Contemporary Education Frontiers, 2026, Volume 4, Issue 7
https://bbwpublisher.com/journal/CEF
Online ISSN: 3029-1860
Print ISSN: 3029-1879

Development and Implementation of an Innovative, Application-Oriented Talent Training System for Mechanical Engineering

Jin Du*, Chonghai Xu, Yuexia Lv, Mingdong Yi, Juan Ge, Ming Song

Faculty of Mechanical Engineering, Qilu University of Technology (Shandong Academy of Sciences), Jinan 250353, Shandong, China

Author to whom correspondence should be addressed.

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Abstract: The digital and intelligent transformation of manufacturing has placed new demands on mechanical engineering education. Current training practices are facing challenges including insufficient integration of value education with professional education, weak connections among curricular learning, research and innovation activities, and industry-based practice, and limited coordination among universities, research institutes, and enterprises. To address these issues, Qilu University of Technology developed an innovative, application-oriented talent training system based on science-education integration and industry-education collaboration. The proposed system integrates three components: value development embedded in professional education, progressive competency development across three learning settings, and collaborative education involving multiple stakeholders. Its implementation improves students' engineering practice and technological innovation capabilities, and supports the development of academic programs, curricula, faculty teams, and practical training platforms. The system has also been adopted beyond the original programs, indicating its applicability to mechanical engineering education at other application-oriented universities.

Keywords: Talent training; Mechanical engineering; Innovative and application-oriented talents; Science-education integration; Industry-education collaboration

Online publication: July 26, 2026

1. Introduction

Manufacturing is a fundamental sector of the national economy and plays an important role in developing new quality productive forces. Recent advances in intelligent control, digital twins, the Industrial Internet, and artificial intelligence are reshaping the design, manufacturing, and operation of mechanical products. These technological changes have also altered the knowledge and skills required of mechanical engineering graduates. Accordingly, mechanical engineering education is shifting from a primary focus on disciplinary knowledge and individual technical skills toward the integrated development of knowledge, competencies, and professional attributes. Therefore, a key challenge is to strengthen students' engineering practice,

technological innovation, and integrated problem-solving abilities while maintaining a solid foundation in mechanical design and manufacturing.

Considerable efforts have been made to improve the training of innovative and application-oriented talents in mechanical engineering in China. Wang et al. [1] reformed the curriculum, teaching methods, and practical training platforms and developed a multilevel practical training system. Jiang et al. [2] examined the upgrading of mechanical engineering programs and corresponding training approaches in response to advances in intelligent manufacturing. At the course level, Sun et al. [3] addressed the weak connection between theory and practice and the slow renewal of teaching content by reforming course resources, teaching methods, and assessment. Yuan et al. [4] incorporated recent industrial technologies and research outcomes into a Fundamentals of Mechanical Manufacturing course and revised its objectives, content, and practical components. Xie et al. [5] integrated engineering graphics with computer-aided drawing to strengthen the connections among engineering design, computer-aided drafting, and practical application.

Mechanical engineering is a highly practice-oriented discipline, and the development of students' innovative and practical capabilities cannot rely solely on classroom instruction. Research training, innovation activities, and industry-based projects also play important roles in engineering education. To strengthen the links among these components, Ding et al. [6] integrated project-based tasks into theoretical and practical courses and combined innovation training with computer simulation. He et al. [7] incorporated enterprise R&D projects into teaching, providing students with opportunities to address practical engineering problems while strengthening the connection between university education and industrial practice.

Existing studies have addressed program upgrading, curriculum reform, project-based learning, practical training, and industry–education collaboration. However, many of these efforts have focused on individual courses, projects, or practical components, while systematic integration across the entire training process remains limited. Building on its integration with the Shandong Academy of Sciences and its previous experience in the Excellent Engineer Education and Training Program, as shown in **Figure 1**, Qilu University of Technology developed a systematic training approach from the perspectives of value development, progressive competency development, and multi-stakeholder collaboration. This study describes the development and implementation of the framework and examines its educational outcomes, with the aim of providing a practical reference for mechanical engineering education at application-oriented universities.

