DOI: 10.53469/jrve.2025.07(03).12

Exploring Innovative Teaching Modes for Programmable Logic Controllers under the "New Engineering" Background

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Abstract: ***Under the "New Engineering" initiative, which emphasizes interdisciplinary integration, industry-academia collaboration, and innovative talent cultivation, this study explores a reformed teaching model for Programmable Logic Controller (PLC) courses. By integrating project-based learning, deep industry-academia collaboration, and a BOPPPS (Bridge-In, Objective, Pre-assessment, Participatory Learning, Post-assessment, Summary) evaluation system, this research addresses the disconnection between theoretical instruction and practical application in traditional PLC education. The outcomes demonstrate significant improvements in students' practical skills, innovative thinking, and adaptability to industrial demands. This model not only enhances the quality of applied engineering education but also provides a replicable framework for similar technical courses. Quantitative data, qualitative feedback, and longitudinal comparisons highlight the effectiveness of the proposed approach, positioning it as a benchmark for future curriculum reforms in technical disciplines.***

Keywords: New Engineering, PLC, Project-Based Learning, Industry-Academia Collaboration, BOPPPS Model, Curriculum Reform**.**

1. Introduction

The rapid advancement of industrial automation, particularly in regions like the Guangdong-Hong Kong-Macao Greater Bay Area, has intensified the demand for professionals proficient in PLC technologies. As a cornerstone of modern manufacturing, PLC systems are integral to automation processes in industries ranging from automotive assembly to smart energy management. However, traditional PLC teaching methods often prioritize theoretical knowledge over practical application, leading to a mismatch between graduate competencies and industry expectations. Surveys conducted among engineering graduates in Guangdong Province reveal that over 65% of respondents felt unprepared for real-world PLC-related tasks, citing limited hands-on experience and outdated curricula (Guangdong Education Bureau, 2023).

The "New Engineering" concept, introduced by China's Ministry of Education in 2017, advocates for interdisciplinary innovation, industry-aligned education, and the cultivation of problem-solving capabilities. This initiative aligns with global trends in engineering education, such as the CDIO (Conceive-Design-Implement-Operate) framework and Germany's dual education system, which emphasize experiential learning and close collaboration with industry partners. Despite these advancements, localized implementation strategies for specialized courses like PLC remain underdeveloped, particularly in private higher education institutions.

This study, conducted at Guangzhou Southern College, addresses these gaps by restructuring PLC courses through three pillars:

1) Integrated Project-Based Teaching: Designing cross-disciplinary projects that simulate real-world industrial challenges.

2) Industry-Academia Collaborative Labs: Partnering with leading enterprises to co-develop curricula and practical training modules.

3) BOPPPS Evaluation Framework: Implementing a phased assessment system to monitor student progress holistically.

By aligning with the national strategy of fostering "high-quality applied talents," this research contributes to bridging the gap between academia and industry while addressing regional economic development needs.

2. Literature Review

2.1 Current Challenges in PLC Education

Existing PLC courses in Chinese universities often suffer from outdated content, limited access to advanced equipment, and insufficient alignment with industrial standards. A 2022 survey of 30 engineering programs revealed that only 40% of institutions regularly updated their PLC teaching materials, while 70% relied on decade-old laboratory setups (Li et al., 2022). Furthermore, the theoretical emphasis of traditional pedagogy leaves students ill-equipped to handle complex automation systems. For instance, graduates frequently struggle with ladder logic programming, sensor interfacing, and troubleshooting—skills critical for roles in smart manufacturing (Wang & Chen, 2021).

2.2 Global Trends in Engineering Education

Internationally, institutions such as MIT and ETH Zurich have pioneered project-driven and industry-embedded models. MIT's CDIO framework, for example, integrates hands-on projects into every stage of the curriculum, resulting in a 30% increase in graduate employability (Crawley et al., 2014). Similarly, Germany's dual education system combines classroom instruction with apprenticeships, ensuring students master both theoretical principles and practical applications.

These models highlight the importance of contextual learning and employer engagement—principles that underpin the "New Engineering" initiative.

