Membrane Technology
ISSN (online): 1873-4049

Exploration and Innovation of a Competition-Integrated Teaching Model for Vehicle Engineering Based on the OBE-CDIO Approach and Artificial Intelligence

Zhi Yang*, Meng Dang
Xi'an University of Science and Technology, Xi'an 710054, Shaanxi, China
**Corresponding Author.*

Abstract:
The rapid advancement of Industry 4.0, intelligent manufacturing, and the new energy vehicle industry has raised higher demands for vehicle engineering talent, particularly in multidisciplinary integration, practical skills, and innovation. However, traditional teaching models exhibit significant shortcomings, such as a disconnect between theory and practice and inadequate cultivation of innovation capabilities. To address these challenges, this study proposes a teaching reform based on case-based teaching and the OBE-CDIO model. By integrating outcome-based education (OBE) with the conceive-design-implement-operate (CDIO) approach and incorporating academic competitions, the reform establishes a multi-level teaching system that deeply integrates theory and practice. Furthermore, artificial intelligence (AI) is employed to support curriculum design, competition analysis, and personalized student feedback, ensuring a dynamic alignment with industry needs. Following implementation, the completion rate of interdisciplinary graduation projects exceeded 80%, academic competition awards increased by 45%, and the employment rate of students rose from 88% to 96%, with some research outcomes adopted by enterprises. The results demonstrate the model's effectiveness in enhancing students' comprehensive abilities and fostering innovative engineering talent, providing practical insights for engineering education reform.

Keywords: vehicle engineering, OBE-CDIO model, academic competitions, artificial intelligence, teaching reform.

INTRODUCTION

In recent years, the importance of engineering education has grown significantly with the ongoing global technological revolution and industrial transformation [1-3]. Fourth Industrial Revolution (Industry 4.0) has accelerated advancements in intelligent manufacturing, the Internet of Things, and artificial intelligence (AI), thereby raising higher demands for multidisciplinary and innovative engineering talent [4-7]. As a key area of engineering education, the field of vehicle engineering is undergoing profound changes. Integrating cutting-edge technologies into teaching and fostering students' practical and innovative abilities have become shared priorities in global engineering education reform [8,9]. Artificial intelligence (AI), as a transformative tool, offers unprecedented opportunities in engineering education. AI can enhance the teaching process through intelligent curriculum design, automated data analysis, and personalized learning feedback, bridging the gap between theory and practice more effectively. For example, AI-driven tools can analyze competition data, optimize vehicle designs, and simulate real-world engineering challenges, enabling students to refine their innovative and practical skills. Internationally, initiatives such as Germany's "Industry 4.0" strategy and the Massachusetts Institute of Technology's "New Engineering Education Transformation (NEET)" program have deeply explored engineering education models. These efforts aim to combine theory with practice to cultivate high-caliber engineers capable of driving future development [10-12].

The rapid development of advanced manufacturing technologies and the new energy vehicle (NEV) industry has driven profound changes in the field of vehicle engineering. Traditional concepts of mechanical design and manufacturing can no longer meet the demands of modern intelligent and automated development [13-15]. The industry now requires vehicle engineering professionals with stronger interdisciplinary, practical, and innovative abilities. For example, the core technologies of NEVs span electric drive systems, battery management, and intelligent driving systems. Students must not only master these technologies but also integrate multidisciplinary knowledge into complex systems [16,17]. Furthermore, with the increasing emphasis on green design and sustainability, vehicle design must balance performance optimization with energy efficiency and environmental protection. This shift places higher demands on students' innovation, systems thinking, and engineering competencies [18,19]. However, traditional teaching models struggle to address these new requirements, particularly in bridging theory and practice, fostering innovation, and keeping curricula aligned with cutting-edge industry advancements. Therefore, reforming current education models to cultivate high-caliber, multidisciplinary talent has become a critical focus of higher engineering education [20,21].

As an integral part of higher engineering education, academic competitions have recently demonstrated unique advantages in developing students' comprehensive abilities. Competitions such as the National College Students Intelligent Vehicle Competition, the China Society of Automotive Engineers Baja SAE Competition, and the Honda China Energy-Saving

Competition provide students with platforms to apply theoretical knowledge to real-world projects. These competitions not only strengthen the integration of theory and practice but also significantly enhance students' innovation, teamwork, and interdisciplinary problem-solving skills. Moreover, the competition tasks often simulate real engineering problems, requiring students to apply knowledge from diverse fields such as vehicle dynamics, electronic control, sensor technology, and algorithm design. This problem-based learning approach effectively addresses the shortcomings of traditional teaching methods. Consequently, integrating academic competitions with classroom teaching has become a key direction for engineering education reform. This "competition-driven learning" model fosters a positive feedback loop of "learning through competition and competing through learning," which comprehensively enhances students' practical and innovative capabilities [22,23].

