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Pathways and Quality Enhancement of Integrating Practical Teaching into Engineering Education: A Case Study of the Automotive Power Battery Technology Course

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Abstract: In the context of the deep advancement of the New Engineering initiative and the increasing alignment between industrial demands and educational provision, engineering education in universities is facing several prominent challenges. These include the disconnection between theory and practice, the abstract and monotonous nature of specialized knowledge, insufficient student learning motivation, and weak engineering competencies, all of which significantly constrain educational quality and the effectiveness of talent cultivation. As a critical bridge linking theoretical knowledge with industrial practice, practical teaching plays a key role in addressing these issues. Its deep integration throughout the entire engineering education process can effectively overcome the limitations of traditional teaching approaches, enhance students' practical skills, engineering thinking, and innovative capabilities, and ultimately promote the continuous improvement of educational quality. Drawing on engineering education practices at the University of Shanghai for Science and Technology, this study takes the course Automotive Power Battery Technology as a case study. It analyses the current status and existing problems in integrating practical teaching into university engineering education, explores feasible integration pathways and instructional design methods, and, based on specific practical cases and outcome data, proposes optimization strategies. The study aims to provide both theoretical insights and practical references for improving the quality of engineering education and cultivating outstanding engineering talents.

1. Introduction

With the rapid development of the new energy vehicle (NEV) industry, power battery technology has become a core component in engineering education, particularly in vehicle-related disciplines [1]. It directly influences vehicle performance and sustainability outcomes. However, a significant gap remains between theoretical instruction and engineering practice, resulting in insufficient practical experience and limited problem-solving capabilities among students [2]. Therefore, integrating practical teaching with theoretical learning has become a key challenge in improving engineering education quality.

In recent years, Project-Based Learning (PBL) has been widely adopted as a student-centered approach in engineering education. Studies show that PBL enhances the application of theoretical knowledge, practical skills, and innovation capacity [3][4], while also promoting interdisciplinary integration and complex problem-solving abilities [5][6]. Nevertheless, in highly interdisciplinary courses such as power battery technology, challenges persist in constructing systematic practice-oriented teaching frameworks, including unclear implementation pathways and fragmented instructional design [7].

From an assessment perspective, traditional outcome-based evaluation methods fail to capture students' competency development effectively. The SOLO taxonomy provides a cognition-based framework for evaluating learning depth and supporting hierarchical teaching design [8]. Furthermore, integrating PBL with diversified evaluation methods, such as peer and formative assessment, can improve team learning effectiveness and highlight individual contributions [9]. The adoption of digital tools and multi-source data analysis further supports the optimization of evaluation systems in engineering education [10].

Based on this context, this study takes the Automotive Power Battery Technology course at the University of Shanghai for Science and Technology as a case study to explore the integration of practical teaching into engineering education. Specifically, it aims to: (1) develop a hierarchical practical teaching framework based on PBL and the SOLO taxonomy; (2) enhance teaching effectiveness through the integration of virtual simulation and hands-on experiments; and (3) establish a multi-dimensional evaluation system to promote deep learning and competency development [9].

This study contributes both theoretically and practically. It extends the application of PBL in complex engineering courses and proposes a systematic framework for practical teaching integration [10]. Meanwhile, it provides actionable strategies for curriculum reform in NEV-related programs, supporting the development of students' practical skills, innovation capacity, and teamwork abilities, and contributing to the cultivation of high-quality engineering talent [11].

2. Current Status and Challenges of Integrating Practical Teaching into University Engineering Education

2.1. Current Integration Status

With the advancement of the New Engineering initiative, universities have increasingly recognized the importance of practical teaching and begun integrating it across the educational process, forming multiple implementation models, as shown in Figure 1.

These include course-integrated practice, where hands-on tasks are embedded into core courses (e.g., battery assembly in Automotive Power Battery Technology); specialized practice, conducted through projects and internships; university–industry collaboration, which introduces real industrial scenarios into teaching through joint programs [2]; and innovation and entrepreneurship practice, which promotes problem-driven learning and innovation through competitions and training programs.

Overall, these approaches have improved student engagement and practical skills, narrowing the gap between education and industry needs. For example, students have achieved tangible outcomes in engineering practice and demonstrated enhanced understanding and innovation capabilities through structured training programs.

