Exploration and Research on Digital Experiment Teaching Model for Electrical Engineering in the Context of Engineering Education Accreditation

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Abstract. In the realm of engineering education accreditation, developing an effective experimental teaching model is crucial for advancing the discipline. This paper examines various experimental teaching models and methods from leading domestic universities and, in conjunction with the current state of electrical engineering experimental teaching at our institution, analyzes the primary causes of existing issues. We propose a research theme focused on exploring and developing a digital experimental teaching model for electrical engineering tailored to engineering education accreditation. By engaging with experimental instructors and conducting surveys and evaluations with students, this study explores three key areas: the research on teaching systems within the context of engineering education accreditation, the construction of digital teaching platforms, and the optimization of experimental teaching content and resources. The goal is to implement an integrated experimental teaching model that encompasses pre-class, in-class, and post-class activities, offering significant research value and potential for broader application.

Keywords: Engineering education accreditation, Experimental teaching model, Electrical engineering experiments, Digital experimental teaching.

1 Introduction

To achieve the goals of engineering professional accreditation and enhance teaching quality, developing effective experimental teaching models is essential. Numerous domestic universities have explored various experimental teaching methods [1-4]. For instance, Wuhan University and Shandong University have researched hierarchical experimental teaching systems within the new engineering context [5]. Shanghai Jiao Tong University and Harbin Engineering University have utilized information technology to develop and promote experimental management platforms. Dalian University of Technology has established a tiered virtual simulation experimental teaching system and introduced a blended online-offline teaching method [6]. Additionally, colleges within our university, such as the School of Mechanical and Electrical Engineering and the School of Information Technology, have explored experimental reservation systems

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and experimental teaching models. However, a universally applicable experimental teaching system and platform remain undeveloped.

In the "Internet+Education" era, enhancing experimental teaching content, innovating course assessment methods, and refining management platforms for electrical engineering courses is crucial for fostering students' autonomous learning, enhancing innovative practice awareness, and advancing high-quality development in schools [7-8].

This paper addresses the current challenges in experimental teaching at our institution by examining three main areas: the teaching system, digital platforms, and supporting educational resources. The study aims to address the shortcomings of the existing experimental teaching model, including an incomplete system, non-standardised experimental management platforms, and insufficient resource support. The goal is to develop a comprehensive digital experimental teaching system within the framework of engineering education accreditation, thereby providing a solid foundation for reforming experimental teaching methods at our institution and other higher education institutions. Specifically, the study focuses on the electrical engineering experimental teaching at our institution. By applying digital and informational methods, the research seeks to overcome the limitations of traditional teaching approaches, which are primarily class-centric and schedule-based. The proposed system is intended to meet professional requirements, manage experimental processes effectively, collect teaching evaluations, and establish a continuous improvement mechanism, thus significantly enhancing the quality of electrical engineering experimental teaching. The digital experimental teaching system is characterised by the following features.

(1) Experimental content is flexibly selected based on the syllabus for different students, allowing even students within the same major to choose different projects according to their needs.

(2) The digital teaching platform improves process monitoring and management efficiency by enhancing full-process management, from "course selection - pre-class reservation - experiment implementation - evaluation feedback," to elevate teaching quality within the context of engineering education accreditation.

(3) The digital experimental teaching model facilitates the timely collection of teaching evaluations from multiple perspectives through functions such as statistical analysis, student feedback, and Q&A systems.

(4) Efficiently collected feedback and evaluations enable continuous improvement and refinement of experimental teaching models and methods, resulting in a rational and effective experimental teaching approach.

2 Current Status and Analysis of Electrical Engineering Experimental Teaching

Our institution offers electrical engineering experiments as a fundamental course, with over 2,500 students enrolling annually across nearly 30 engineering disciplines. In the context of new engineering education, experimental teaching is a key aspect of engineering education accreditation. Our university has explored various teaching methods

[9-10], including virtual experiments, online courses, and management systems. However, traditional and fixed experimental content and experimental teaching models fail to meet the diverse needs of different majors, leading to student fatigue and reduced engagement.

