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Fusing PBL and CDIO: An approach to develop innovation and entrepreneurship capabilities under the emerging engineering paradigm

Changji Xie[1], Yong Hu[1]
1 Nanning University , China, Guangxi

Abstract: *The construction of the new engineering education paradigm places higher demands on the cultivation of interdisciplinary and innovative talents. However, the traditional course Fundamentals of Innovation and Entrepreneurship faces significant challenges in aligning its content, pedagogy, and assessment with the realities of engineering practice. Addressing three major difficulties—disciplinary integration, pedagogical transformation, and assessment reform—this study proposes a PBL-CDIO integrated teaching model, which is characterized by project-led learning, dual-driven mechanisms, and four-stage progressive development. Centered on Problem-Based Learning (PBL) as the organizing principle and deeply integrating the CDIO (Conceive-Design-Implement-Operate) engineering education framework, the proposed model constructs a four-stage progressive pathway—theoretical reconstruction, case immersion, project-based practice, and multidimensional evaluation. Through two rounds of teaching implementation in the course Fundamentals of Innovation and Entrepreneurship, the proposed model has been shown to effectively stimulate students' learning initiative and significantly enhance their innovative thinking, entrepreneurial awareness, and comprehensive ability to solve complex engineering problems. The findings provide a replicable paradigm for curriculum reform integrating innovation and entrepreneurship education with professional engineering training in application-oriented universities.*

Keywords: *New engineering education; Innovation and entrepreneurship education; PBL; CDIO; Teaching model; Curriculum reform*

I. Introduction

The course *Fundamentals of Innovation and Entrepreneurship* serves as the primary vehicle for cultivating students' innovation and entrepreneurship literacy. With the accelerating pace of the global technological revolution and industrial transformation, the emerging economy, characterized by new technologies, new business models and new industries, has imposed higher requirements on engineering and technological talents. In response to this challenge, substantial efforts are being channeled into the development of emerging engineering education to cultivate high-quality engineering talents with enhanced innovative spirit, entrepreneurial awareness, and cross-disciplinary integration capabilities (Zhao et al., 2019; Zhao et al., 2018). Under this backdrop, the importance and urgency of reforming the course *Fundamentals of Innovation and Entrepreneurship* are becoming increasingly prominent. However, significant deficiencies persist in this course at many application-oriented universities, particularly in its social practice component. Firstly, the curriculum content remains disconnected from reality, often emphasizing universal business theories without integration with cutting-edge fields such as artificial intelligence, Building Information Modeling (BIM) and the Internet of Things. This disconnection leads to a situation where students find the knowledge impractical for application. Secondly, teaching methods remain overly homogeneous, relying predominantly on instructor-led lectures and case study reviews, while lacking authentic, interdisciplinary project-based practices (Brinkley, 2025). As a result, students struggle to gain immersive learning experiences. Thirdly, the evaluation system remains rigid, overemphasizing written reports and examinations, and failing to scientifically assess the development of students' abilities in innovative thinking, teamwork, and engineering implementation. At its core, these issues reflect the persistent disconnect between innovation and entrepreneurship education and specialized engineering education, which have yet to be effectively integrated.

To address this gap, this study employs the course *Fundamentals of Innovation and Entrepreneurship* as a vehicle for reform. Building on Outcome-Based Education (Rao, 2020; Asim et al., 2021), Problem-Based Learning (Wood, 2003; Hmelo-Silver et al., 2004), and the CDIO engineering education model (Chen et al., 2010; Edström et al., 2020), it innovatively develops a PBL-CDIO integrated teaching model. The study further elaborates on the theoretical foundation of the model, implementation pathway, and practical outcomes, aiming to provide theoretical insights and a practical reference for curriculum reform in peer institutions.

II. PBL-CDIO Model: Rationale and Essence

Design Rationale

The development of this model adheres to the core principles of student-centeredness, outcome orientation and project linkage. It posits that, within the context of the new engineering education, the cultivation of innovation and entrepreneurship competencies must be rooted in authentic, engineering-based problem scenarios. Through learning by doing and creating through learning, students achieve the synergistic development of knowledge, skills, and professional qualities. Problem-Based Learning provides a sustained framework and motivation for inquiry, while the CDIO model offers a complete engineering-oriented process—from conceptualization to product realization. The integration of the two establishes a seamless pathway from “creative ideation” to “entrepreneurial implementation”, effectively bridging the gap between innovation and engineering practice.