However, despite these advances, the integration of practical teaching remains limited in depth and scope, particularly in abstract and interdisciplinary courses such as Automotive Power Battery Technology.

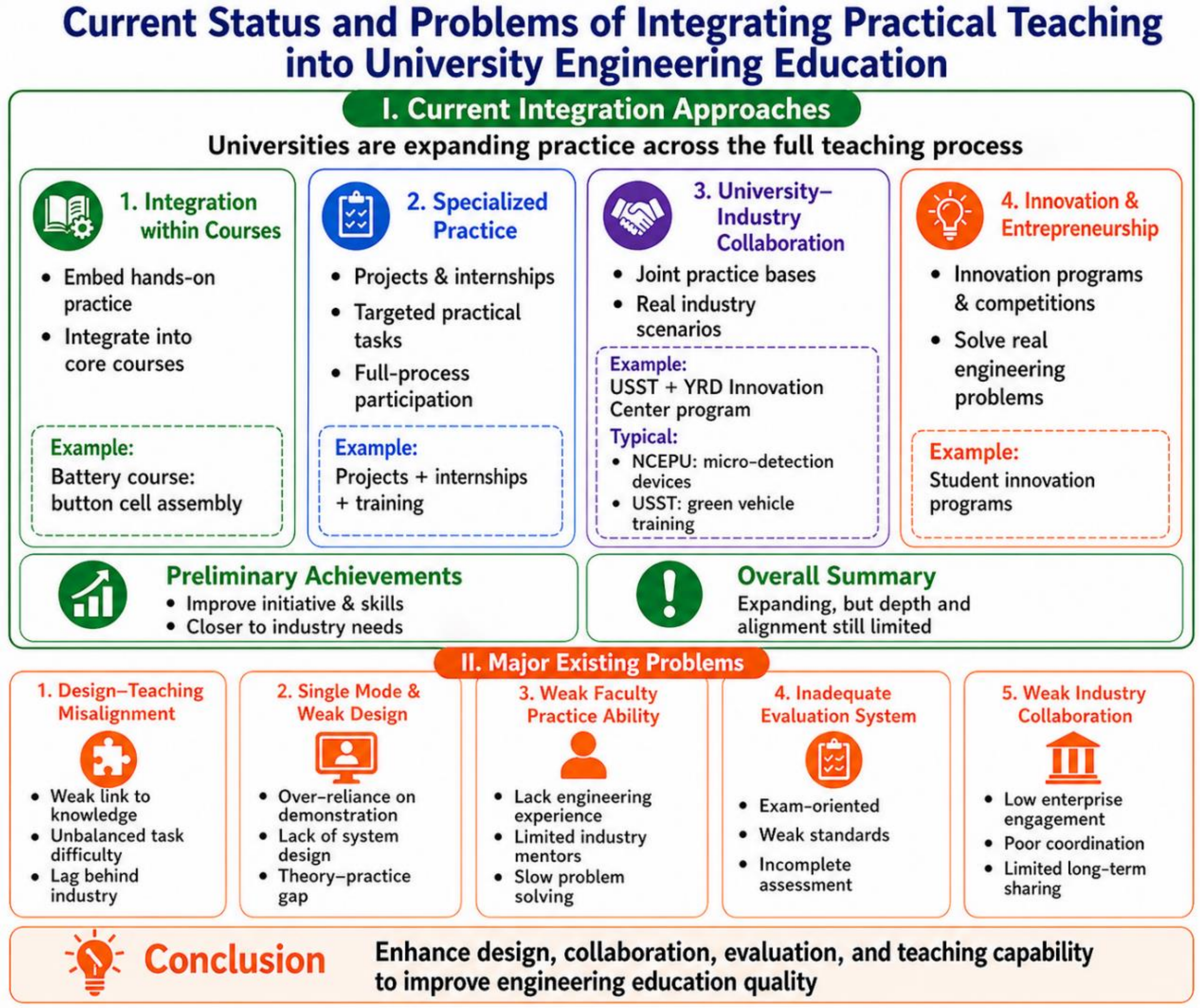

Figure 1: Current Status and Problems of Integrating Practical Teaching into University Engineering Education

2.2. Major Existing Problems

(1) Misalignment of Practice and Theory

Practical tasks are not well aligned with core theoretical concepts, limiting their instructional value. In addition, task difficulty is often poorly designed, either too simple or overly complex for students.

