management and evaluation. Future exploration should delve into deeper educational innovations like AI-driven personalized learning path recommendations and virtual teaching-research collaboration platforms, while carefully defining ethical boundaries to ensure technology empowers education while respecting pedagogical principles.

6. Conclusions

This study addresses the practical challenges in engineering talent cultivation at local universities, establishing a multi-stakeholder collaborative education model anchored in "digital intelligence empowerment" and "industry-education integration," supported by three core systems: curriculum design, practical training, and faculty development. The implementation of this model in Qilu University of Technology's Automation program has demonstrated remarkable effectiveness in bridging the talent supply-demand gap while enhancing students' engineering innovation capabilities and professional competencies. This initiative not only provides robust support for engineering education accreditation and first-class program development in automation, but its core principles—"demand-driven, intelligence-powered, multi-stakeholder collaboration, and systematic restructuring"—also offer replicable solutions for new engineering education and program upgrades across similar institutions. Future research will focus on continuous model optimization, strengthening long-term collaboration mechanisms, and expanding its application and validation across broader academic disciplines.

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