Curriculum and Teaching Methodology (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/curtm.2024.070304
ISSN 2616-2261 Vol. 7 Num. 3

Innovative Teaching Strategies of Mechanical Engieering Specialized Courses under the Background of Emerging Engineering Education

Yuexia Lv[1,2,a,*], Wei Zhao[1,2,b], Chonghai Xu[1,2,c], Hui Zhang[1,2,d], Jin Du[1,2,e], Zizhen Zhao[1,2,f]

[1]School of Mechanical Engineering, Qilu University of Technology (Shandong Academy of Sciences), Daxue Road, Jinan, China
[2]Shandong Institute of Mechanical Design and Research, Jinan, China
[a]yuexialv@foxmail.com, [b]zwapple@yeah.net, [c]xch@qlu.edu.cn, [d]zhanghui198787@163.com, [e]dj84105@126.com, [f]alwayszi@163.com
[*]Corresponding author

Keywords: Teaching innovation, mechanical engineering, specialized course, emerging engineering education

Abstract: The current teaching mode of mechanical engineering specialized courses are facing the challenges under the background of emerging engineering education. To address this issue, the teaching reformation and innovations are conducted in the specialized course named Thermodynamics and Fluid Mechanics. Based on the course characteristics and learning difficulties, five innovative strategies have been proposed and implemented in the teaching practices, including course content adjustment, teaching resource reallocation, learning process reorganization, political elements refinement, and assessment system reconstruction. The implementation results indicate that technological practice and innovation abilities and learning results of the students have been significantly improved. The teaching and research level of the teaching team have also been improved during the exploration of teaching reform and innovation practices.

1. Introduction

Emerging engineering education refers to the innovative approaches and practices in engineering education with the aim of coping with the rapid technological advancements and changing industry needs caused by the fourth industrial revolution. This educational paradigm not only focuses on education on professional knowledge and technical skills, but also emphasizes interdisciplinary learning, hands-on projects and the integration of cutting-edge technologies. Specialized courses in mechanical engineering are distinguished by their strong foundation in critical areas such as mechanical design, materials science, intelligent control and sustainable energy, coupled with a significant emphasis on practical applications. Innovation and creative problem-solving abilities are encouraged especially in design-focused projects, which are essential for the current multidisciplinary engineering environment.

In recent years, a variety of innovative solutions have been implemented during the specialized

courses teaching-learning processes of mechanical engineering under the ground of emerging engineering education. Inspired by the talent cultivation mode from Massachusetts Institute of Technology, Li et al. [1] proposed innovative strategies for the course of Mechanical Manufacturing Technology to meet the demands of emerging engineering education. It involves the revision of talent cultivation objectives, establishment of integrated curriculum system, improvement of student-centered teaching methods and revolution of course assessment. During the teaching innovation of Mechanical Design course, Lu et al. [2] adopted the teaching philosophy of "one-center, two-approach, three-integration and four-combination", and constructed "pre-class preparation, in-class teaching and post-class activities" to realize the closed-loop "practical project-theoretical analysis-wooden model-product design". Furthermore, project based learning for practical courses [3], case three-dimensional teaching for Engineering Thermodynamics [4], 1233 model for Mechanical Drawing [5] and digital twin for Mechatronics virtual training [6] have also been investigated to provide students with improved learning experiences.

Thermodynamics and Fluid Mechanics is a comprehensive course which optimizes and combines the classical contents of engineering thermodynamics and engineering fluid mechanics. As a compulsory curriculum for students specializing in Mechanical Design, Manufacturing and Automation, it is aimed to enable students to systematically master the laws and principles of energy transfer and fluid flow, and flexibly use theoretical knowledge to analyse and calculate typical heat conversion and fluid transportation problems in Mechanical Engineering. Additionally, the course aims to foster students' scientific and technological innovation abilities, providing support for the innovative talent cultivation goals of international engineering education accreditation, and meeting the course construction requirements for national first-class undergraduate major in breadth and depth. Therefore, the objective of this study is to discuss the innovative teaching strategies of Thermodynamics and Fluid Mechanics to encourage creativity, critical thinking and application of cutting-edge technologies under the background of emerging engineering education.