This study aims to explore teaching reforms in vehicle engineering education based on case-based teaching and the OBE-CDIO model, using academic competitions as a driver to build a multi-layered teaching system [24]. By incorporating outcome-based education (OBE) and the conceive-design-implement-operate (CDIO) approach, alongside real-world projects from academic competitions, the research creates a positive feedback loop of "learning through competition and competing through learning." This approach aims to comprehensively enhance students' competencies in theory-practice integration, innovation, and interdisciplinary knowledge application. Specifically, the study focuses on the following objectives: (1) integrating academic competitions with course teaching to strengthen students' ability to connect theory and practice; (2) adopting progressive training and open-ended tasks to foster innovative thinking and interdisciplinary knowledge integration; and (3) introducing industry-leading technologies through competitions to dynamically align curricula with industrial needs, thereby cultivating higher-quality engineering professionals. This research not only provides innovative solutions for vehicle engineering education but also offers theoretical and practical references for reforming higher engineering education and fostering innovative talent.

CONCEPTS AND THEORETICAL FRAMEWORK

The rapid development of industrial technology has highlighted the limitations of traditional engineering education in meeting the demand for high-quality, multidisciplinary talent. Outcome-Based Education (OBE) and the Conceive-Design-Implement-Operate (CDIO) models, two core concepts in international engineering education reform, provide essential theoretical and practical frameworks for cultivating students' practical skills, innovative abilities, and interdisciplinary competencies. The OBE model focuses on learning outcomes by setting clear objectives, designing targeted teaching activities, and assessing learning effectiveness to ensure students acquire the knowledge and skills required by the industry. Meanwhile, the CDIO model emphasizes hands-on learning through real-world engineering projects, allowing students to integrate theory with practice. Combining these two approaches (OBE-CDIO) has become a vital direction in engineering education reform, offering innovative solutions to align education with modern industrial needs [25,26].

OBE Education Model

Outcome-Based Education (OBE) is a student-centered teaching model that prioritizes learning outcomes by aligning teaching activities with explicitly defined goals. The core of OBE lies in designing the curriculum and assessment methods backward from the desired "final outcomes" students must achieve. Key features of OBE include clearly defined learning outcomes, backward curriculum design, and multidimensional assessment methods. For instance, in vehicle engineering, course objectives such as designing and optimizing an electric drive system can be achieved through project-based practices and case studies, allowing students to demonstrate their capabilities in knowledge application, system design, and problem-solving [27,28].

The main advantage of the OBE model lies in its alignment with industry demands, ensuring students achieve the expected competence levels through rigorous outcome assessments. However, its implementation faces challenges, such as defining reasonable learning objectives and designing scientific evaluation methods. In vehicle engineering, effective application of OBE requires aligning teaching activities with industry-specific needs by incorporating diverse practices, such as analyzing case studies on NEV design or simulating intelligent driving systems. These activities enhance students' innovation and practical skills [29].

CDIO Education Model

The Conceive-Design-Implement-Operate (CDIO) education model emphasizes cultivating students' practical skills and engineering literacy by simulating real-world engineering processes. Its core philosophy integrates theoretical knowledge with practical operations, guiding students through the complete engineering cycle, from need analysis to product realization. The four stages—conceive, design, implement, and operate—form a comprehensive engineering education framework. For example, in vehicle engineering, students might analyze market needs to conceive a development plan for an intelligent driving system, complete hardware and software design, manufacturing, and debugging, and finally test the system's performance [30,31].

The CDIO model's strengths lie in its practice-oriented approach and emphasis on interdisciplinary integration. For instance, developing an autonomous vehicle system requires students to synthesize knowledge from mechanical design, signal processing, and artificial intelligence algorithms. This method not only improves students' technical skills but also fosters teamwork and problem-solving abilities. However, implementing CDIO demands significant resources, skilled instructors, and well-structured courses. In vehicle engineering, CDIO can be effectively applied through academic competitions (e.g., the National College Students Intelligent Vehicle Competition) and project-driven courses, helping students transition from theoretical learning to practical application [32].

Integration of OBE and CDIO Models

The OBE and CDIO models focus on different aspects of education but are highly complementary. OBE emphasizes achieving learning outcomes, while CDIO prioritizes the development of comprehensive skills through practical processes. Combining the two can address the traditional gap between theory and practice in teaching. In vehicle engineering, this integration can be achieved in the following ways: First, set specific learning outcomes based on OBE principles, such as mastering core competencies in vehicle dynamics analysis and electric drive system design. Second, adopt the CDIO approach to design multi-phase practical projects, enabling students to complete the full engineering cycle from need analysis to prototype development. These projects should combine formative and summative assessments to ensure learning goals are achieved. Third, introduce interdisciplinary projects, such as intelligent driving system development, requiring the integration of mechanical design, electronic control, and AI algorithms. This collaborative approach enhances students' systems thinking and innovation skills [33].