(2) Limited Integration Model

Practical teaching mainly relies on passive approaches such as demonstration and imitation. A complete theory–practice learning cycle is often missing, weakening learning effectiveness.

(3) Weak Faculty Practical Capability

Many faculty members lack hands-on industry experience, which constrains effective practical teaching. Collaboration with industry mentors is limited and lacks sustainability.

(4) Inadequate Evaluation System

Evaluation systems remain theory-oriented and overlook key practical competencies. This weakens their ability to guide students' engagement in practice.

(5) Weak University–Industry Collaboration

University–industry cooperation is often superficial and lacks long-term mechanisms. As a result, industrial resources are not effectively integrated into teaching.

3. Core Pathways and Instructional Design Methods for Integrating Practical Teaching into Engineering Education in Universities

3.1. Precisely Design Practical Teaching to Strengthen Alignment with Theoretical Knowledge

The core value of practical teaching is to apply theoretical knowledge and help students understand abstract concepts. Practical teaching should closely align with core course content, consider students' knowledge levels, and follow a deconstruction of knowledge points—practical task design—theory linkage—result verification approach to ensure synchronization of theory and practice. In the Automotive Power Battery Technology course, layered practical tasks are designed: basic tasks involve disassembling button cells to understand structural components; intermediate tasks deepen understanding of material properties and assembly processes through battery assembly; and advanced tasks, such as battery performance comparison, help students grasp working principles. Throughout the process, students are guided to connect theory and practice through inquiry and problem-solving. Moreover, practical teaching design should integrate industry needs, incorporating real-world scenarios and technical standards from industry to ensure alignment with current industrial practices.

3.2. Innovative Integration Models: Building a Systematic Practical Teaching Framework

To enhance teaching quality, it is necessary to break the single integration model and build a diversified, systematic practical teaching framework. First, course-integrated practice involves embedding small-scale practical tasks with each theoretical concept. For instance, in the Automotive Power Battery Technology course, practical tasks help students understand theoretical knowledge. Second, specialized practice integration introduces comprehensive practical tasks through course design, internships, etc., such as the Power Battery Performance Optimization practice, deepening students' application of theory. Third, university-industry collaborative practice involves co-building practice bases with enterprises, integrating real-world industrial scenarios into teaching, and enhancing students' practical application skills. Finally, innovation and entrepreneurship practice integration encourages students to engage in interdisciplinary projects through innovation training programs and competitions, fostering their innovative thinking and practical abilities.

3.3. Enhancing Faculty Development and Practical Teaching Guidance Capabilities

Faculty development is crucial to the integration of practical teaching into education. It is necessary to improve teachers' practical teaching design and guidance capabilities through a combination of on-campus training, external recruitment, and university-industry collaboration to ensure that practical teaching effectively supports theoretical instruction. First, the practical teaching capabilities of on-campus faculty should be enhanced by regularly organizing faculty internships in enterprises, participating in industry research projects, and gaining insights into cutting-edge industrial practices and standards. For courses like Automotive Power Battery Technology, teachers should attend practical teaching training sessions and industry seminars to learn advanced teaching design methods and improve their practical teaching abilities. Second, universities should recruit industry professionals with hands-on engineering experience as full-time or part-time faculty members to fill the gap in practical teaching experience among university faculty. These industry experts would focus on guiding practical teaching. Third, universities should refine the collaborative guidance model between academic and industry mentors, clearly delineating their roles. Academic mentors should focus on the design of practical teaching and theoretical guidance, while industry mentors should concentrate on practical operations and explaining industry standards. This dual-mentor, complementary expertise model ensures a holistic approach to teaching. For instance, the University of Shanghai for Science and Technology's Automotive Power Battery Technology course has established a joint academic-industry mentor team to design practical teaching plans and guide students in hands-on operations, ensuring the scientific and practical nature of practical teaching.

3.4. Diversified Evaluation System for Practical Teaching and Its Application

To enhance the role of practical teaching in engineering education, a scientific and systematic evaluation system must be established. This system should break away from the traditional focus on theory-heavy evaluations and emphasize the central role of practical teaching. The evaluation system should incorporate a process evaluation + outcome evaluation + comprehensive evaluation approach to guide students in prioritizing practical operations, actively connecting theory to practice, and ensuring that practical teaching effectively drives learning, as shown in Figure 2.