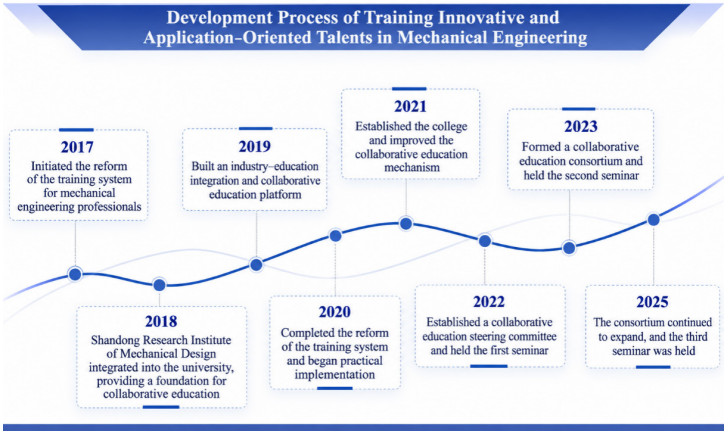


Figure 1. Evolution of Innovative and Application-Oriented Talent Training in Mechanical Engineering.

2.2. Weak connections among the three learning settings

Competency development in mechanical engineering still relies heavily on formal curricular learning. Connections among coursework, research training, student competitions, and industry-based practice remain

insufficient. Research projects and innovation competitions are not always closely linked to the curriculum, while participation in authentic industrial projects is limited in both coverage and depth. Consequently, curricular learning, research and innovation activities, and industry-based practice have not yet formed a clearly structured progression in terms of learning objectives, content, and implementation. In addition, students also lack sustained involvement in research tasks and complex engineering projects. The progression from disciplinary learning to research and innovation, and subsequently to engineering application, is therefore not sufficiently developed. This fragmentation limits the continuous development of engineering practice, technological innovation, and complex problem-solving abilities and can lead to a gap between graduate competencies and evolving industrial needs.

2.3. Insufficient coordination among science, education, and industry

The cultivation of innovative and application-oriented mechanical engineering talents involves universities, research institutes, and industrial enterprises. At present, however, collaboration among these stakeholders is still largely limited to research projects, internships, practical training, and graduation projects. University teaching, scientific research, and industrial engineering practice are not yet closely connected throughout the training process. In particular, technological advances, research findings, and engineering needs are not consistently incorporated into course content, teaching materials, laboratory work, and engineering projects. As a result, science–education–industry collaboration often takes the form of individual activities or short-term projects, with limited continuity across different stages of student training. This limits the effective use of research and industrial resources in undergraduate education.

3. Reform strategies for talent training in mechanical engineering

3.1. Integrating value development with professional education

The "Red Gear" framework shown in **Figure 2** was developed to strengthen the integration of value education into professional training. Inspired by the meshing and coordinated transmission of mechanical gears, the framework incorporates social responsibility, craftsmanship, engineering ethics, commitment to technological advancement, and innovation throughout the training process.

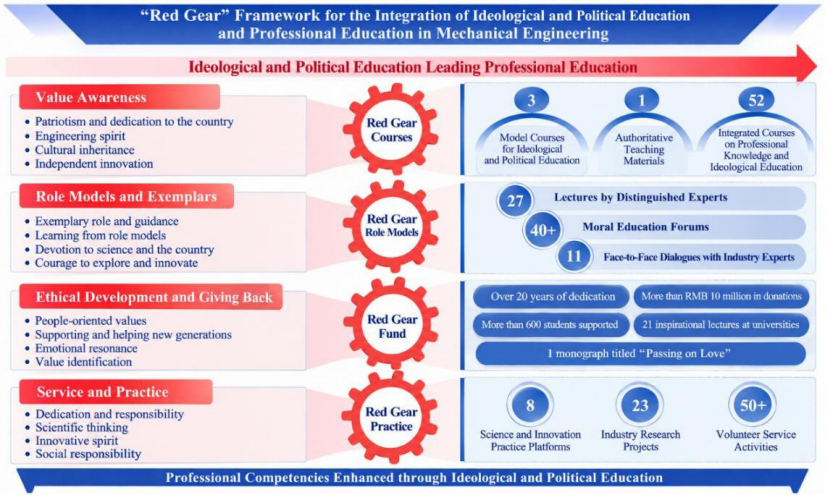


Figure 2. "Red Gear" framework.

3.1.1. Integrating value development into the curriculum

Value-related educational resources were systematically identified across the mechanical engineering curriculum. Professional responsibility, engineering ethics, craftsmanship, innovation, and commitment to technological development were integrated with disciplinary knowledge, engineering cases, and recent industrial developments. A total of 52 "Red Gear" courses were developed following the principle of assigning specific educational objectives and appropriate implementation approaches to individual courses and teaching modules. Three courses were recognized as national- or provincial-level model courses for value education. A monograph entitled Teaching System for Integrating Value Education into the Curriculum: Mechanical Engineering was also published. Together, these activities established a structured approach covering core disciplinary courses, practical courses and innovation-oriented courses.