By combining OBE and CDIO, vehicle engineering programs can establish a student-centered, outcome-driven, and practice-focused teaching system. This approach meets industrial demands by cultivating high-quality engineering talent with both theoretical knowledge and practical skills.

VEHICLE ENGINEERING COMPETITION-INTEGRATED TEACHING SYSTEM

Theoretical Teaching System: Modular Curriculum Design Integrated with Competitions

The vehicle engineering teaching system develops students' ability to solve complex engineering problems throughout the four years of undergraduate education. By establishing a modular curriculum, theoretical teaching is closely integrated with academic competitions and embedded into the talent cultivation plan. The curriculum is divided into three core modules: the mechanical module (aligned with the China Society of Automotive Engineers Baja SAE Competition), the electrical module (linked to the Honda China Energy-Saving Competition), and the control module (associated with the National College Students Intelligent Vehicle Competition), as shown in Figure 1.

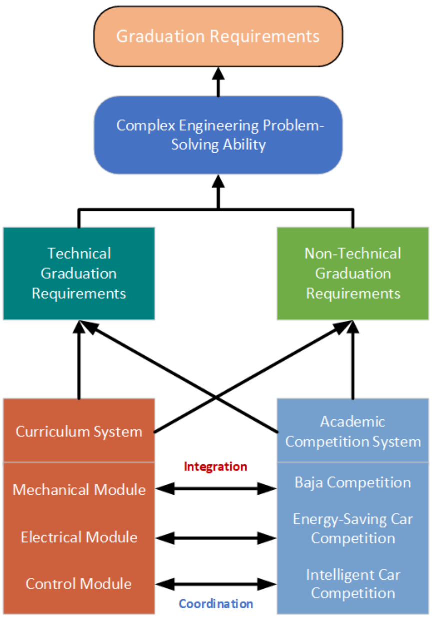

Figure 1. Dual-driven framework of curriculum and competitions

Theoretical teaching content corresponds directly to the processes and stages of these competitions. The curriculum system supports technical graduation requirement indicators (e.g., design, experimentation, and analysis skills) while academic competitions address non-technical indicators (e.g., professional ethics, teamwork, and interdisciplinary collaboration), which are relatively weaker in traditional teaching methods. This integration creates a multi-level support structure combining theoretical and practical education, effectively meeting the demand for cultivating students' ability to solve complex engineering problems.

Progressive Training: Integrating Theoretical Teaching with Competition Projects

To meet the progressive training needs of students in solving complex engineering problems, the vehicle engineering program integrates and reorganizes the curriculum system around competition knowledge. The program establishes a closed-loop system of "theoretical teaching-academic competitions-curriculum optimization," encompassing syllabus design, theoretical teaching activities, evaluation, and curriculum updates, as illustrated in Figure 2.