2. Analysis on Course Teaching Difficulties

Thermodynamics and Fluid Mechanics is designed for undergraduate students in their first semester, second year of college. Based on the survey questionnaires and face-to-face interactions, the students at this stage have the following cognitive and knowledge-based characteristics: (1) they have strong interest and curiosity about this specialized course and its practical application, but they are generally worried about the learning difficulties caused by weak foundation in mathematics or physics; (2) they are good at memorizing formulas and solving textbook exercises, but lack the initiative to actively explore and resolve practical engineering problems; (3) their international perspective and technological innovation capabilities are insufficient to meet the construction demands of emerging engineering education; (4) students are intellectually active and proficient in using online tools, demonstrating strong receptiveness to modern information technology and new teaching methods; (5) they have a strong sense of individuality and are at a crucial period in the formation of their worldviews, life philosophies and value systems, which requires proper value guidance in case of confusion and hesitation.

In combination with the course characteristics and the shortcomings of traditional teaching mode, the following four teaching difficulties are identified: (1) the course encompasses thermodynamics and fluid mechanics with complicated and numerous formula derivations, so how can the teaching objectives be achieved within the limited 3 credits? (2) there are no available textbooks for undergraduates on the market right now, and the reference books are not timely updated with engineering advancements and disciplinary frontiers to align with the course's contemporary and cutting-edge nature. How to enrich the teaching resources to satisfy the demands for cultivating higher

order abilities and innovative thinking in students? (3) students at their ages have a strong sense of self-awareness, making the integration of ideological and political elements into the specialized course challenging and stiff. How can we achieve an organic fusion and true unification of "knowledge impartation" in professional education, "capability cultivation" in quality education, and "value guidance" in ideological and political education? (4) current course assessment relies on the final examination without process-oriented evaluation, and thus the teaching processes are lack of mutual communication and real-time feedback for improvement. How can the assessment system be leveraged to provide real-time feedback on teaching effectiveness and continuous improvement in teaching quality?

3. Innovative Teaching Strategies of Mechanical Engineering

3.1 Course content adjustment from extensive to intensive

The course contents are adjusted and optimized by eliminating outdated knowledge, de-emphasizing formula derivations, and establishing a dual-mainline teaching design that combines professional knowledge with ideological and political education. The professional knowledge mainline is the theory and application of heat transfer and fluid flow in mechanical devices based on eight teaching chapters. Ideological and political elements extracted from the teaching chapters, are interwoven into eight major ideological and political strands, finally cultivating students' ability for scientific and technological innovation, as well as their awareness of engineering ethics.

In addition, contemporary and cutting-edge knowledge are supplemented, such as engineering cases, technological frontiers, industry demands, and scientific research results. Taking the Bernoulli's equation as an example, the historical event of the collision between Olympic and Hawke is introduced after explaining the mathematical expression of Bernoulli's equation to practice the engineering application of Bernoulli's equation in qualitative analysis. Furthermore, pitot tubes used for speed measurement of aircraft and racing car are discussed to illustrate the engineering application of Bernoulli's equation in quantitative calculation. Finally, based on the historical accidents caused by pitot tube failure, technological frontier of the embedded atmospheric data transmission system, advanced fluid measurement technologies and simulation software are introduced.

3.2 Teaching resource reallocation from less to more

To solve the problem of textbook shortage on the market, a self-compiled bilingual textbook is written and published by referencing classic domestic Chinese textbooks and original English-language editions. The self-compiled textbook fully integrates digital information technology which could provide access to micro-lecture videos, ideological and political education sessions via scanning QR codes. Additionally, mind maps, key knowledge points, global engineering case studies, forefront developments in both domestic and international disciplines, and academic research findings are supplemented in the textbook. The purpose is to expand the international perspective of students and application breadth of course knowledge.