3.1.2. Strengthening professional identity through role models

Leading academics, industry experts, entrepreneurs, distinguished alumni, and successful innovators were incorporated into professional education as role models. A multilevel approach was established to expose students to different career and professional development pathways. Through academic lectures, professional forums, and face-to-face sessions with entrepreneurs, academicians, industry experts, corporate executives, and alumni were invited to share their experiences in technological innovation, engineering practice, industrial development, and career progression. These activities connected professional education with authentic career experiences and engineering achievements. They enabled students to understand the contribution of mechanical engineering to technological and industrial development through concrete examples rather than abstract instruction.

3.1.3. Linking student support with social responsibility

The "Wang Ling Financial Aid Fund" was incorporated into the "Red Gear" framework to broaden the educational role of financial assistance. In addition to providing financial support, the fund links student development with responsibility education and community service. Through the experiences of former recipients, thematic activities, and volunteer service, students are encouraged to understand the social responsibilities associated with personal growth and to support others when circumstances permit. In this way, financial assistance becomes part of an ongoing educational process that fosters responsibility, gratitude, and a willingness to contribute to society.

3.1.4. Translating value development into engineering and social practice

Value development was further extended to engineering practice and community service through the "Intelligent Manufacturing for the Future" innovation platform, student innovation and entrepreneurship competitions, industry-based activities, and volunteer programs. Students participated in innovation projects with socially relevant themes and visited manufacturing enterprises to gain direct exposure to industrial practice. Students also applied mechanical engineering knowledge through community appliance maintenance, science outreach, and intelligent manufacturing volunteer programs. By engaging with authentic engineering and community settings, students were able to translate professional values, craftsmanship, and social responsibility into engineering practice.

3.2. A three-stage learning framework for progressive competency development

To address the fragmentation of theoretical instruction, research training, and industrial practice, a three-stage learning framework was established to develop students' engineering and innovation competencies progressively. As shown in **Figure 3**, The framework connects three learning settings: curricular learning, research and innovation, and industry-based practice. These settings correspond to three stages of competency development: foundation building, innovation development, and engineering application. This progression establishes a continuous pathway from knowledge acquisition to research training and engineering application.

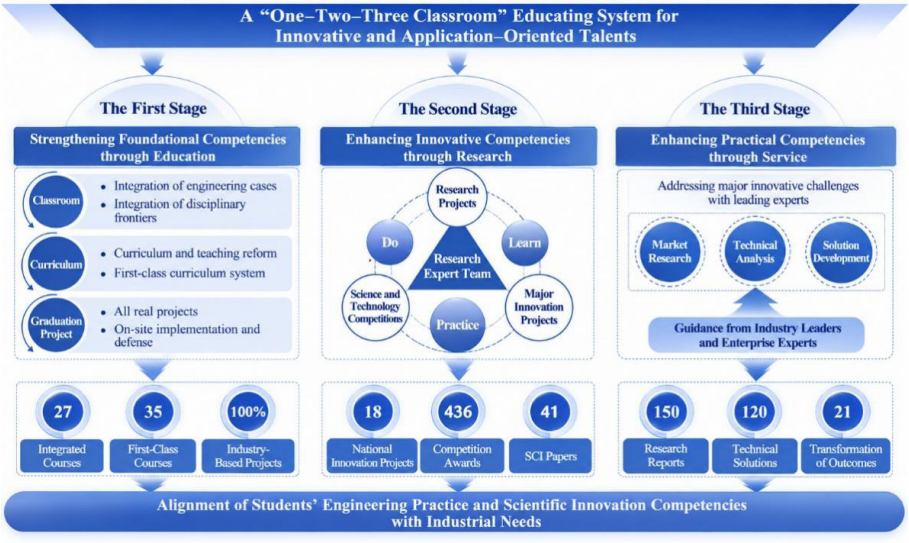


Figure 3. Three-stage learning framework.

3.2.1. Building disciplinary and engineering foundations

The first stage focuses on disciplinary foundations and fundamental engineering competencies. Research outcomes, engineering cases, industrial projects, and recent technological advances were continuously incorporated into course content. Twenty-seven courses integrating education, research, and industrial practice were developed. Discussion-based, inquiry-based, and project-based teaching approaches were introduced, together with 26 specialized courses delivered in English or bilingually or incorporating English-language and artificial intelligence components. These efforts were supported by a portfolio of nationally and provincially recognized first-class undergraduate courses.

