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Exploration and Practice of New Engineering Innovative Talent Training Empowered by Digital Intelligence

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Abstract: As a leading provincially supported industrial university in Shandong, Qilu University of Technology is dedicated to driving regional industrial growth and cultivating elite engineering talent. Despite this mission, it faces critical challenges such as the mismatch between program structures and urgent industry demands, insufficient innovation capacity among emerging engineering students, and the lag of teaching content behind rapid technological advancements. Based on seven years of exploration and practice at Qilu University of Technology, this paper systematically presents the construction of an emerging engineering talent cultivation system, which is characterized by program optimization as the foundation, innovation capability as the core, institutional reform as the guarantee, and digital-intelligent empowerment as the driving force. Specifically, the paper introduces the practical pathways of a "three-dimensional coordinated" program development system, an "one-axis and dual-chain" training model, and a "one-core and two-circle" operational mechanism. These initiatives have produced measurable success in talent development, disciplinary advancement, and social contribution.

Keywords: Digital-Intelligence Empowerment; New Engineering; Innovative Talent Cultivation; Integration of Science and Education; Integration of Industry and Education

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1. Introduction

Currently, a new round of technological revolution and industrial transformation is accelerating worldwide. Emerging technologies such as big data and artificial intelligence are increasingly integrated with strategic emerging industries, including intelligent manufacturing, integrated circuits, and new energy[1-3]. In this context, the demand for high-quality engineering talents with strong engineering practice capabilities, innovative competence, and interdisciplinary thinking is

becoming increasingly urgent. The cultivation and reserve of such talents are closely related to the implementation of the national strategy of technological self-reliance and self-strengthening, and also provide essential support for promoting high-quality regional economic development.

As a key application-oriented industrial university supported by Shandong Province, Qilu University of Technology has developed a distinctive model for applied talent cultivation and plays an important role in supporting regional industrial development. The university undertakes the dual mission of technological innovation and serving the transformation and upgrading of local industries. Consequently, the effectiveness of its talent cultivation model directly influences the quality and efficiency of talent supply for key and urgently needed fields in the province.

The development of emerging engineering education represents an inevitable response of higher engineering education to national development strategies and the evolving needs of new industries[4-6]. Its central objective is to improve the quality of engineering talent cultivation by clarifying the competency structure required of future engineers and exploring innovative education models that meet contemporary industrial demands. However, traditional engineering education still faces several challenges[7-8]. In response, Qilu University of Technology has adhered to its institutional positioning as an application-oriented university and taken digital and intelligent technologies as key drivers for educational reform. By adopting a demand-oriented approach and deepening the integration of industry and education, the university has gradually established an emerging engineering talent cultivation system aligned with national strategic needs and regional industrial development. Based on seven years of exploration and practice since 2018, this study systematically analyzes the pathways and achievements of digitally empowered emerging engineering talent cultivation at Qilu University of Technology, with the aim of providing useful references for similar application-oriented universities.

2. Practical Challenges for Emerging Engineering Talent Cultivation

2.1. Insufficient Alignment Between Program Structure and Urgently Needed Industrial Fields

Traditional engineering program structures are primarily discipline-oriented. In the past, some programs at Qilu University of Technology were not sufficiently aligned with the development needs of strategic emerging industries in Shandong Province, such as next-generation information technology, green and low-carbon industries, and marine technology. As a result, noticeable gaps existed between program content and the competency requirements of industrial positions, making it difficult to meet the demand for interdisciplinary and composite engineering talents.

In addition, program development lacked a cluster-oriented perspective. Individual programs often had limited competitiveness and were unable to generate a coordinated talent cultivation force to support the development of Shandong's eleven key industrial chains. This situation was not fully consistent with the development principle of "building programs based on industrial demand and constructing program clusters along industrial chains," nor did it fully match the university's mission of serving the major provincial strategy of transforming old and new growth drivers.

2.2. Limitations in Cultivating Students' Innovation Capability

Innovation capability and the ability to solve complex engineering problems are essential competencies for emerging engineering talents. However, within the traditional talent cultivation model, there were gaps between theoretical teaching, scientific research practice, and industrial practice at Qilu University of Technology. Students had limited opportunities to participate in high-level research projects or engage in solving real industrial problems, which constrained the development of their innovative thinking and practical abilities.