Through seminars and surveys, the primary issues identified in experimental courses include: traditional experimental teaching lacks pre-lab assessments and adequate supervision mechanisms, leading to insufficient student preparation. This inadequacy can result in experimental failures or, in severe cases, damage to equipment and safety hazards. The limited number of experimental hours, with electrical engineering students having 32 hours over two semesters and non-electrical engineering students only 6 hours, results in limited experimental content options. The alignment between non-electrical engineering programs' goals and current curricula is minimal. The misalignment between theoretical and experimental course schedules leads to insufficient preparation and a weak grasp of theoretical fundamentals, making it difficult for students to integrate theory with practice and complete complex, innovative tasks. Instructors spend excessive time explaining and demonstrating experimental content and equipment, which consumes valuable experimental time. There are limited feedback channels for students, which restricts both their learning and the teachers' ability to reflect and improve their teaching methods. Insufficient monitoring of the experimental process and significant plagiarism issues, with assessments of reports alone failing to accurately reflect students' understanding, further compound the problem. Previous experimental teaching employed an "open-loop" approach, lacking feedback mechanisms post-experiment, resulting in task-oriented learning without effective knowledge reinforcement. Common challenges across universities include the excessive volume of experimental reports, which are of little value, consume substantial student time, and contribute to resource wastage due to the accumulation of reports for quality assessment and inspections. The digital experimental teaching system is primarily characterised by the following features.

(1) Inadequate Teaching System: Lack of assessment mechanisms for safety education, insufficient student attention during explanations, and limited feedback channels for updating teaching methods.

(2) Incomplete Platform Functions: Dependence on instructors for process monitoring, time-consuming grading, and inconsistent grading standards.

(3) Limited Resources: Fixed experimental projects, minimal use of virtual experiments, and inadequate pre-experiment simulations.

3 Research on Digital Experimental Teaching in Electrical Engineering

In response to the current issues in electrical engineering experimental teaching, we propose a digital experimental teaching model that transitions the entire process to a digital and informational approach [11-12]. This model aims to create a closed-loop teaching process, as illustrated in Fig. 1.

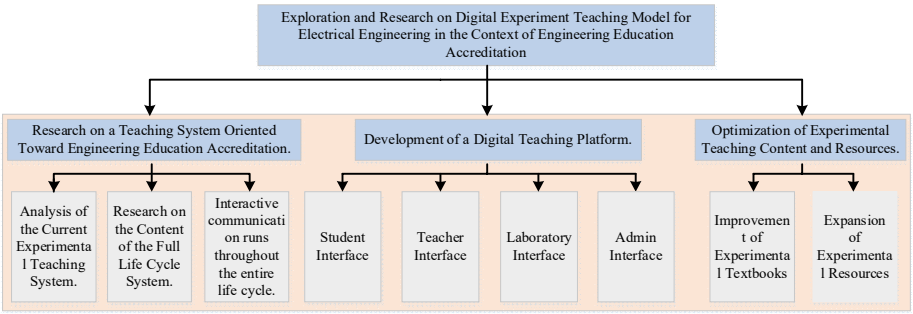

Fig. 1. Research Content of the Digital Experimental Teaching Model for Electrical Engineering in the Context of Engineering Education Accreditation.

3.1 Research on a Blended Online and Offline Teaching System Supported by a Q&A System

Engineering education accreditation requires meticulous control of each teaching phase, encompassing the entire process from initiation to conclusion. The blended online and offline teaching system, supported by a Q&A system, focuses on the entire process from student preparation before the experiment to feedback after its completion, with a student-centered approach. This system consists of four main phases: pre-class preparation, pre-class reservation, the experimental process, and experiment feedback, with a Q&A system integrated throughout these phases. The schematic diagram of the electrical engineering experimental phases is shown in Fig. 2.

