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Research on Mechanical Engineering Teaching System Based on Integration of Science, Education, Industry and Perspective of New Engineering

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Abstract: With the society development and technology advancement, the significance of mechanical engineering disciplines has grown substantially in the fields of manufacturing and engineering. Grounded in the context of the integration of science, education and industry within higher education institutions, in combination with the construction requirements of new engineering, the present study comprehensively investigates the theoretical mechanisms and practical pathways for constructing the teaching system in mechanical engineering. The research is carried out mainly from four perspectives: construction of theoretical curriculum framework, establishment of practical teaching system and platform, building of quality assurance system for teaching, and the cultivation of a multidisciplinary, cross-disciplinary faculty team.

1. Introduction

Integration of science, education and industry is a fundamental core concept upheld by top-tier universities worldwide and a necessary choice for achieving high-quality development in China's higher education during its new developmental stage. In 2017, the Shandong Provincial Government established the reinvigorated Qilu University of Technology by combining the educational advantages of original Qilu University of Technology with the exceptional research resources of the Shandong Academy of Sciences. This initiative is aimed to accelerate the integration of science, education and industry and facilitate the new and old kinetic energy conversion of Shandong Province. Leveraging the synergies of integration of science, education and industry, Qilu University of Technology has undertaken a variety of reform explorations and practical implementations, which involve collaborative education-research, structural adjustments in disciplines, talent classification evaluations, teaching methodology research, international exchanges, and cooperation [1-3]. Qilu

University of Technology was included in Double First-Class Initiative of Shandong Province in 2020, and obtained authorization for doctoral degree conferment in 2021.

There are also many other noteworthy domestic cases of integration of science, education and industry, for example: School of Medicine and Life Sciences established in 2007 due to the collaboration between Jinan University and the Shandong Academy of Medical Sciences, Shandong First Medical University by merging Taishan Medical University and Shandong Qianfoshan Hospital in 2018, the formation of Shanxi Agricultural University through the amalgamation of Shanxi Agricultural University and the Shanxi Academy of Agricultural Sciences in 2019. Internationally, integration of science, education and industry has also become a prevailing trend which steers the modernization of teaching practices in Western institutions. Berlin University in Germany pioneered the concept of integrating teaching and research, which further proposed two teaching systems of “teaching-research laboratories” and “teaching-research seminars” [4]. Johns Hopkins University in USA introduced principles from German universities and coupled with local American culture, shaping a modern research-oriented university concept and successfully advancing the structure of integration of science, education and industry [5]. Evidently, integration model of science, education, and industry is a shared global trend in university modernization, as well as an inevitable choice for achieving high-tier excellence in domestic universities.

New engineering refers to the proactive measures taken by higher engineering education to address the challenges posed by the new wave of technological revolution and industrial transformation. It represents a strong demand from the new economy characterized by new technologies, industries, formats, and models, for reforms in higher engineering education. As an inevitable path to deepen the reforms in higher engineering education, the Ministry of Education has since 2017 introduced a series of documents and guidelines related to the construction of emerging engineering disciplines, progressively increasing the support for policies aimed at nurturing talents in this field. Researchers have conducted studies in various aspects, including structural adjustments of disciplines, development of clusters of specialized courses, talent cultivation models, enhancement of teaching capabilities among faculty, and establishment of teaching platforms [6-7]. However, there is currently a lack of comprehensive and systematic research on the establishment of an educational system in the context of the new engineering disciplines.

Correspondingly, it is the interest of the present paper to investigate the theoretical mechanisms and practical pathways for constructing teaching systems for mechanical disciplines in the context of the integration of science, education and industry, as well as the perspective of new engineering. The discussion mainly includes four perspectives: construction of theoretical curriculum framework, establishment of practical teaching system and platform, building of quality assurance system for teaching, and the cultivation of a multidisciplinary, cross-disciplinary faculty team. The purpose is to fully leverage the educational resources of the university and the high-quality resources of the research institutes, thus cultivating innovative talents with high-quality skills and practical abilities.

2. Construction of theoretical curriculum framework

The curriculum framework is the fundamental guarantee and strong support for achieving the goals of professional training. Currently, engineering disciplines' theoretical courses commonly face issues such as unclear course objective values, insufficient interdisciplinary integration in course structures, limited societal applications of course content, lack of student-centered course implementation, and evaluation mechanisms without covering continuous improvement. For mechanical disciplines, it is essential to leverage the advantages of integrating science, education, and industry within the university, aligning with the new requirements for talent development in engineering disciplines under the context of new engineering. This involves transforming research outcomes into specialized theoretical courses from the aspects of teaching philosophy, teaching tools, teaching methods and teaching modes.