Moreover, in earlier stages of program development, the absence of strong support from major research platforms, experienced mentors, and large-scale research projects limited students' access to disciplinary frontiers and industrial practice environments. Consequently, the pathways for cultivating innovation capability were not sufficiently clear. This situation was inconsistent with the emerging engineering objective of cultivating "innovative, interdisciplinary, and strategically oriented" engineering talents and could not fully meet the growing demand for high-level innovative

professionals driven by industrial upgrading in Shandong Province.

2.3. Teaching Content Lagging Behind Technological and Industrial Innovation

Rapid technological and industrial innovation has accelerated the iterative development of engineering technologies, placing higher demands on engineering education. However, traditional teaching systems at Qilu University of Technology have sometimes lagged behind in updating course content and curriculum structures. The curriculum lacked sufficient flexibility to incorporate emerging digital and intelligent technologies, such as artificial intelligence and big data, as well as cutting-edge industrial technologies and research achievements generated within the university.

As a result, a certain time lag emerged between the knowledge and skills acquired by students and the evolving technological requirements of industry, which weakened graduates' ability to adapt to the digital and intelligent transformation of regional industries. In addition, the relatively slow renewal of teaching materials and pedagogical approaches further constrained improvements in talent cultivation quality, creating a gap between the existing education model and the university's goal of building a high-level industrial university.

3. Construction and Practical Path of a Digitally Empowered Talent Cultivation System

In response to the above challenges, since 2018 Qilu University of Technology has systematically explored a digitally empowered emerging engineering talent cultivation mode. Based on its disciplinary strengths and institutional positioning, the university has gradually developed a structured talent cultivation system through continuous exploration and practice. This system is characterized by the coordinated integration of "three-dimensional linkage," "one-axis dual-chain," and "one-core dual-circle," which forms a closed-loop mechanism connecting demand identification, cultivation processes, and outcome output.

3.1. Establishing a "Three-Dimensional Linkage" Program Development System

Guided by the urgent talent demands of Shandong Province, Qilu University of Technology has constructed a program development system integrating three dimensions: demand orientation, program optimization, and cluster integration, to promote the coordinated development of academic programs and industrial needs.

3.1.1. Demand Orientation Dimension: Establishing Programs in Urgently Needed Fields

Aligned with national strategic priorities and the development needs of Shandong's key industries, the university has established several urgently needed programs, including Artificial Intelligence, Cyberspace Security, and Security Technology, while also developing interdisciplinary programs such as Intelligent Manufacturing Engineering and Robotics Engineering[9]. To further support regional strategic industries, programs such as Energy Storage Science and Engineering, Marine Technology, and Integrated Circuit Design and Integrated Systems have been introduced. In total, 29 emerging engineering programs oriented toward urgently needed fields have been established, covering areas including next-generation information technology, high-end equipment manufacturing, and new energy and materials. These programs correspond closely to the talent demands of Shandong's eleven key industrial chains and provide important human resource support for regional industrial upgrading.

3.1.2. Program Optimization Dimension: Deepening Program Connotation Development

To enhance the quality of traditional engineering education, the university has implemented systematic program improvement initiatives. Existing programs, such as Intelligent Interaction Design and Optoelectronic Information Materials and Devices, have been upgraded by integrating digital-intelligent technologies and strengthening their industrial relevance. In addition, the university has developed specialized program directions aligned with regional

industrial characteristics, including green papermaking and carbon neutrality, forming 89 specialized tracks as well as 15 interdisciplinary directions related to artificial intelligence. To further support interdisciplinary learning, 25 micro-programs have been established in urgently needed and cross-disciplinary areas, covering fields such as technology and humanities, green production, artificial intelligence, and big data, supported by more than 150 micro-courses.

Talent cultivation schemes have also incorporated curriculum modules related to industry–education integration, research-education integration, interdisciplinary learning, and "AI+" education, ensuring closer alignment between program content and emerging industrial development needs.