Engineering projects drawn from industrial practice were incorporated into formal teaching. All undergraduate graduation projects were based on actual engineering problems and jointly supervised by university faculty and enterprise engineers. Through these projects, students applied disciplinary knowledge to real engineering tasks and gained practical experience in industrial settings.

3.2.2. Developing innovation competencies through research projects

The second stage uses research activities to strengthen students' innovation competencies. Research platforms, funded projects, and research teams were incorporated into undergraduate education. More than 130 research projects, including projects supported by the National Natural Science Foundation of

China, provided opportunities for students to participate in research under the supervision of experienced researchers. Students were involved in project design, experimental validation, data analysis, and the preparation of research outputs.

Engineering projects drawn from industrial practice were incorporated into formal teaching. All undergraduate graduation projects were based on actual engineering problems and jointly supervised by university faculty and enterprise engineers. Through these projects, students applied disciplinary knowledge to real engineering tasks and gained practical experience in industrial settings.

3.2.3. Applying competencies to authentic engineering problems

The third stage extends student learning from the university to industrial settings and focuses on the application of acquired competencies to engineering problems. Enterprise technical needs were converted into student project tasks through provincial innovation programs and university–industry collaborative projects. Students worked under the joint supervision of researchers, faculty members, and enterprise engineers and participated in market investigation, technical analysis, solution development, and engineering validation.

Projects in areas such as precision machining and intelligent manufacturing exposed students to practical industrial constraints and technical requirements. Instead of following predefined laboratory procedures or conventional course assignments, students worked on complex engineering problems drawn directly from industrial practice. This experience connected disciplinary learning and research training with engineering practice, enabling students to apply technical knowledge and innovative ideas to the development of practical solutions.

3.3. A collaborative ecosystem among universities, research institutes, and industry

To address fragmented resources, insufficient coordination, and the limited use of industrial resources in education, a collaborative ecosystem as shown in **Figure 4** was established among universities, research institutes, and industrial enterprises. Regular consultation, joint platform development, and continuous content renewal mechanisms were introduced.

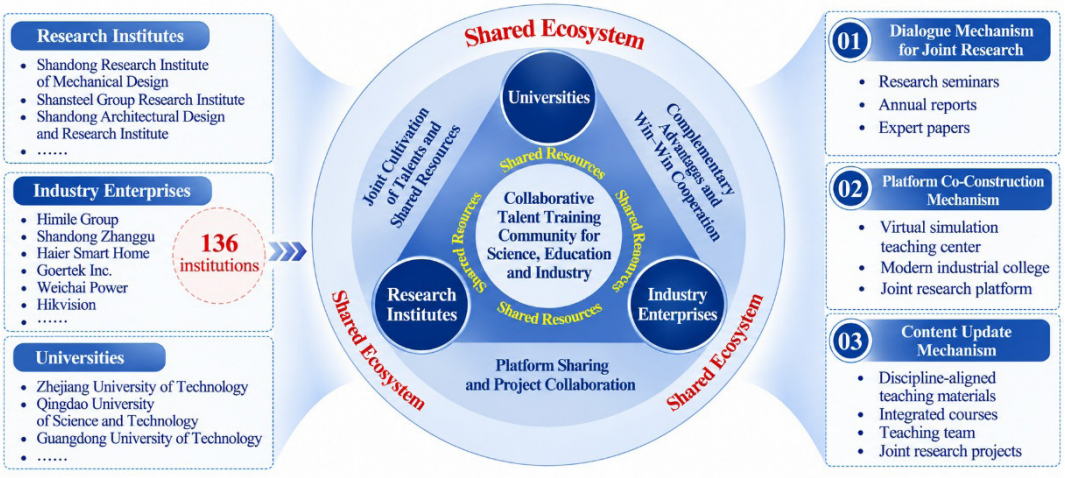


Figure 4. A Collaborative ecosystem linking education, research, and industry.

3.3.1. Establishing a consultation mechanism for joint decision-making

A collaborative education consortium for mechanical engineering was established with 136 participating universities, research institutes, and leading industrial enterprises. A steering committee consisting of academicians, experts from national teaching advisory committees, and senior industry representatives was formed to guide its operation. The consortium also established formal governance rules and a regular consultation mechanism.

Information on industrial trends, workforce needs, and educational outcomes was collected through mechanical engineering education forums, surveys of graduates and their supervisors, and consultations with enterprises. The findings informed revisions to training programs, course content, and practical teaching activities. Regular consultation and evaluation linked industry needs and stakeholder feedback with subsequent program adjustments, while allowing enterprises and other external stakeholders to participate more directly in the development and revision of talent training programs.