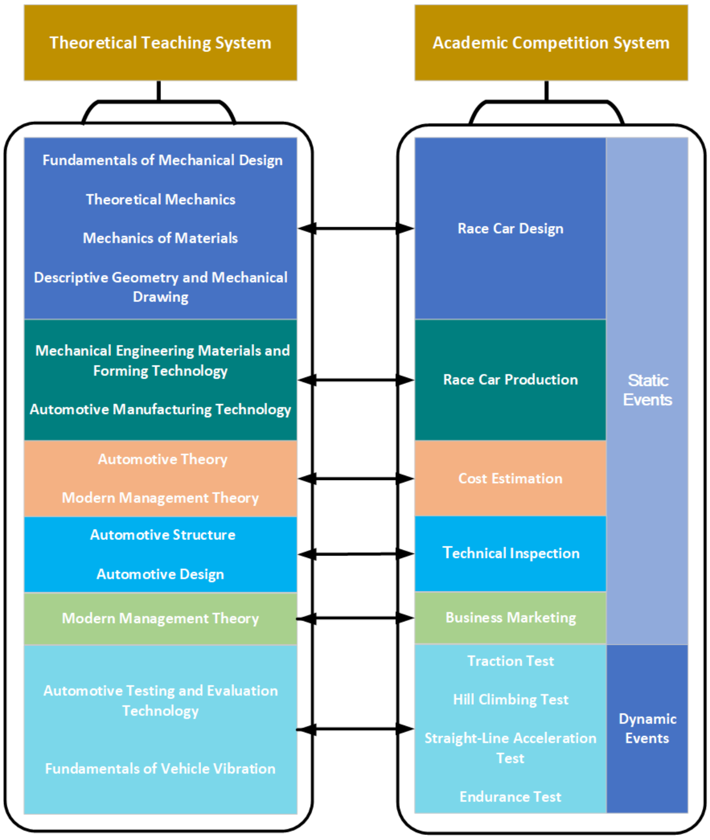

Figure 2. Relationship between theoretical teaching and academic competitions

Through project-based management, academic competitions are embedded into both course design and capstone projects. Platforms such as student learning groups and automotive enthusiast associations strengthen students' understanding of balancing technical achievements with non-technical factors. For example, in a smart driving system development course, students progress from theoretical learning to completing the entire process of demand analysis and solution design through competition-based projects. Evaluation criteria focus not only on students' technical achievements but also on their ability to balance non-technical factors (e.g., cost-effectiveness, sustainability). This approach further enhances students' ability to apply theoretical knowledge and develop innovative practical skills.

Practical Teaching System: Multi-Level Engineering Practice Driven by Competitions

The practical teaching system in the vehicle engineering program focuses on developing students' engineering practice and innovation skills. It is structured into three levels: general practice, professional practice, and comprehensive practice. The system integrates theory and practice by addressing key components such as syllabus design, activity implementation, evaluation, platform development, and system revision, forming a cohesive teaching framework. Engineering practice includes experiments, training, course design, internships, and comprehensive practice courses, emphasizing the interconnectedness and overall coherence of these components, as shown in Figure 3.

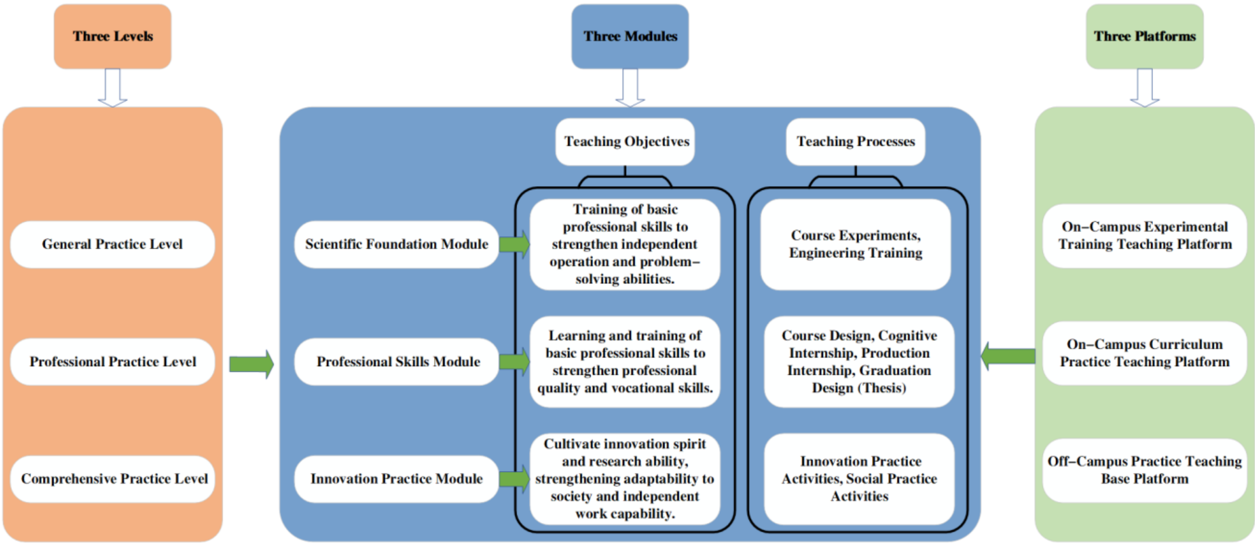

Figure 3. Basic structure of the engineering practice teaching system

Practical courses leverage interdisciplinary competition projects (e.g., the China Society of Automotive Engineers Baja SAE Competition) to enhance students' integration and application of knowledge across multiple fields. The practice platform offers fixed experimental content but also allows students to define their own tasks and objectives, fostering creativity and problem-solving skills. After completing practical courses and competition projects, students can participate in automotive engineer certification exams. This process provides a comprehensive evaluation of learning outcomes and strengthens graduates' competitiveness in the job market. The practical teaching system is designed not only to address engineering practice but also to align with the requirements of technological competitions. This ensures that students gain the ability to apply professional knowledge comprehensively in real-world engineering scenarios.

The vehicle engineering program offers comprehensive practical courses that integrate engineering practice, theoretical knowledge, and technological competition. These courses address the limitations of single-course designs, which often focus narrowly on specific knowledge areas and lack connection to real-world engineering practice. By aligning with both engineering practice and competition requirements, the courses ensure comprehensive coverage of professional knowledge, as illustrated in Figure 4.