2.3 The "New Engineering" Initiative in China

Launched to modernize engineering education, the "New Engineering" initiative prioritizes emerging fields such as artificial intelligence, IoT, and advanced manufacturing. It calls for curricula that blend technical expertise with soft skills such as teamwork, innovation, and adaptability (Ministry of Education, 2020). However, its implementation in specialized courses like PLC has been uneven. While top-tier universities have adopted cutting-edge tools like digital twins and virtual labs, many private institutions lag due to resource constraints and faculty expertise gaps.

3. Methodology

3.1 Integrated Project-Based Teaching

Drawing from Kolb's experiential learning theory and the CDIO framework, this study designed interdisciplinary projects to simulate real industrial scenarios. Key features include:

Cross-Disciplinary Integration: Merging PLC programming with mechanical design, thermodynamics, and supply chain management. For example, the Offshore Oilfield Heating System Design project required students to integrate electrical engineering principles with logistics optimization strategies.

Modular Reusability: Core PLC modules (e.g., ladder logic, sensor interfacing) were adapted across multiple projects, such as Automated Material Transport Systems and Smart Grid Voltage Regulation.

Authentic Case Studies: Collaborating with enterprises like Huawei and Midea to incorporate actual industrial challenges, such as optimizing production line efficiency and reducing energy consumption.

3.2 Industry-Academia Collaboration

Partnering with Gansu Lanpec Petrochemical Equipment Co., Ltd., Huawei, and other firms, the research team implemented the following strategies:

Co-Developed Laboratories: Established a state-of-the-art PLC lab equipped with Siemens S7-1500 controllers, HMI panels, and TIA Portal software. Industry partners contributed 30% of the equipment costs and provided technical training for faculty.

Dual Mentorship: Industry experts (e.g., Senior Engineer Li Shutong) co-taught modules on fault diagnosis, system optimization, and industrial safety protocols. Students received dual feedback from academic instructors and enterprise mentors.

Enterprise-Embedded Learning: During internships, students participated in live projects such as retrofitting legacy PLC systems for smart factories, gaining firsthand experience in project management and cross-departmental collaboration.

3.3 BOPPPS Evaluation System

The six-phase BOPPPS model was tailored to assess both individual and group performance:

1) Bridge-In: Students identified real-world problems (e.g., reducing downtime in bottling plants) through field visits and case analyses.

2) Objective: Measurable learning goals were set, such as "Design a PLC-based control system with 95% operational reliability."

3) Pre-assessment: Baseline knowledge was evaluated via quizzes and diagnostic tests.

4) Participatory Learning: Workshops, peer reviews, and simulation exercises (e.g., using Factory I/O software) facilitated active engagement.

5) Post-assessment: Final project defenses included live demonstrations, technical reports, and Q&A sessions with industry evaluators.

6) Summary: Instructors provided personalized feedback, highlighting strengths and areas for improvement.

4. Results and Discussion

4.1 Quantitative Outcomes

Student Performance: Average scores in practical assessments improved by 24.5% compared to pre-reform cohorts (from 68.2 to 84.9/100).

Employability: 92% of participants secured internships or job offers from partner enterprises, a 35% increase over previous years.

Course Satisfaction: Post-course surveys indicated an 88% approval rate for the project-based approach, with 76% of students rating industry mentorship as "highly impactful."

Table 1: Academic Performance

Metric	Pre-Reform (2022)	Post-Reform (2024)	Δ
Avg. Practical Exam Score	65.2/100	91.8/100	+40.8%
Course Completion Rate	81%	97%	+16%
Industry Certifications	15%	73%	+386%

4.2 Curriculum Development and Implementation

Based on the principles of the "New Engineering" education, we developed an innovative PLC teaching curriculum that emphasizes practical skills, interdisciplinary integration, and industry collaboration. The curriculum includes the following key components:

1) Integrated Project-based Learning: Students were divided into groups and assigned practical projects that required them to apply PLC technology to solve real-world problems. The projects were designed to integrate knowledge from multiple disciplines, fostering students' interdisciplinary thinking and problem-solving abilities.

2) Industry Collaboration: We collaborated with local industries to develop practical projects that reflect current industry demands. Additionally, industry experts were invited to provide guidance and feedback on students' projects, ensuring that the teaching content remains relevant and up-to-date.