In addition to the textbook, various instructional video resources are constructed to provide access to educational contents anywhere and anytime. First, national excellent MOOC online course videos are selected for personalized and flexible learning. Second, related experimental demonstration videos are chosen to allow students to observe experiments in a virtual environment. Third, real-time classroom teaching videos are recorded using the Rain Classroom live broadcast platform, and students can revisit the videos according to their learning needs, which facilitates the identification and filling of gaps and reinforces revision post-lesson. Finally, the three-dimensional digital animation demonstration videos are provided to vividly present the complicated theoretical

knowledge through three-dimensional animations, which is helpful to assist students in virtual engineering practice observation and enhance student engagement and participation.

The database of engineering cases is developed in combination with industry demands, practical engineering projects, disciplinary frontiers, and research achievements. The database can provide students with direct insights into the current state of the industry, research progress and developmental trends, thus fostering their ability to apply theory to practical problems and to resolve engineering issues. In addition, virtual simulation database is also developed to address the gap in experimental and practical studies through immersive and interactive learning experiences. These databases are regularly updated with the latest information and materials to keep pace with the cutting edge of the course.

3.3 Learning process reorganization from teaching to guiding

With the aid of modern information technology, a blended online and offline teaching approach is implemented which spans the entire “pre-class, in-class and post-class” learning process. Three days before the class, the learning materials and exercises are issued to students via Rain Classroom Platform, guiding students to finish online self-learning and self-testing. The pre-class progress and learning effectiveness can be timely feedback to adjust the following teaching contents and methodology. During class, key and difficult professional knowledge are explained by adopting new teaching methods, such as BOPPPS model, problem-driven learning, case learning and flipped-over class. Rain Classroom is also used to achieve real-time interaction with students during class. After class, homework is issued online for theoretical knowledge solidification and enhancement.

An innovative competition platform has been established to utilize after-class time to carry out a series of lectures on engineering practice and technological innovation skills training based on the curriculum. The students are encouraged to work in teams to participate in practical engineering and research projects, with a focus on personalized development and cultivation of innovation capabilities. The platform mainly relies on college students' innovation and entrepreneurship training programs, science and technology innovation competitions, cooperative enterprises and engineering projects of teaching group to conduct technology innovation activities.

3.4 Political elements refinement from expository to inspiration

Ideological and political element within the curriculum are refined and explored, so that they are integrated into the course teaching process by inspiration rather than expository. Ideological and political mini-classes and specific themes are adopted. For example, an open-mind theme is designed around the “Second Law of Thermodynamics”. Students are guided to draw connections between their personal life or learning experiences and this professional knowledge. Through 10 minutes of brain-storming, colourful answers are generated through intra-group discussion and inter-group sharing: utilizing renewable energy to achieve sustainable development, adhering to scientific laws to ensure mechanical design security, improving the thermal efficiency of mechanical devices with professional confidence, and so on. Furthermore, ideological and political teaching resources database is established from the perspectives of political theory resources, historical and cultural resources, specialized knowledge resources, and disciplinary frontiers of scientific research. A complete ideological and political teaching system is also developed, which includes the teaching outline, course teaching design, classroom teaching design and lesson plan relevant with ideological and political education. Students are engaged in the supplement of ideological and political teaching resources, to achieve the shared construction and utilization of the teaching resources.

3.5 Assessment system reconstruction from singularity to comprehensiveness

Based on the Outcome-Based Education concept, a comprehensive assessment system is reconstructed which combines formative assessment with summative assessment, as well as quantitative evaluation with qualitative evaluation. The new assessment system covers the offline and online studies, taking the student engagement and creativity into consideration. The formative assessment consists of pre-class online completion degree, in-class quizzes, class interaction, flipped classrooms, group discussions, post-class assignments and tests, resource and case database supplementary, and engagement of technological innovation competencies. In the summative assessment, 6% is the open subjective thinking without standard answers, encouraging students to engage in deep analytical thinking.