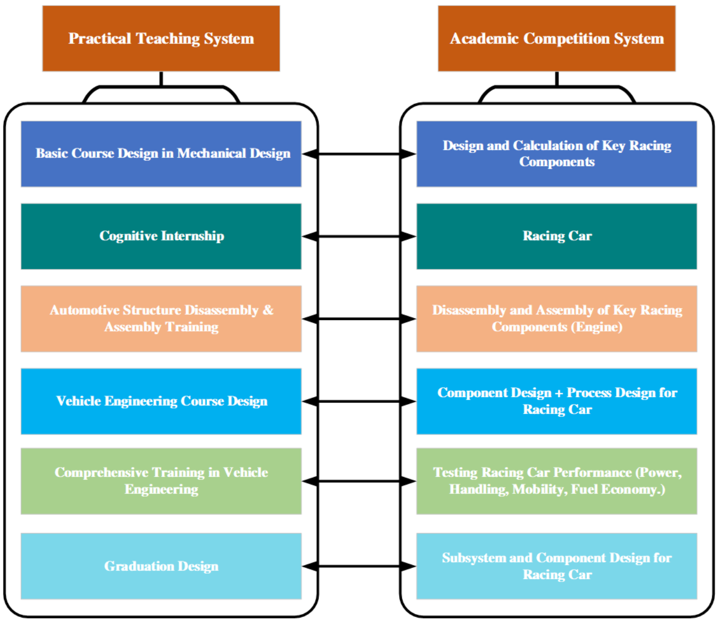

Figure 4. Connection between practical teaching and academic competitions

Through training based on interdisciplinary competition projects, students enhance their ability to integrate and apply knowledge from multiple disciplines while developing practical skills. The training platforms not only provide fixed experimental content but also allow students to design their own tasks and objectives, fostering problem-solving and innovation skills. Upon completing these competition-based projects, students participate in automotive engineer certification exams, which assess their practical training outcomes and improve their employability.

CASE-BASED TEACHING DISCUSSION

Case-based teaching is a vital approach in engineering education for developing students' comprehensive abilities, innovative thinking, and practical skills. By introducing real-world engineering problems and projects into the teaching process, students can enhance their ability to solve complex engineering challenges through the integration of theory and practice. In the context of vehicle engineering education, case-based teaching emphasizes both scientific rigor and systematic instruction while fostering student autonomy and practical engagement. The following discussion focuses on the implementation of case-based teaching using academic competition examples.

Case Implementation Process: In the teaching design, instructors guide students to participate as teams in the full process of the Baja SAE competition, from requirements analysis to design, prototype manufacturing, and performance testing. This step-by-step approach develops students' engineering practice skills. For instance, during the powertrain optimization phase, students integrate content from courses such as Automotive Theory and Fundamentals of Mechanical Design. Using dynamic simulation tools like MATLAB or ADAMS, they analyze and optimize the vehicle's dynamic performance. Similarly, during the suspension tuning phase, students conduct experiments to verify the effects of different parameters on off-road vehicle performance. Figure 5 shows the Baja racing car U18, designed by Xi’an University of Science and Technology’s Qin Feng Racing Team in 2021.

Figure 5. Baja racing car U18 in 2021

Teaching Outcomes: This case-based teaching approach has significantly enhanced students’ understanding of vehicle engineering concepts while improving their non-technical skills, such as teamwork, communication, and project management. For example, during the competition, students present their design proposals to expert judges and participate in Q&A sessions. This process strengthens their presentation skills and interdisciplinary collaboration abilities. The Baja SAE case demonstrates that competition-based case teaching effectively cultivates students’ comprehensive abilities and innovative thinking, laying a solid foundation for their future careers.

The vehicle engineering program integrates competitions such as the Baja SAE, Honda China Energy-Saving Competition, and the National College Students Intelligent Vehicle Competition. These competitions have spurred the creation of multiple automotive innovation teams, including Xi’an University of Science and Technology’s Qin Feng Racing Team. In July 2018, the Qin Feng Racing Team collaborated with nine members of the Brunel University Formula Racing Team at the Lishan Campus to form a Sino-British joint racing team. In July 2019, five members of the Qin Feng Racing Team traveled to Brunel University to participate in the international Formula Student competition. These competitions serve as a driving force for establishing a stable model of international exchange, broadening students' global perspectives, and fostering their abilities to communicate and collaborate in cross-cultural contexts.