Taking the core course “Thermodynamics and Fluid Mechanics” in mechanical engineering as an example, the course is built upon a new teaching philosophy that combines “imparting professional knowledge + cultivating competency skills + leading through ideological and political education”. It introduces a trinity of teaching objectives centered on “heat transfer and fluid flow in mechanical systems” as the knowledge target, “Yellow River strategy, culture, and spirit” as the ideological target, and the cultivation of students’ technological innovation capabilities as the expanded targets. The course employs a blended approach of online and offline teaching methods, encompassing the entire teaching process from pre-class preparation to in-class instruction and post-class expansion. Online teaching primarily utilizes high-quality educational resources like China's University MOOC and exemplary courses from renowned institutions. Pre-class assignments are delivered through the "Rain Classroom" platform. Offline teaching primarily involves multimedia presentations integrated with the "Rain Classroom" platform and traditional classroom board teaching, with elements of flipped classroom pedagogy appropriately integrated. Post-class expansion focuses on teacher research projects, training programs for student innovation and entrepreneurship, and student technology competitions. Various innovative teaching methods such as project-based teaching, case-based teaching, and research-oriented teaching are primarily utilized.

3. Establishment of practical teaching system and platform based on OBE concept

In order to cultivate engineering applied talents that meet the requirements of the new engineering, the professional practical teaching system based on the principles of outcome-based education (OBE) is redefined by leveraging the integration of science, education and industry, which can be further divided into fundamental practice, integrated practice, engineering practice, and innovative practice. The fundamental practice primarily includes foundational in-class experiments and specialized in-class experiments. It can reinforce and apply knowledge acquired after completing theoretical courses, with the aim of cultivating students' fundamental skills. The integrated practice comprises mechanical discipline comprehensive experiments, course designs, and open laboratory projects. Using a curriculum cluster that interweaves various knowledge points, the educational approach facilitates comprehensive design-oriented experiments to thoroughly assess students’ integrated application abilities. The engineering practice mainly involves graduation projects and internships at corporate or industrial bases. It requires students to understand enterprise demands and industry trends, emphasizing the integration of theory and practical application to enhance students’ engineering skills. The innovative practice revolves around subject competitions, innovation and entrepreneurship projects, and research topics from research institutes. It guides undergraduates to engage in research projects within laboratories, and encourages participation in various subject competitions to cultivate their innovative practical abilities. Simultaneously, in addition to the existing practical teaching platforms and internship bases, the laboratory equipment is updated for the establishment of new high-level national and provincial practical teaching platforms. Collaborative innovation laboratories co-created with enterprises and off-campus practical education bases are also being developed. These initiatives provide robust support and assurance for the smooth execution of practical teaching components.

In 2019, the School of Mechanical Engineering at Qilu University of Technology established the Mechanical Engineering Collaborative Education Alliance. This initiative proactively aligns with the talent demands of the mechanical industry, and invites industry experts and research institutions to deeply engage in practical teaching and other educational segments, thus presenting the collaborative education model characterized by a “one-core dual-drive, multidimensional linkage” for mechanical disciplines. "One core" is centered on cultivating highly skilled applied talents in mechanical fields. "Dual-drive" indicates the dual propulsion of integration between science and education, as well as industry and education. "Multidimensional linkage" strategy encompasses the joint establishment of practical platforms, collaborative curriculum and textbook development, collective guidance for graduation projects, enhancement of faculty capabilities, and co-construction of educational entities. These efforts delve into reforms and practices related to collaborative education within mechanical disciplines. Through this collaborative educational approach, a long-lasting mechanism is explored that involves resource sharing, mutual cultivation of talents, shared management of processes, and outcomes distribution, achieving a win-win situation for industry, academia, research and application.

4. Building and implementation of teaching quality assurance system

The teaching quality assurance system should span the entire process of talent development under the integration of science, education and industry, as well as the context of new engineering. With teaching at its core, it implements a comprehensive quality management concept that involves all processes, all perspectives, and participation of all parties.

Firstly, the system aims to establish a strong teaching operation management system. This involves creating a teaching management framework at different levels within departments and schools. Additionally, it seeks to enhance administrative responsibilities for effective management.