3.1.3. Cluster Integration Dimension: Building Program Clusters for Strategic Fields

Leveraging its disciplinary strengths in computer science, light industry, and marine science, the university has promoted cluster-based program development in strategic fields, including next-generation information technology, green and low-carbon technology, advanced computing, high-end equipment manufacturing, marine technology, and new energy materials. More than 100 undergraduate talent cultivation plans have been revised and updated to better support the cultivation of academic leaders, engineering innovators, industry professionals, and strategic talents. Through cluster-based development, the university has effectively implemented the principle of building programs based on industrial demand and constructing program clusters along industrial chains, enhancing resource integration and promoting the coordinated development of education and industry.

3.2. Implementing the "One-Axis Dual-Chain" Cultivation Path

Taking innovation capability cultivation as the central axis, Qilu University of Technology has established science-education integration and theory-practice synchronization, forming a talent cultivation model that integrates research training, curriculum reform, and practical education to enhance students' abilities to solve complex engineering problems.

3.2.1. Science-Education Integration

To strengthen students' innovation capabilities, the university has implemented a "2+2" staged education model, in which the first two years emphasize foundational knowledge while the latter two years focus on research-oriented learning and innovation training. In addition, integrated bachelor-master-doctoral training pathways have been explored. Supporting mechanisms such as the course-project dual-spiral model, large-platform support, and distinguished mentor guidance have been established to encourage students to participate in research projects, laboratories, and research teams at an early stage.

Relying on high-level research platforms, including two national key laboratories and the National Supercomputing Center in Jinan, the university has established innovation talent training bases in emerging fields such as next-generation information technology and artificial intelligence. Elite talent programs, innovation experimental classes, and the Qilu Elite Academy provide students with opportunities for high-quality research training, enabling them to develop innovative thinking through participation in scientific research.

3.2.2. Technology-Driven Curriculum System

Driven by digital-intelligent technologies, the university has promoted the development of artificial intelligence general education courses, interdisciplinary "AI+" courses, and AI-related professional core courses, forming an integrated curriculum system described as "AI + G + P + P": Artificial Intelligence, General Education, Professional Education, and Practical Training. A total of 91 AI interdisciplinary courses and 346 smart courses have been developed. Distinguished scholars have been invited to deliver lectures on artificial intelligence general education across universities in the province, strengthening students' digital literacy. Meanwhile, scientific research achievements generated by the university have been incorporated into teaching cases, and cutting-edge technologies and key industrial challenges have been integrated into course teaching, ensuring that teaching content evolves in parallel with technological innovation.

3.2.3. Synchronization of Theory and Practice

The university has established three major practice platforms including research training, disciplinary competitions, and innovative graduation projects, thus forming a three-level experimental teaching system covering basic, comprehensive, and innovative experiments. Project-based teaching approaches combining theoretical exploration and practical verification have been widely implemented. A dual-mentor system has been introduced, in which industry experts jointly supervise students together with university faculty members. As a result, all undergraduate graduation projects are derived from real enterprise projects, enabling students to improve their practical abilities by solving real industrial problems. In addition, students are also encouraged to participate in disciplinary competitions, and innovation and entrepreneurship credits have been incorporated into the curriculum system to promote the transformation of theoretical knowledge into innovative achievements.

3.3. Establishing a "One-Core Dual-Circle" Operational Mechanism

To ensure the effective implementation of the talent cultivation system, Qilu University of Technology has promoted institutional and organizational reforms, forming an operational framework characterized by internal and external coordination. This "one-core dual-circle" mechanism integrates digital technologies, scientific research resources, and industrial resources throughout the talent cultivation process.

3.3.1. Internal Operational Mechanism: Promoting Science-Education Integration

The university has promoted the integration of research institutes and academic schools following the institutional merger with the Shandong Academy of Sciences. Based on disciplinary similarities, research institutes and academic units have been reorganized to establish five science-education integration colleges and fourteen operational academic divisions. This structure forms an internal operational mechanism characterized by university leadership, joint institute-college governance, and coordinated science–education collaboration, enabling the integration of research and teaching resources and facilitating the transformation of scientific achievements into teaching resources.