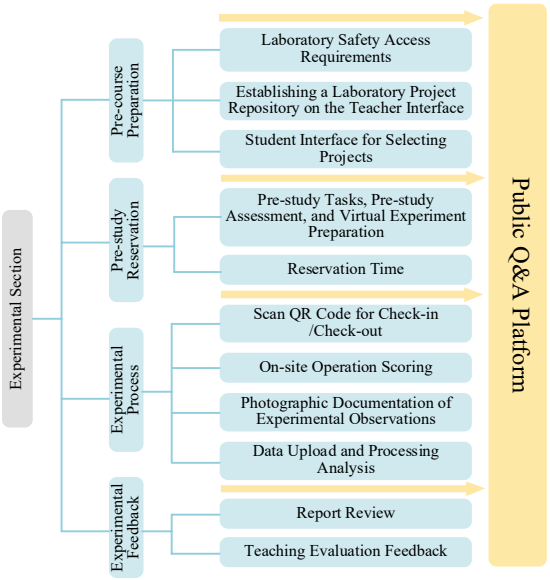

Fig. 2. Schematic Diagram of Electrical Engineering Experimental Phases.

(1) Pre-Class Preparation: Laboratory Safety Access, Establishment of an Experiment Project Database by Instructors, and Student Selection of Projects.

a) Introduction of Safety Education Assessment Mechanism: Safety education includes general safety training and specific experimental project safety training. General safety education covers basic protocols across various laboratory disciplines, forming a multi-disciplinary foundation. Students must complete safety video viewing and assessment before participating in any experiments.

b) Establishment of an Experiment Project Database by Instructors: Instructors modularize experimental knowledge into categories, each containing several knowledge modules. Each module corresponds to one or more experimental contents, with varying weights and levels of complexity. Experiments are categorized into verification, integrative, and self-designed experiments, including both offline and online formats. Students may be randomly assigned different parameters, including confirmatory and falsification groups.

c) Student Course Selection: Students can choose different experimental modules based on their interests to meet operational and virtual experiment requirements for each category. Students exceeding the required points may select some additional experiments for grading, encouraging participation in multiple experiments and achieving an open status within the experimental categories. Some experimental projects may use a flipped classroom model, where students complete the experiment first and then study theoretical concepts, enhancing their understanding. Students from different majors may select cross-disciplinary experiments. After completing required experiments, students may submit documentation for self-innovated experiments online for instructor review, which may result in feedback or approval.

(2) Pre-Class Reservation: Pre-Class Tasks, Pre-Class Assessment, Virtual Experiments, and Reservation Timing.

a) Pre-Class Completion Assessment Mechanism: Pre-class assessments will evaluate task completion, assessment questions, and virtual experiments. Task completion is recorded by the system based on video and PPT engagement, with scoring for page views and duration. Assessment questions focus on experimental content and safety.

b) Reservation Timing: Within the experimental category's open cycle, students reserve experiments based on their availability and check in on time. For students who have submitted and passed innovative experiments, the reservation platform may offer special appointment slots outside regular hours. Experiment instructors prepare equipment in advance based on reservations to maximize laboratory resource utilization. Non-planned students can apply for temporary accounts to complete required assessments and basic operations before reserving available slots for planned experiments.

(3) Experimental Process: Scanning for Machine Start and End, On-Site Scoring, Photographing Experimental Phenomena, Data Upload, and Analysis.

Students enter the laboratory at their reserved time and scan to start the experiment. Basic operational points are assigned, and instructors assess and adjust scores based on performance. Students must photograph and upload experimental connections, measurements, waveform diagrams, and phenomena. These records are available for later review if needed. After completing the experiment, the system saves a complete record of the experimental process upon scanning out.

(4) Experiment Feedback: Report Grading and Teaching Evaluation Feedback.

a) Report Grading System: This system includes automatic and manual grading components. The automatic grading system processes data and provides weighted scores and error statistics. After grading, both the system and the instructor can release grades and feedback.

b) Teaching Evaluation Feedback: Students can provide insights into teaching, content, and processes. They complete evaluations based on a question bank and submit them to platform administrators, promoting reforms in teaching methods and content optimization.

(5) Open Q&A Platform: Considering the varied personalities of students, classroom questions are limited, and online group inquiries, while immediate, are often chaotic and difficult to reference. An open Q&A platform accessible throughout the experimental period addresses these issues, allowing teachers to highlight valuable or frequently asked questions. Students can search for previously answered questions using keywords as needed.