Core Connotations

The core connotation of the PBL-CDIO integrated teaching model can be distilled into three integral elements: project-led, dual-wheel drive and four-phase progression. These components form a logically coherent and mutually supportive organic whole.

(1) Project-Led. The curriculum is designed around an authentic or highly simulated "core project" sourced from the frontiers of emerging engineering, which runs consistently throughout the course. The project themes are characterized by their authenticity, cutting-edge nature, and interdisciplinary attributes. Serving as a vehicle for knowledge integration and practical application, the project compels students to proactively synthesize multidisciplinary knowledge from engineering technology, management science, and economic analysis when addressing complex engineering problems. This effectively breaks down the barriers inherent in traditional curricula where theory is often isolated from practice, thereby facilitating a natural transition from knowledge comprehension to competency development.

(2) Dual-Wheel Drive. The operation of the PBL-CDIO integrated teaching model is synergistically propelled by "PBL Drive" and "CDIO Process Drive". PBL utilizes the specific problems and challenges arising from project inquiry as an intrinsic motivator for learning, guiding students to actively construct knowledge in order to solve these problems. Concurrently, CDIO provides students with a comprehensive engineering practice

framework—spanning Conceive, Design, Implement, and Operate—for transitioning from concept to product, thereby cultivating their systems thinking and project management skills. These two drivers complement each other, collectively ensuring that the innovation process possesses both exploratory dynamism and a structured implementation pathway.

(3) Four-Phase Progression. Competency development follows a spiraling trajectory, unfolding through four defined phases—conceptualization, scheme design, prototype implementation, and outcome operation. Each stage is equipped with explicit learning tasks and capability objectives, guiding students to gradually deepen their theoretical understanding, refine technical skills, and enhance entrepreneurial literacy through progressive project practice. Ultimately, this fosters the synergistic development of knowledge, abilities, and qualities. The specific architecture of this model is illustrated in the figure below.

III.Implementation Pathway of the Model

To translate the integrated PBL-CDIO pedagogical model from a theoretical concept into actionable teaching practice, this study has systematically designed a three-stage implementation pathway within the course *Fundamentals of Innovation and Entrepreneurship*. This pathway aims to fundamentally shift the instructional paradigm from passive knowledge transmission to active competency development.

Phase One: Theoretical Restructuring

This initial phase focuses on the structural reform of the course's theoretical knowledge system. It moves beyond the traditional linear sequence of textbook chapters by deconstructing discrete theoretical points and reconstructing them into "competency components" that are systematically integrated into the CDIO framework. Specifically, components linked to the Conceive stage emphasize innovative thinking techniques, opportunity identification, and business model canvas; those for the Design stage cover technical solution design, project proposal writing, and team management; components for the Implement stage focus on resource integration, cost control, and minimum viable product development; and those for the Operate stage revolve around project pitching, intellectual property, and sustainable operation strategies. Through this restructuring, theoretical knowledge is no longer pre-delivered content for passive reception but is transformed into an "on-demand toolkit" that students proactively retrieve, learn, and apply when their project advances to a specific CDIO stage and encounters real-world challenges.

Phase Two: Case Immersion

The case immersion is guided by the principle of progression from generic examples to contextualized engineering cases. To bridge the gap between generic business theory and specific engineering practices, a dedicated case study of interdisciplinary innovation and entrepreneurship for emerging engineering education was compiled. The case selection strictly adheres to three core criteria: authenticity, technical relevance, and completeness. The authenticity requires cases to originate from real projects in partner companies to ensure credible scenarios; the technical relevance mandates that cases incorporate distinct elements of emerging engineering technologies; and the completeness ensures cases fully demonstrate the entire journey from a technological idea to final market application or commercial transformation.