Case Implementation Process: In the teaching design, instructors guide students to participate as teams in the full process of the Baja SAE competition, from requirements analysis to design, prototype manufacturing, and performance testing. This step-by-step approach develops students' engineering practice skills. For instance, during the powertrain optimization phase, students integrate content from courses such as Automotive Theory and Fundamentals of Mechanical Design. Using dynamic simulation tools like MATLAB or ADAMS, they analyze and optimize the vehicle's dynamic performance. Similarly, during the suspension tuning phase, students conduct experiments to verify the effects of different parameters on off-road vehicle performance. Figure 5 shows photos of students participating in the China Society of Automotive Engineers Baja SAE competition in recent years.

RESULTS

By implementing case-based teaching and the OBE-CDIO talent cultivation model, the vehicle engineering program has achieved significant improvements in student competencies, curriculum optimization, and teaching outcomes, as detailed below:

Improvement in Students' Comprehensive Abilities

Case-based teaching has significantly enhanced students' ability to solve complex engineering problems, integrate interdisciplinary knowledge, and innovate in practice. For example, in projects such as the Baja SAE competition and the Intelligent Driving Vehicle System, over 85% of students reported mastering core skills in vehicle dynamics, mechanical design, and control algorithms. Additionally, interdisciplinary projects, such as the development of an autonomous mining vehicle, enabled students to achieve breakthroughs in combining artificial intelligence with vehicle engineering, fostering their systems thinking and innovation in multidisciplinary environments.

Survey data indicated that students' satisfaction with their engineering practice abilities increased from 68% before the reforms to 92%. Among students participating in interdisciplinary projects, 65% proposed innovative solutions with practical application value. These enhancements have significantly improved students' competitiveness in the job market.

Optimization of the Curriculum System and Teaching Practice

The curriculum reform led to modularization and interdisciplinary integration, with closer alignment between practical and theoretical teaching. For example, the introduction of academic competitions and comprehensive project designs covered more than 70% of core course content within the mechanical, electrical, and control modules. The proportion of courses incorporating case-based teaching increased to 75% after the reforms.

The practical teaching system was further refined, with a layered structure of general practice, professional practice, and comprehensive projects. This allowed students to progressively develop their engineering abilities throughout their four years of undergraduate study. Supported by practical teaching platforms, over 80% of students completed interdisciplinary projects in their graduation designs, with some outputs adopted by partner companies for product development.

Significant Improvement in Teaching Outcomes

The teaching reforms have significantly enhanced the quality of student training and improved the program's reputation within the academic and industrial communities. Over the past three years, the total number of awards in national competitions, such as the National College Students Energy-Saving Vehicle Competition and the Intelligent Vehicle Competition, increased by 45%. Additionally, the graduate employment rate rose from 88% before the reforms to 96%, with a 25% increase in the proportion of graduates working in vehicle engineering-related industries in roles such as design, R&D, or management.

From 2018 to 2023, the number of students participating in academic competitions increased from 110 to 260, with the award-winning rate rising to 68%. In collaboration with industry, research outcomes from several students involved in autonomous vehicle development projects were adopted by partner companies, further demonstrating the effectiveness of the reforms in cultivating practical engineering abilities.

Summary

The implementation of case-based teaching and the OBE-CDIO model has achieved a deep integration of theory and practice in the vehicle engineering program. Students' professional competencies and innovation capabilities have significantly improved, while the social recognition and employment competitiveness of graduates have steadily increased. The successful experience of these teaching reforms demonstrates that incorporating real-world engineering projects into curriculum design not only promotes the comprehensive development of students' abilities but also provides strong support for cultivating high-quality engineering and technical talent. These outcomes provide actionable insights and practical references for advancing teaching reforms in other engineering disciplines.

CONCLUSIONS

The introduction of case-based teaching and the OBE-CDIO model, supported by artificial intelligence, has significantly enhanced students' engineering practice skills, innovation awareness, and ability to solve complex engineering problems. The OBE (Outcome-Based Education) model focuses on clearly defined learning outcomes, ensuring that students' knowledge and skills meet societal and industry demands. The CDIO (Conceive-Design-Implement-Operate) model, with its systematic framework for engineering practice, enables students to comprehensively improve their competencies in real-world engineering environments. The integration of these two models, enhanced by AI-driven tools for curriculum design and competition analysis, provides a robust framework for addressing the demands of modern engineering education.

The reform results demonstrate that the implementation of case-based teaching and the OBE-CDIO model, combined with AI technologies, has achieved deep integration of theory and practice, interdisciplinary knowledge synthesis, and the cultivation of engineering innovation capabilities. More than 80% of students completed interdisciplinary projects in their graduation designs, with some research outcomes adopted by companies, showcasing students' innovative abilities in engineering practice. Furthermore, the employment rate of graduates increased from 88% to 96%, and the total number of awards in high-level academic competitions grew by 45%, further validating the effectiveness of the teaching reforms.