Figure 2: Practice-Driven Learning

First, the evaluation content should include students' performance in practical tasks (such as operational standards, problem-solving ability, and theoretical linkage), practical results (such as practice reports, operational outcomes, and innovative solutions), and their level of engagement. This comprehensive approach reflects the overall effectiveness of practical teaching and students' competencies. For example, in the Automotive Power Battery Technology course, key evaluation factors include the detail of disassembling and observing button batteries, the standardization of assembly, the accuracy of performance testing, and the theoretical analysis of material properties and working principles in the practice report.

Second, innovative evaluation methods should be adopted, including a diversified evaluation system with self-assessment, peer assessment, teacher evaluation, and industry evaluation to ensure objectivity and comprehensiveness. In this system, industry evaluation focuses on students' performance during industry practices, with industry mentors assessing students based on their practical skills, work attitude, and ability to apply theoretical knowledge. The University of Shanghai for Science and Technology uses this multi-source evaluation approach to ensure the quality of practical teaching in its industry-resident practice model.

Third, the results of the practical teaching evaluation should be tied to students' course grades, merit awards, final projects, and employment recommendations. This linkage encourages students to value practical operations, deepen their understanding of theoretical knowledge through practice, and promote a deeper integration of practical and theoretical teaching.

4. Case Studies and Effectiveness Analysis: A Case Study of the Automotive Power Battery Technology Course at the University of Shanghai for Science and Technology

4.1. Case Study: Practical Teaching Design and Implementation of the Automotive Power Battery Technology Course

(1) Pre-Class Preparation and Practical Resource Setup

The Automotive Power Battery Technology course divides core knowledge into three modules: Material Properties, Structural Components, and Working Principles, and designs tiered practical tasks (basic, intermediate, and advanced). Essential resources such as button cells, current collectors, materials, and testing equipment are prepared. Pre-class tasks help students bridge theory and practice, preparing them for hands-on operations, as shown in Figure 3.

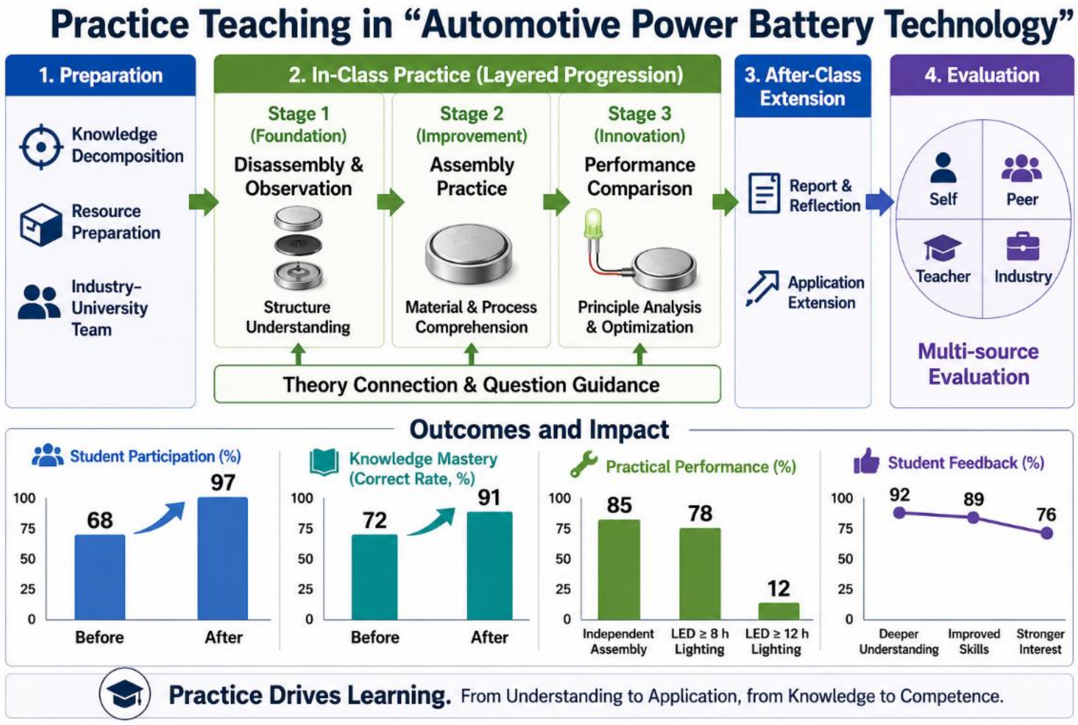

Figure 3: Practice-Teaching

(2) In-Class Practice Implementation

Practical teaching is divided into three stages:

Basic Practice: Disassembling button cells to understand the structure and function;

Intermediate Practice: Assembling button cells while analysing material properties and assembly techniques;

Advanced Practice: Conducting a performance comparison of button batteries, optimizing material ratios and assembly processes, and enhancing understanding of working principles.

(3) Post-Class Extension

Students write practice reports to analyse the connection between practice and theory, and extend their learning to the application of power batteries in electric vehicles, comparing industrial batteries with button cells.

(4) Evaluation Method

A diversified evaluation system is employed, combining self-assessment, peer evaluation, teacher assessment, and industry evaluation to focus on students' operational standards, theoretical linkage, problem-solving skills, and innovation. This ensures objective and comprehensive evaluation of practical teaching.

4.2. Practical Outcomes

Through the implementation of a well-structured practical teaching design, the teaching effectiveness of the Automotive Power Battery Technology course at the University of Shanghai for Science and Technology has been significantly improved, demonstrating the strong role of practice in enhancing learning outcomes. The specific results are as follows.

This practical teaching case involved 83 undergraduate students from one engineering major across two classes. After implementation, student participation increased from 68% to 97%, and classroom interaction frequency rose by 120%, effectively addressing issues of low engagement and lack of motivation. In the final assessment, the accuracy rate for core knowledge points—such as current collectors, electrodes, and electrolytes—increased from 72% to 91%, indicating a substantial improvement in students’ understanding and retention of abstract concepts.

In terms of practical skills, 85% of students were able to independently complete button battery assembly and troubleshooting. Additionally, 78% of the assembled batteries could power an LED continuously for more than 8 hours, while 12% of students, through optimization of material ratios and assembly processes, achieved performance durations exceeding 12 hours. These results demonstrate notable improvements in students’ hands-on abilities and innovation capabilities.

Furthermore, post-course survey results show that 92% of students reported a deeper understanding of core concepts in the course, moving beyond rote memorization. Meanwhile, 89% indicated improved practical skills and the ability to integrate theory with hands-on operation, and 76% developed increased interest in the field, laying a solid foundation for subsequent professional learning. The teaching design approach has also been extended to other abstract engineering courses, such as Fundamentals of Materials Science and New Energy Materials, achieving similarly positive outcomes.

These findings collectively demonstrate that scientifically designed practical teaching, combined with diversified integration models, can effectively address the challenges of abstraction and disengagement in engineering courses. Such approaches significantly enhance educational effectiveness and provide a feasible pathway for advancing engineering education reform and cultivating high-quality engineering talent.

5. Conclusion

Practical teaching, as a critical bridge between theoretical knowledge and industrial application, plays a pivotal role in engineering education. Its deep integration into university engineering programs represents a key pathway for addressing persistent challenges in traditional engineering education, such as the disconnect between theory and practice and the lack of student engagement, thereby enhancing educational quality and supporting the cultivation of high-level engineering talent.

However, several issues remain in the current integration of practical teaching, including insufficient alignment between practice design and instructional content, limited integration models, inadequate faculty capabilities in practical teaching, incomplete evaluation systems, and underdeveloped university–industry collaboration mechanisms. To address these challenges, this study proposes a systematic approach that includes precise practice-oriented instructional design (aligned with course knowledge and employing a hierarchical and theory-linked framework), innovative integration models, strengthened faculty development, improved evaluation systems, and enhanced university–industry collaboration.

The implementation of these strategies enables the deep integration of practical teaching into engineering education, effectively leveraging practice to support learning. It facilitates students' understanding of abstract concepts, enhances practical skills and engineering competencies, and reduces the gap between talent cultivation and industry demands, ultimately promoting high-quality development in engineering education.

The case of the Automotive Power Battery Technology course at the University of Shanghai for Science and Technology demonstrates that targeted practical teaching design can effectively address the challenges of abstract engineering courses and significantly improve teaching outcomes, providing valuable insights for similar curricula.

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