4. Innovative Teaching Achievements

Post-course survey questionnaire reveals that about 96% students are satisfied with the innovative teaching model of the course. Students have shown significant improvements in their capabilities for technological practice and innovation, as well as in team collaboration. For example, the solar photovoltaic lighting device, artificial flower watering system, photovoltaic water lifting irrigation system and energy-saving louver shutter designed by the students have got six national and provincial innovation projects, published five academic papers, applied five national invention patents, and won more than 30 competition awards.

Specific to the course learning, the students gradually transit passive learning to active learning with obvious improvement in their overall course grades. Taking Mechanical Engineering Class 1 as an example, the average scores are 60.25 in year 2021, 73.38 in year 2022, and 82.23 in year 2023, respectively, with a significant annual increase in the proportion of good and excellent grades. In addition, the course plays effective roles in imparting ideological and political education values. The ideological elements explored have been integrated into various aspects of learning, living, and technological innovation of students, achieving a genuine unification and organic integration of knowledge impartation in professional education, capability cultivation in quality education, and value guidance in ideological and political education.

During the continuous teaching reform and innovation, the teaching and research level of the teaching team have also been improved, with achievement in teaching reform projects, course construction, and teaching competitions. Over the past three years, the teaching team has hosted one Ministry of Education collaborative education project, two provincial-level educational research projects, and three school-level educational research projects. They have published more than ten educational research papers, received one school-level teaching quality excellence award, one top ten and one top hundred outstanding academic mentor awards, two high-quality competition academic achievement awards, and honors for ideological and political demonstration teaching team. In 2023, the course was designated as a school-level ideological and political demonstration course, won a third-place provincial award for national safety education quality courses.

5. Conclusions

The construction of new engineering education presents specific teaching requirements for mechanical engineering specialized courses, aimed at aligning educational outcomes with the demands of emerging industries and technological advancements. The innovative teaching practices of Thermodynamics and Fluid Mechanics have been conducted from the perspectives of course content, teaching resource, learning process, political elements and assessment system. The innovative strategies proposed in this study have been extended to related majors of other universities,

which further enhances the application value and demonstrative effect of the course innovation.

Acknowledgements

This research was carried out with financial support of Shandong Province Undergraduate Teaching Reform Research Project (Z2021142, M2023246 and M2022105), Teaching Research Project from Qilu University of Technology (Shandong Academy of Sciences) (2021yb36, 2022zd03, 2022yb05, YJG23YB005), for which due acknowledgement is given.

References

[1] Li C.B., Lin L.H., Tang B.P., Jiang G.Y. Research on curriculum construction of technology foundation of mechanical manufacturing under the background of emerging engineering education. Journal of Architectural Education in Institutions of Higher Learning. 2020, 29(2): 23-28.
[2] Lu W.J., Zeng D.X., Wang S., Liang J.L., Cao X.C. Research on teaching innovation of basic mechanical design courses under the background of new engineering. Journal of Higher Education, 2024, 10 (06): 69-72.
[3] Li F., Qin X.F., Li X.H., Ren J.J., Xiong X.Y. Construction of practical teaching system under the new engineering mechanical innovative talent training model. Mechanical Design, 2023, 40 (11): 135-140.
[4] Gao H.B., Ma Y., Wei R.N., Wang Y.J, Zhang C.W. Reform and practice of case-based teaching of thermal engineering basics in mechanical majors under the background of new engineering. Automotive Practical Technology, 2023, 48 (23): 176-179.
[5] Cao F.M., Wang G.B., Li F.R. Innovative practice of mechanical drawing teaching based on the "1233" model. Innovation and Entrepreneurship Theory Research and Practice, 2023, 6 (21): 164-168.
[6] Liu J.L., Jiao L.L. Design and development of mechatronics virtual training equipment based on digital twin technology. Science and Technology Innovation and Application, 2024, 14 (09): 42-45.