3.2.2. External Operational Mechanism: Advancing Industry-Education Collaboration

The university has established extensive collaboration mechanisms involving government, industry, academia, and research institutions. It has taken the lead in establishing platforms such as the Shandong Confidentiality College, the Shandong New-Generation Information Technology Higher Education Community, and the Mechanical Engineering Collaborative Education Alliance. In addition, the university has established one provincial-level Future Technology Institute, four industry-oriented colleges, and five modern industrial colleges, closely aligning talent cultivation with regional industrial development. Inter-university cooperation has been strengthened through partnerships with institutions including Shanghai Jiao Tong University, University of Shanghai for Science and Technology, and Zhejiang University of Technology, while international cooperation has expanded through partnerships with universities along the Belt and Road Initiative.

3.2.3. Full-Chain Cultivation Mechanism: Promoting Digital Empowerment

The university has integrated artificial intelligence and digital technologies throughout the talent cultivation process to establish a digitally empowered full-chain education mechanism combining virtual and real learning environments. A university-level Knowledge Innovation Center has been established, and more than 300 knowledge graphs and competency maps have been developed for courses and academic programs. The Cloud Digital Textbook Platform has supported the development of 46 digital textbooks. Virtual simulation experiment platforms with 68 virtual simulation projects have also been constructed, while smart classrooms and virtual teaching and research offices support blended learning and online–offline integration. These initiatives promote the digital transformation of teaching and enable the practical implementation of digitally empowered talent cultivation.

4. Practical Outcomes of Talent Cultivation

After seven years of exploration and practice, the digitally empowered emerging engineering talent cultivation system at Qilu University of Technology has been fully implemented and gradually expanded to other universities within and beyond the province. The initiative has generated notable achievements in talent cultivation, disciplinary development, and social service, and has received broad recognition from government authorities and industry sectors, demonstrating the university's practical contributions to the development of emerging engineering education.

4.1. Significant Improvement in Talent Cultivation Quality

The level of talent cultivation at Qilu University of Technology has achieved substantial breakthroughs. The university has independently cultivated one academician and one Changjiang Scholar, while six faculty members have been recognized as Shandong Provincial Teaching Masters. One faculty member won the first prize in the Fifth National College Teachers' Teaching Innovation Competition, and three teams were selected as Huang Danian-style teaching teams in Shandong Province, further promoting the integrated development of education, science, and talent cultivation.

In 2024, the university was approved for five new doctoral degree programs, including the first national interdisciplinary doctoral program in Intelligent Science and Technology, which is also the first of its kind in Shandong Province. In 2025, the university obtained the qualification to recommend outstanding undergraduate students for postgraduate study without examination, marking a significant improvement in its talent cultivation level and positioning the university among the leading institutions for high-level talent cultivation in Shandong Province.

Students' innovation capabilities have also improved significantly. Over the past five years, students have won more than 1,000 national awards in competitions such as the National Undergraduate Mathematical Contest in Modeling and the "Challenge Cup." In 2024, the university won two special prizes in the national "Challenge Cup" competition and three gold medals in the China International College Students' Innovation Competition, ranking first among provincial universities in Shandong. According to the 2023 National College Student Competition Analysis Report, the university received 553 awards in that year, ranking 55th among universities nationwide, and 65th in the five-year ranking. The graduate employment rate has remained above 90%, with employer satisfaction exceeding 98%, indicating strong recognition of the university's graduates by regional industries.

4.2. Remarkable Achievements in Disciplinary and Program Development

Significant progress has been made in disciplinary platform construction. The university has been approved to establish one provincial-level Future Technology Institute, five provincial characteristic colleges, and four provincial modern industrial colleges, as well as a provincial top-notch talent cultivation base for computer science and a provincial implementation institution for top innovative talent cultivation in the field of artificial intelligence. These platforms provide strong support for high-quality talent cultivation and further strengthen the university's disciplinary advantages.

The influence of disciplines and academic programs has continued to increase. Nine disciplines, including computer science, have entered the top 1% of the ESI global rankings, while the marine discipline has become an important regional base for marine technology talent cultivation. In addition, three disciplines have been recognized as provincial high-level disciplines.