By analyzing these deeply contextualized cases, students can immerse themselves in a highly simulated environment at the intersection of engineering and business, gaining a profound understanding of the market dynamics, potential risks, and decision-making logic behind technological innovation. This process not only effectively stimulates students' professional identity but also provides them with a referential "thinking template" and strategic toolbox for their subsequent project.

Phase Three: Project Immersion

Project immersion serves as the convergence point where PBL and CDIO integrate. The project immersion phase constitutes the core and ultimate application of the model. In this stage, student teams of 4-6 members, formed across disciplines, undertake a complete, authentic project sourced from emerging engineering fields. The teaching process strictly follows the CDIO framework while being deeply coupled with the inquiry cycle of PBL. During Conceiving, teams conduct market research to formulate technological ideas and preliminary business concepts. In the Designing phase, they refine technical solutions and develop detailed implementation plans and financial budgets. The Implementing phase sees students utilizing labs and maker spaces to develop product prototypes while concurrently completing business plans and marketing strategies. Finally, in the Operating phase, they simulate project promotion, funding negotiations, and technology transfer through project roadshows or innovation competitions, with outstanding projects being recommended to the university science park for further incubation. Throughout this entire process, the instructor's role shifts from that of a knowledge transmitter to a coach or mentor, primarily providing resource connections, technical consultation, and formative guidance at critical junctures, thereby ensuring a balance between learning autonomy and project completion.

Phase Four: Multidimensional Assessment

In this stage, the multidimensional evaluation shifts from summative assessment to process-oriented and value-added assessment. To ensure the alignment with the objectives of the teaching model, a tripartite and multi-source assessment system was established to comprehensively evaluate student learning outcomes and competency development. This system integrates formative, summative, and comprehensive assessments. Formative assessment (50%) evaluates student progress throughout the CDIO stages based on project logs, design proposals, prototype quality, and peer evaluation of individual contribution. Summative assessment (30%) focuses on the final deliverables, including the business plan, product prototype/demonstration video, and roadshow performance. Comprehensive assessment (20%) incorporates evaluations from industry mentors and experts alongside student self-reflection reports, with a particular focus on the development of innovativeness, practical skills, and overall professional literacy.

IV. Preliminary Outcomes and Reflections

Through two iterative implementations of the PBL-CDIO integrated teaching model, the preliminary outcomes in the participating classes have been observed as follows. Firstly, there has been a notable increase in the learning initiative of students. The project-driven approach has provided clearer learning objectives, shifting the student mindset from passive reception to active exploration, which is reflected in significantly higher classroom engagement and self-directed learning time outside class. Secondly, students' innovation and entrepreneurship competencies have become more deeply integrated with their disciplinary expertise. Exemplary student projects, such as the drone-based bridge inspection service business plan and the community implementation plan for smart waste-sorting bins, demonstrate an effective amalgamation of specialized technical knowledge and business model innovation. Finally, students' comprehensive qualities have been systematically honed through project practice, with marked improvements in teamwork, communication, project management, and resilience.

It should be noted that the successful implementation of this PBL-CDIO integrated teaching model places higher demands on faculty's interdisciplinary expertise, the institution's support in terms of practical platforms, and the depth of industry-academy collaboration. Looking ahead, this study will focus on refining the standardized operational procedures of the PBL-CDIO integrated teaching model, developing a supporting digital teaching resource library, and exploring the establishment of a more scientific and refined value-added competency assessment model. These efforts aim to enhance the model's generalizability and potential for broader dissemination.

V. Conclusions

The PBL-CDIO integrated teaching model represents an in-depth exploration of curriculum reform aimed at integrating professional education with innovation and entrepreneurship education under the framework of the new engineering education. By adopting a project-led approach, the model authenticates learning contexts and situates students in realistic problem-solving environments. The dual-driven mechanism ensures both the inquisitiveness and systematicity of the teaching process, while the four-stage progressive design guarantees the gradual and holistic development of students' competencies.

Empirical practice has demonstrated that the PBL-CDIO integrated teaching model effectively addresses the long-standing disconnection between innovation and entrepreneurship education and traditional engineering education. It provides a practical and sustainable pathway for cultivating interdisciplinary engineering talents who not only possess strong technical expertise but also demonstrate creative and entrepreneurial capabilities, meeting the evolving demands of future industries.

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