Looking ahead, the vehicle engineering program will continue to optimize case study designs, deepen industry-academia collaboration, and strengthen the integration of artificial intelligence and international perspectives to further enhance the OBE-CDIO-based practical teaching system. These teaching reform experiences not only provide critical support for cultivating high-quality engineering and technical talent in the vehicle engineering discipline but also offer a valuable model for educational reforms in other engineering fields. Through continuous exploration, the vehicle engineering program will consistently deliver high-quality, innovative talent to meet societal and industrial needs, contributing to scientific progress and economic development.

REFRENCES

[1] Cico O, Jaccheri L, Nguyen-Duc A & Zhang H: Exploring the intersection between software industry and Software Engineering education-A systematic mapping of Software Engineering Trends. Journal of Systems and Software 2021, 172: 110736. doi: 10.1016/j.jss.2020.110736

[2] Porter DO, Irmak S, Lamm F, Marek T & Rein B: Challenges and opportunities for education in irrigation engineering. Transactions of the ASABE 2020, 63(5): 1289-1294. doi: 10.13031/trans.13943

[3] Ruiz-Ortega AM, Gallardo-Rodríguez JJ, Navarro-López E & Cerón-García MC: Project-led-education experience as a partial strategy in first years of engineering courses. Education for Chemical Engineers 2019, 29: 1-8. doi: 10.1016/j.ece.2019.05.004

[4] AlMalki HA & Durugbo CM: Institutionalising Industry 4.0: a Delphi study of institutional change readiness for the fourth industrial revolution in an emerging economy. Production Planning & Control 2024, 35(14): 1741-1759. doi: 10.1080/09537287.2023.2217414

[5] Castelo-Branco I, Amaro-Henriques M, Cruz-Jesus F & Oliveira T: Assessing the Industry 4.0 European divide through the country/industry dichotomy. Computers & Industrial Engineering 2023, 176: 108925. doi: 10.1016/j. cie.2022.108925

[6] David LO, Nwulu NI, Aigbavboa CO & Adepoju OO: Integrating fourth industrial revolution (4IR) technologies into the water, energy & food nexus for sustainable security: A bibliometric analysis. Journal of Cleaner Production 2022, 363: 132522. doi: 10.1016/j.jclepro.2022.132522

[7] Culot G, Nassimbeni G, Orzes G & Sartor M: Behind the definition of Industry 4.0: Analysis and open questions. International Journal of Production Economics 2020, 226: 107617. doi: 10.1016/j.ijpe.2020.107617

[8] Chang H T & Lin C Y: Applying Competition-Based Learning to Stimulate Students' Practical and Competitive AI Ability in a Machine Learning Curriculum. IEEE Transactions on Education 2024. doi: 10.1109/TE.2024.3350535

[9] Valenzuela‐Domínguez FA, Munguía‐Martínez LF, Meléndez‐Tiznado S, Guzmán‐Limón Z, Benitez VH & Félix‐Herrán LC: Design of a two‐degrees‐of‐freedom robotic arm for monitoring applications for teaching robotics and artificial intelligence technology. Computer Applications in Engineering Education 2024, 32(6): e22786. doi: 10.1002/ cae.22786