3.2 Construction of the Digital Teaching Platform

Currently, the open platform used in the laboratory provides only pre-class materials, pre-class assessment questions, and reservation systems, lacking process control, assessment mechanisms, and evaluation feedback. To enhance the electrical engineering experimental teaching system under engineering education accreditation, the development of the "Digital Platform for Electrical Engineering Experiments" is crucial. This platform consists of four interfaces: Administrator, Instructor, Student, and Laboratory, as shown in Fig. 3.

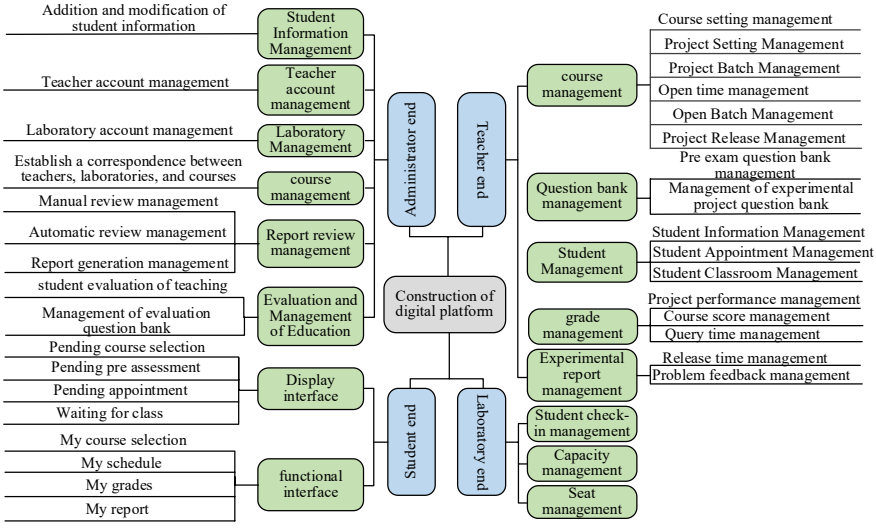

Fig. 3. Content of the Digital Platform Construction.

3.3 Optimization of Experimental Teaching Content and Resources

To meet the requirements of engineering education accreditation, it is essential to enhance teaching resources by improving textbooks, integrating experimental resources, and optimizing experimental setups. The key components include:

(1) Experimental Teaching PPTs: Each experimental knowledge module should have accompanying PPTs that explain experimental principles and operational considerations. These PPTs are uploaded to the digital platform for student access.

(2) Experimental Teaching Videos: These should include general safety education videos, basic operation guides for laboratory instruments, experimental operation videos, and virtual experiment videos. Instrument videos should cover basic usage and troubleshooting, while operation videos should provide safety instructions for each experiment.

(3) Pre-Class Assessment Question Bank and Project Database: A diverse experimental project database should be established, including innovative student experiments. The database should include various parameters and corresponding answer sets for grading purposes.

(4) Experimental Textbooks: Textbooks should break down experimental principles into modules, each corresponding to multiple experimental contents. They should include both hands-on and virtual experiments to expand students' knowledge base.

(5) Laboratory Equipment Resources: This includes a comprehensive list of laboratory equipment and user manuals. Students can refer to these resources for designing and conducting their innovative experiments.

4 Conclusion

In the context of engineering education accreditation, this project leverages existing open experimental platforms to introduce process control mechanisms and evaluation feedback systems, while also enriching and enhancing teaching resources. The approach aims to center on student needs, integrate theory with practice, and develop foundational awareness, capability, and overall quality in experimental teaching. This model emphasizes cultivating practical skills and fostering innovative thinking, striving to create an experimental teaching system conducive to developing students' practical abilities and creativity.

The study will target all first- and second-year students from the School of Automation and the School of Information Technology, as well as some non-electrical majors. After practical validation, the experimental teaching system and platform will be expanded to other departmental laboratories and eventually to other engineering institutions. The successful implementation of this experimental teaching model is expected to benefit all faculty and students, contributing significantly to the advancement of our experimental teaching framework.

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