Secondly, it establishes a comprehensive teaching process monitoring system. This system primarily addresses the following points: establishment of teaching supervisory mechanisms at both departmental and school levels, implementation of a standardized process monitoring system, emphasis on continuous surveillance and inspections of the teaching process, collaboration with university administrators to maintain teaching order and standardize educational activities.

Thirdly, a comprehensive teaching quality evaluation system is established. This includes developing evaluation systems for faculty development and student growth, setting up a course teaching effectiveness assessment system, implementing curriculum resource evaluation, and creating evaluation mechanisms for supervisory experts, students, and peers.

Fourthly, it involves constructing an internal assurance system based on diagnosis and improvement, along with the establishment of a comprehensive teaching quality feedback system. This iterative process continuously enhances the teaching quality assurance system, creating a fully-fledged, networked management system with self-improvement and enhancement capabilities. This system ensures the quality of teaching to cultivate the applied talents that meet the demands of society under the integration of science, education and industry, as well as the context of new engineering.

5. Cultivation of a multi-disciplinary and cross-disciplinary faculty team

The pursuit of innovative mechanical engineering education necessitates educators who can seamlessly merge principles from various domains, creating a cohesive learning experience for students. This faculty team should consist of experts possessing diverse expertise across engineering subfields, spanning mechanical design, manufacturing processes, thermodynamics, materials science, robotics, and more. For instance, the integration of materials science with robotics can offer fresh insights into smart material applications in autonomous machines. Moreover, the intersection of mechanics and computer science can lead to breakthroughs in mechatronics and automation, while coupling mechanical design with environmental science can drive sustainable engineering solutions. Based on the advantages of integration of science, education and industry of Qilu University of Technology, a high-caliber faculty team that embodies the "Science-Education-Industry" triad are cultivated. Scientists from research institutes with the potent research capabilities, teachers with substantial pedagogical experiences from university departments with substantial pedagogical experience, and professionals from collaborative enterprises with industry expertise are all involved to become a multi-disciplinary and cross-disciplinary faculty team. The balance between research and teaching is maintained internally, while the equilibrium between industry and education is upheld externally. This interdisciplinary approach not only enriches the educational landscape of mechanical engineering, but also reflects the real-world complexity of modern engineering challenges. Collaborative research and problem-solving, inspired by the diverse perspectives of a multi-disciplinary faculty, can empower students to develop holistic problem-solving skills. Therefore, the establishment of a faculty team with a strong cross-disciplinary foundation is essential for fostering comprehensive, forward-looking mechanical education that aligns with the demands of new engineering.

6. Conclusions

The establishment teaching system for mechanical disciplines which is anchored in the integration of science, education and industry holds immense promise for the future of engineering education, along with the requirements of new engineering. It aims to cultivate innovative and application-oriented multi-disciplinary talents with the ability to solve complicated mechanical engineering problems, strong engineering practicality, continuous learning capabilities, innovative thinking and an international perspective. The implementation of above teaching system can be further applied to similar programs within sister institutions, demonstrating a broad range of potential applications.

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References

[1] Xu C. H. , An L. L. , Xiao G. C. (2021) Research and practice of synergetic education based on the theory of synergetics-Taking Qilu University of Technology (Shandong Academy of Sciences) as an example. China Light Industry Education, 24(4), 45-50.

[2] Yu H. W. , Cheng Q. , Zhang X. Y. (2023) Reform of professional comprehensive experiment teaching under the background of integration of science and education-Taking energy and power engineering as an example. Journal of Higher Education, 9(18), 138-141.

[3] Shao C. W., Fu Z. K., Qiu H. M., Fan P. P. (2022) The Role of Academic Tutors in the Cultivation of Undergraduates-A Case Study of the School of Science and Education Integration of Qilu University of Technology. Journal of Science and Education (Electronic Edition), 12, 14-16.

[4] Fang H. J., Zhu Y. F. (2018) Foreign Research and Reform Progress of Science and Education Integration Education. Times Economy and Trade, 34, 94-95.

[5] Zhang L. (2016) The Structuring of the Integration of Science and Education and the Origin of Research Universities-Institutional Innovation of Johns Hopkins University. Higher Education Research, 37(05), 79-86.

[6] Wang M. J. (2023) Research and practice of teaching reform in colleges and universities under the construction of new engineering. Science and Technology Information, 21(3), 176-179.

[7] Chu Z. , Ji W. , Jing X. W. , Shi W. S. (2020) Research on the Cultivation of Engineering Talents under the Background of New Engineering Construction. Journal of Science and Education, 10, 55-56.