[10] Nolting L, Kies A, Schönegge M, Robinius M & Praktiknjo A: Locating experts and carving out the state of the art: A systematic review on Industry 4.0 and energy system analysis. International Journal of Energy Research 2019, 43(9): 3981-4002. doi: 10.1002/er.4427
[11] Norström P & Hallström J: Models and modelling in secondary technology and engineering education. International Journal of Technology and Design Education 2023, 33(5): 1797-1817. doi: 10.1007/s10798-023-09808-y
[12] Mumba F, Rutt A, Bailey R, Pottmeyer L, van Aswegen R, Chiu J & Ojeogwu J: A model for integrating engineering design into science teacher education. Journal of Science Education and Technology 2024, 33(1): 45-56. doi: 10.1007 /s10956-023-10055-y
[13] Li H, Qi H, Cao H & Yuan L: Industrial policy and technological innovation of new energy vehicle industry in China. Energies 2022, 15(24): 9264. doi: 10.3390/en 15249264
[14] Xu H & Chen Y: The impact of air pollution on the stock performance: Evidence from China new energy vehicle industry. Energy Reports 2022, 8: 315-320. doi: 10.1016 /j.egyr.2022.10.276
[15] Wang X, Qiu L, Hu F & Hu H: Characteristics and influencing factors of the industry-university-research collaborative innovation network in China's new energy vehicle industry. Energy Strategy Reviews 2024, 55: 101505. doi: 10.1016/j.esr.2024.101505
[16] Shrubsole K: Implementation of an integrated multidisciplinary Movement Disorders Clinic: applying a knowledge translation framework to improve multidisciplinary care. Disability and Rehabilitation 2021, 43(14): 2071-2083. doi: 10.1080/09638288.2019.1691666
[17] Zheng C, Bricogne M, Le Duigou J, Hehenberger P & Eynard B: Knowledge-based engineering for multidisciplinary systems: Integrated design based on interface model. Concurrent Engineering 2018, 26(2): 157-170. doi: 10.1177/1063293X17734591
[18] Tiseira A, Novella R, Garcia-Cuevas LM & Lopez-Juarez M: Concept design and energy balance optimization of a hydrogen fuel cell helicopter for unmanned aerial vehicle and aerotaxi applications. Energy Conversion and Management 2023, 288: 117101. doi: 10.1016/j.enconman. 2023.117101
[19] Németh B & Gáspár P: The design of performance guaranteed autonomous vehicle control for optimal motion in unsignalized intersections. Applied Sciences 2021, 11(8): 3464. doi: 10.3390/app11083464
[20] Fahim A, Tan Q, Naz B, ul Ain Q & Bazai SU: Sustainable higher education reform quality assessment using SWOT analysis with integration of AHP and entropy models: A case study of Morocco. Sustainability 2021, 13(8): 4312. doi: 10.3390/su13084312
[21] Chen H, Wang S & Li Y: Aligning engineering education for sustainable development through governance: The case of the International Center for Engineering Education in China. Sustainability 2022, 14(21): 14643. doi: 10.3390/su1421146 43
[22] Gallarta-Sáenz D, Rico-Azagra J & Gil-Martínez M: Learning Enhancement of Control Engineering: A Competition-Based Case. IEEE Access 2023, 11: 38240-38250. doi: 10.1109/ACCESS.2023.3267966
[23] Nunez JL, Tovar Caro E & Hilera Gonzalez JR: From higher education to open education: Challenges in the transformation of an online traditional course. IEEE Transactions on Education 2016, 60(2): 134-142. doi: 10.1109/TE.2016.2607693
[24] Chen WP, Lin YX, Ren ZY & Shen D: Exploration and practical research on teaching reforms of engineering practice center based on 3I‐CDIO‐OBE talent‐training mode. Computer Applications in Engineering Education 2021, 29(1): 114-129. doi: 10.1002/cae.22248
[25] Yuan X, Wan J, An D, Lu J & Yuan P: Multi-method integrated experimental teaching reform of a programming course based on the OBE-CDIO model under the background of engineering education. Scientific Reports 2024, 14(1): 16623. doi: 10.1038/s41598-024-67667-6
[26] Julius Fusic S, Anandh N, Anitha D, Sugumari T & Sri Vinodhini H: Impact of implementing project‐based assignment (PBA) in CDIO framework for computer numerical control application course. Computer Applications in Engineering Education 2022, 30(5): 1577-1590. doi: 10.1002/cae.22545
[27] Chan MK, Wang CC & Arbai AA: Development of dynamic OBE model to quantify student performance. Computer Applications in Engineering Education 2022, 30(5): 1293-1306. doi: 10.1002/cae.22520
[28] Zheng W, Wen S, Lian B & Nie Y: Research on a sustainable teaching model based on the OBE concept and the TSEM framework. Sustainability 2023, 15(7): 5656. doi: 10.3390/su15075656
[29] Qiao Y & Fu H: Study on OBE teaching concept in the context of deep learning for the construction of university mathematics microcourses. Computational Intelligence and Neuroscience 2022, 2022(1): 6860842. doi: 10.1155/2022/ 6860842

[30] Wang Y, Gao S, Liu Y & Fu Y: Design and implementation of project-oriented CDIO approach of instrumental analysis experiment course at Northeast Agricultural University. Education for Chemical Engineers 2021, 34: 47-56. doi: 10.1016/j.ece.2020.11.004
[31] Fan Y, Zhang X & Xie X: Design and Development of a Course in Professionalism and Ethics for CDIO Curriculum in China. Science and Engineering Ethics 2015, 21: 1381-1389. doi: 10.1007/s11948-014-9592-2
[32] Li N, Han Y & Gao F: Theory and practice of BIM skills of construction management professional based on conceive-design-implement-operate engineering teaching mode. Computer Applications in Engineering Education 2024: e22719. doi: 10.1002/cae.22719
[33] Zhong HX, Chiu PS & Lai CF: Effects of the use of CDIO engineering design in a flipped programming course on flow experience, cognitive load. Sustainability 2021, 13(3): 1381. doi: 10.3390/su13031381