3.3.2. Developing shared platforms for education, research, and engineering practice

Teaching resources from universities, research facilities from research institutes, and engineering resources from enterprises were integrated to establish a multilevel platform for collaborative education. Jointly developed facilities included national experimental teaching demonstration centers, national virtual simulation experimental teaching centers, a national modern industrial college for digital manufacturing, key laboratories, public training centers, and other teaching and research platforms.

These platforms enabled participating institutions to share experimental facilities, research infrastructure, engineering environments, and technical expertise. Research and industrial resources were thereby made accessible to undergraduate students for practical training, project development, and innovation activities. The shared platform system provided sustained practical support across different stages of talent training.

3.3.3. Establishing a mechanism for continuous renewal of educational content

Teaching content was regularly updated in response to technological advances and changes in industrial practice. Emerging technologies, recent research findings, technical standards, and industry competency requirements were introduced into course content, textbooks, laboratory activities, and engineering cases.

Through university-industry collaboration, 11 textbooks were jointly developed, together with 27 courses integrating education, research, and industrial practice, 16 collaborative teaching teams, and 41 virtual simulation laboratory resources. This mechanism created a continuous cycle in which industrial needs generated engineering problems, research produced new knowledge and technologies, and these outcomes were subsequently translated into educational content. The updated content was then used to prepare students to address emerging industrial challenges, maintaining a dynamic connection between mechanical engineering education and technological development.

4. Outcomes of the Reform

4.1. Student development and educational outcomes

The integration of value development, professional education, research training, and engineering practice produced measurable outcomes in student development. All mechanical engineering students participated in innovation and entrepreneurship projects or disciplinary competitions. Over the past five years, students

received 436 awards at national and provincial levels, including a national gold award in the China International College Students' Innovation Competition. They completed 39 national- level and provincial-level innovation and entrepreneurship training projects and published 47 research papers, including 41 papers indexed by the Science Citation Index. Seventeen national invention patents were also granted based on student-related research and innovation activities.

The outcomes of the training system were not limited to technical and innovation capabilities. Some former recipients of the Wang Ling Financial Aid Fund later volunteered in Tibet, contributed to the fund after graduation, and provided financial assistance to students in need, demonstrating continued engagement in social responsibility after graduation. More than 85% of graduates entered the mechanical engineering sector, including major manufacturing enterprises such as China National Heavy Duty Truck Group and Himile Group. Among 187 surveyed employers, over 93% expressed satisfaction with graduates' overall performance, practical skills, and innovation capabilities, reflecting the relevance of the training outcomes to industry needs.

4.2. Program and educational infrastructure development

The reform was accompanied by coordinated development of academic programs, curricula, educational platforms, and practical training facilities. Two national experimental teaching demonstration centers, two national virtual simulation experimental teaching centers, and one national modern industrial college for digital manufacturing were established. Fifteen undergraduate programs were selected as first-class undergraduate programs, including ten at the national level, and eight programs received engineering education accreditation. In addition, one national teaching team and two provincial-level model teaching organizations were recognized.

Industry collaboration contributed to the establishment of 17 national- and provincial-level teaching and research platforms, including the National Innovation Center for Micro/Nano Manufacturing, provincial experimental teaching centers, an intelligent manufacturing public training center, modern industrial colleges, and key laboratories. These platforms provided shared facilities and resources for practical teaching, research training, and industry-oriented projects, supporting the continued implementation of the training system.

4.3. Faculty development and integration of teaching and research

Faculty development accompanied the implementation of the training system, with faculty increasingly engaged in research-based teaching and engineering practice in addition to classroom instruction. During the implementation period, one Changjiang Scholar was recruited, while one national-level leading scholar and four national-level young scholars, including a Young Changjiang Scholar, were developed within the faculty. In addition, two faculty members were recognized as provincial teaching masters, two as Young Taishan Scholars, and three as Taishan Industry Leading Talents.

Faculty members received 26 national and 16 provincial awards in teaching competitions, including a national second prize in the National College Teacher Teaching Innovation Competition. Nine national and 26 provincial first-class undergraduate courses were developed. Faculty members also published 31 textbooks, three monographs on educational reform, and 81 papers on teaching and education.