Program development has also achieved notable progress. A total of 37 programs has been approved as national or provincial first-class undergraduate programs, and seven programs have passed engineering education accreditation, aligning the university's engineering education with international standards. In terms of course development, the university has been approved for 15 national first-class undergraduate courses, 64 provincial first-class courses, and one national demonstration course for curriculum-based ideological education, reflecting continuous improvements in teaching quality and disciplinary strength.

4.3. Enhanced Social Service Capacity and Recognition

The university has demonstrated strong capacity to support strategic industries. Qilu University of Technology has been selected as one of the first universities for national industry–education integration projects. It has also taken the lead in establishing two national key laboratories, the National Supercomputing Center in Jinan, and a total of 14 national-level platforms.

The university has undertaken more than 500 national research projects and achieved breakthroughs in key technological fields, including marine buoy systems, supercomputing internet technologies, and green papermaking technologies, receiving seven national science and technology awards.

Through collaboration with more than 50 leading enterprises across Shandong's eleven key industrial chains, the university has solved over 130 major technical challenges for enterprises. Jointly cultivated talents have contributed to over 2 billion RMB in newly generated industrial output value, providing strong support for regional industrial upgrading and demonstrating the university's mission in serving regional economic development.

The university's achievements have also received strong recognition from government authorities. Its experiences in emerging engineering talent cultivation have been reported 15 times in authoritative media outlets such as China Education Daily and Shandong Education News, and the Shandong Provincial Department of Education has promoted its practices as a typical case across the province.

4.4. Extensive Demonstration and Dissemination Effects

The talent cultivation system has been widely implemented across the university. It has been adopted by 20 schools and more than 60 undergraduate programs, forming a strategic talent cultivation pattern characterized by "distinctive models for each school and customized schemes for each program." This has effectively improved the overall quality of talent cultivation across the university. The influence of the model has also expanded beyond the university. Qilu University of Technology has shared "AI+" curriculum resources with universities both within and outside the province, receiving more than 50 visits from peer institutions for academic exchange and investigation. Educational resources such as the "Waterdrop Camp" courses have been adopted by over 30 universities.

The model has been promoted in 54 universities within Shandong Province, including Shandong University of Science and Technology and Qingdao University of Technology, as well as two universities outside the province, including Shaanxi University of Science and Technology and Guangxi University. Experts have evaluated the initiative as highly original, practically effective, and distinctive, with strong potential for wider dissemination, providing valuable experience for the development of emerging engineering education in similar institutions.

4.5. Evident Outcomes of Digital and Intelligent Educational Applications

The university has established a comprehensive smart teaching environment. Facilities including seven smart classrooms, one VR education base, and one artificial intelligence teaching and learning center have been constructed, promoting the digital transformation of teaching spaces.

At the same time, the university has developed a systematic "AI+" interdisciplinary talent cultivation model, expanding diversified development pathways for artificial intelligence-related talents. The Shandong Provincial Artificial Intelligence General Education Course has been developed and launched on the provincial platform. In collaboration with relevant institutions, the university has also initiated the development of an Artificial Intelligence Series of Textbooks.

In addition, eight provincial lectures on artificial intelligence general education have been organized, reaching more than 70,000 participants. These initiatives have significantly promoted the popularization of digital literacy education and highlighted the distinctive features of digitally empowered talent cultivation at the university.

5. Conclusions

Faced with the mismatch between traditional engineering talent cultivation and the urgent demands of national strategies

and regional industrial development in Shandong Province, Qilu University of Technology has conducted seven years of continuous exploration and practice. Based on its institutional positioning and regional industrial needs, the university has established a digitally empowered emerging engineering talent cultivation system. This system optimizes program structure through a "three-dimensional linkage" mechanism, strengthens innovation capability cultivation through the "one-axis dual-chain" training pathway, and ensures cultivation quality through the "one-core dual-circle" operational mechanism. Practice shows that this system effectively addresses key issues in traditional engineering education, including the weak alignment between academic programs and industrial needs, insufficient pathways for innovation capability development, and the lag in updating teaching content. It has achieved notable outcomes in improving talent cultivation quality, advancing disciplinary and program development, and enhancing the university's capacity to serve regional industries. These experiences provide a feasible practical approach for application-oriented industrial universities seeking to promote digitally empowered emerging engineering talent cultivation.

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