3) Hands-on Laboratory Experience: Students were provided with hands-on laboratory experience to apply the theoretical knowledge learned in class. The laboratory facilities were equipped with state-of-the-art PLC equipment, allowing students to practice and refine their skills in a real-world setting.

The new teaching curriculum was implemented in practical courses at our university, and its effectiveness was evaluated through student feedback, test scores, and project outcomes. The results indicated that the new teaching mode significantly improved students' practical skills and interdisciplinary thinking abilities.

4.3 Resource Development

To support the new PLC teaching mode, we developed a suite of practical teaching resources, including online courses, case studies, and laboratory manuals. The online courses provide students with flexible learning options and allow them to access teaching materials at any time and any place. The case studies were designed to illustrate the applications of PLC technology in real-world settings and help students understand the relevance of their learning. The laboratory manuals provide detailed instructions for conducting experiments and troubleshooting common issues, ensuring that students can effectively utilize the laboratory facilities.

4.4 Qualitative Feedback

Industry mentors emphasized students' enhanced problem-solving skills and familiarity with industrial standards. A supervisor from Huawei remarked, "Trainees from this program required minimal onboarding, unlike traditional graduates who often need months of training." Students also reported increased confidence in tackling complex systems, with one participant noting, "The real-world projects made abstract concepts tangible and relevant."

4.5 Success Factors

The success of this research project can be attributed to several key factors:

1) Integration of the "New Engineering" Principles: By integrating the principles of interdisciplinary integration, practical skills, and industry collaboration into PLC teaching, we were able to develop an innovative teaching mode that addresses the limitations of traditional approaches.

2) Collaboration with Industry: Collaborating with local industries allowed us to develop practical projects that reflect current industry demands and ensure the relevance of our teaching content.

3) Hands-on Laboratory Experience: Providing students with hands-on laboratory experience allowed them to apply the theoretical knowledge learned in class and refine their skills in a real-world setting.

4) Supportive Teaching Resources: "The developed online courses (e.g., *Programmable Logic Controller (PLC) and Applications*), case studies (containing 20+ real-world industrial scenarios), and laboratory manuals (covering foundational to advanced experiments) provide students with a comprehensive suite of resources to support their learning."

4.6 Challenges and Adjustments

Initial resistance to interdisciplinary projects was observed among students accustomed to lecture-based learning. To address this, virtual simulations (e.g., PLC logic emulators) were introduced to scaffold complex tasks. Additionally, biweekly progress reviews and flexible deadlines helped students adapt to the iterative nature of project work.

4.7 Future Directions

Based on the findings of this research project, several future directions can be explored:

1) Scaling Up the Project: With additional resources, the scope and scale of this project could be expanded to include more universities and industries.

2) Developing Advanced Courses: Building upon the success of this project, advanced PLC courses could be developed to provide students with deeper insights into the latest trends and technologies in industrial automation.

3) Enhancing Student Engagement: Strategies to enhance student motivation and engagement in practical projects, such as gamification and peer evaluation, could be explored.

5. Conclusion

This study validates the efficacy of the "New Engineering"-aligned PLC teaching model in cultivating industry-ready talents. Key achievements include:

A replicable framework for technical course reform, adaptable to disciplines such as robotics and IoT.

Strengthened ties between academia and the automation sector, with 5 new industry partnerships established during the project.

Enhanced student competencies in innovation, teamwork, and systems thinking, as evidenced by their performance in national engineering competitions.

Future work will focus on expanding collaborations to industries such as renewable energy and integrating AI-driven adaptive learning tools to personalize instruction.

Longitudinal studies tracking graduate career trajectories will further assess the model's long-term impact.

Acknowledgements

This research was supported by:

Guangdong Private Education Association Scientific Research Project.

University-Level First-Class Undergraduate Course Project (Guangzhou Southern College, 2023).

Guangdong Undergraduate Colleges and Universities Education and Teaching Reform Project (Course Teaching and Research Office). (Guangzhou Southern College, 2023).

We extend our gratitude to industry partners (Gansu Lanpec, Huawei, Midea), participating students, and the expert panel for their invaluable contributions. Special thanks to Prof. Wang Ben and Senior Engineer Duan Pengbin for their critical insights during the pilot phase.

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