Research and industrial collaboration provided an additional source of educational resources. Faculty members participated in 95 national and provincial research projects, including National Science and

Technology Major Projects, and more than 420 industry-funded projects, with total funding exceeding RMB 220 million. These activities generated more than ten national and provincial science and technology awards, including a Second Prize of the State Scientific and Technological Progress Award. Research outcomes, engineering projects, and industrial technologies were subsequently incorporated into teaching, strengthening the interaction among education, research, and engineering practice.

4.4. Dissemination and broader adoption

The training approach was applied beyond its initial mechanical engineering context. Within the university, it was implemented in four mechanical engineering-related programs and 36 other engineering programs, involving approximately 28,000 students. Its practices were also adopted by 14 universities, including Guangdong University of Technology and Shandong University of Science and Technology, reaching more than 34,000 students.

The reform practices were presented at 22 national and regional forums on mechanical engineering education, with participants from more than 100 universities. Five open courses in mechanics and engineering graphics were also developed and made available through online platforms such as Bilibili. Together, these courses attracted more than 220,000 followers and received over 15 million views, further broadening the reach of the teaching resources.

5. Conclusion

Rapid technological advances in the mechanical engineering industry require talent training to move beyond isolated reforms of individual courses or practical components. Greater emphasis should be placed on the systematic integration of value development, progressive competency development, and educational resources. The implementation of the proposed approach showed that the "Red Gear" framework can integrate professional identity, engineering responsibility, and commitment to technological development into professional education. The three-stage learning framework connects curricular learning, research and innovation, and industry-based practice, enabling students to progress from knowledge acquisition to innovation training and the solution of complex engineering problems. Collaboration among universities, research institutes, and industry further supports the continuous renewal of course content and the integration of authentic engineering projects into undergraduate education.

Together, these components establish a coherent training process in which value development is embedded in competency development, engineering competencies are strengthened through authentic projects, and research and industrial resources are continuously incorporated into education. This approach shifts mechanical engineering education from relatively independent teaching and practice activities toward a progressive and multi-stakeholder training process. Future work should further improve mechanisms for updating educational content and evaluating learning outcomes in response to advances in artificial intelligence, intelligent manufacturing, and changing industrial needs.

Funding

Shandong Province Undergraduate Teaching Reform Research Project (Project No.: Z2025232, Z2025236), Jinan Urban University Integration Development Strategic Engineering Project (Project No.: JNSX2025029,

JNSX2024041) and Special Research Project on "Educational Digitalization and Industry-Education Collaboration" of the Ministry of Education of China (Project No.: CSDP26LF1G211); Qilu University of Technology "Craftsmanship" Faculty Studio Project (Project No.: GZS202603)

Disclosure statement

The authors declare no conflict of interest.

References

[1] Wang F, Shao Q, Ma QL, et al., 2024, Exploration of an Application-Oriented Talent Training Model for Mechanical Engineering under the Background of Emerging Engineering Education. Journal of Higher Education, 10(23): 159–162.

[2] Jiang C, Yang XJ, Long XY, et al., 2022, Exploration and Practice of Intelligent Manufacturing-Enabled Transformation and Upgrading of Traditional Engineering Programs: A Case Study of Mechanical Engineering. Research in Higher Education of Engineering, (4): 25–30.

[3] Sun MX, Zheng LK, Feng Y, et al., 2022, Teaching Innovation and Practice of Mechanical Engineering Courses under the Background of Emerging Engineering Education. Journal of Nanjing Institute of Technology (Social Science Edition), 22(4): 74–78.

[4] Yuan ZS, Wu SX, Zheng LJ, et al., 2025, Exploration of Teaching Reform in Fundamentals of Mechanical Manufacturing for Emerging Engineering Education. Frontiers of Modern Education, 6(2): 119–122.

[5] Xie LX, Ma YC, Shi JF, et al., 2025, Integrated Teaching Reform of Engineering Graphics and Computer-Aided Drawing for Mechanical Engineering Programs under the Background of Emerging Engineering Education. Agricultural Engineering, 15(9): 138–143.

[6] Ding L, Wang HX, Zhou BJ, et al., 2022, Interactive and Collaborative Teaching Model for Mechanical Engineering Programs from the Perspective of Emerging Engineering Education: A Case Study of West Anhui University. Journal of Xichang University (Natural Science Edition), 36(3): 108–113.

[7] He P, Zhang XC, Jiang MF, 2024, Talent Training Model Based on Deep Industry-Education Integration for Mechanical Engineering Programs at Application-Oriented Universities. Heilongjiang Education (Higher Education Research and Evaluation), 5: 54–56.

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