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Exploration into the Reform of Electrical and Electronic Technology Experimental Teaching under the Digital Background

Yang Liu*

School of Electrical Engineering, Dalian Jiaotong University, Dalian, China
* **Corresponding author:** Yang Liu

Abstract: With the rapid advancement of information technology, digital teaching has become a key direction in modern educational reform. As a vital component of engineering disciplines, experimental teaching of Electrical and Electronic Technology plays a significant role in cultivating students' hands-on competence, practical capabilities, and innovative potential. To address the existing challenges in current experimental teaching, this paper explores a digital-driven teaching reform framework, aiming to enhance teaching quality and students' overall proficiency. By integrating digital tools such as virtual simulation technology, experimental data analysis platforms, and online learning resources, the traditional experimental teaching model is innovated, and a blended teaching environment that combines online and offline modalities is established, thereby achieving the innovation and optimization of experimental teaching of Electrical and Electronic Technology.

Keywords: Digital Teaching, Electrical and Electronic Technology Experiment, Blended Teaching.

1. Introduction

Electrical and Electronic Technology courses serve as crucial foundational subjects for engineering majors. Particularly, the experimental component not only requires students to master basic experimental skills but also aims to cultivate their competence in solving practical problems. However, constrained by the limitations of traditional teaching models and experimental facilities, current experimental teaching of Electrical and Electronic Technology is confronted with a series of challenges, such as outdated experimental content, singular teaching methods, and insufficient student interest in learning [1]. Therefore, exploring the innovation of experimental teaching through digital approaches holds significant practical significance and broad development prospects.

2. Current Status of Experimental Teaching

Traditional experimental teaching in Electrical and Electronic Technology primarily relies on physical experiments, with teaching content depending heavily on laboratory equipment and instruments. While this approach helps students grasp basic theoretical knowledge and operational skills, it is plagued by the following issues.

2.1. Problems with Experimental Teaching Content and Form

Traditional experimental content is dominated by basic and confirmatory experiments, lacking design-oriented, comprehensive, and innovative experiments. Students mechanically verify experimental results by following instructions in laboratory manuals [2]. To a certain extent, this teaching model neglects students' dominant role and the cultivation of their innovative capabilities. Furthermore, due to outdated experimental equipment and long-unupdated experimental projects, such an experimental environment fails to provide abundant resources, lacks cutting-edge relevance and contemporary value, and is unfavorable for nurturing innovative talents.

2.2. Problems with Experimental Processes and Teaching Method

(1)Mechanized experimental processes: Most experimental sessions adopt a teaching model of "principle explanation-demonstration-operation." Teachers lecture on experimental principles and conduct on-site demonstrations, while students merely need to memorize the experimental circuits and wiring procedures demonstrated by teachers to complete the experiments [3]. The single teaching method restricts students' exposure to advanced knowledge and related demonstrations, hindering the development of their abilities to proactively analyze and solve problems.

(2)Insufficient sets of experimental equipment: Most experiments that require independent completion by students can only be conducted in groups. This leads to passive participation among some students, who rely on others to fulfill tasks and fail to meet teachers' requirements. Effective classroom management and learning behavior supervision are also difficult to implement, preventing students from improving their own experimental capabilities [4]. Additionally, the aging of some experimental testing instruments and the difficulty in debugging have completely dampened students' interest in this experimental course, further limiting the cultivation of their innovative thinking and application development abilities.

2.3. Problems with Evaluation and Feedback

In traditional experiments, teachers usually spend a great deal of time grading experimental reports and evaluating students' results. Due to the long duration of experiments and the large number of students, it is challenging for teachers to provide timely and detailed feedback to each student. Consequently, some students cannot identify and correct their mistakes promptly.

2.4. Potential Safety Hazards

Motor control experiments involve high-voltage electricity, posing a risk of electric shock. For students encountering motor control experiments for the first time, the lack of relevant experience and familiarity with experimental equipment may lead to safety accidents due to improper operations. Restricted by students' course selection schedules and laboratory opening hours, traditional experimental teaching fails to enable students to understand the principles behind each step before hands-on operation, reducing the likelihood of blind and incorrect operations.

2.5. Problems with Laboratory Maintenance Costs

Students often enter the laboratory without effective pre-class preparation and insufficient understanding of experimental circuit principles and content. This results in frequent operational errors when dealing with complex experimental circuit wiring, such as frequent plugging and unplugging of connectors and short circuits caused by incorrect operations. These issues not only reduce experimental efficiency but also lead to chip damage and frequent equipment failures, thereby increasing the consumption of experimental materials and equipment maintenance costs and affecting the smooth conduct of subsequent experimental teaching.

3. Main Content of the Reform

3.1. Construction of a Digital Intelligent Experimental Platform

A digital intelligent experimental platform is an experimental teaching platform integrated with modern information technology, as illustrated in Figure 1. It aims to enhance the effectiveness of experimental teaching through virtual instruments, software simulation, and other means. The application of this platform can bring about the following transformations:

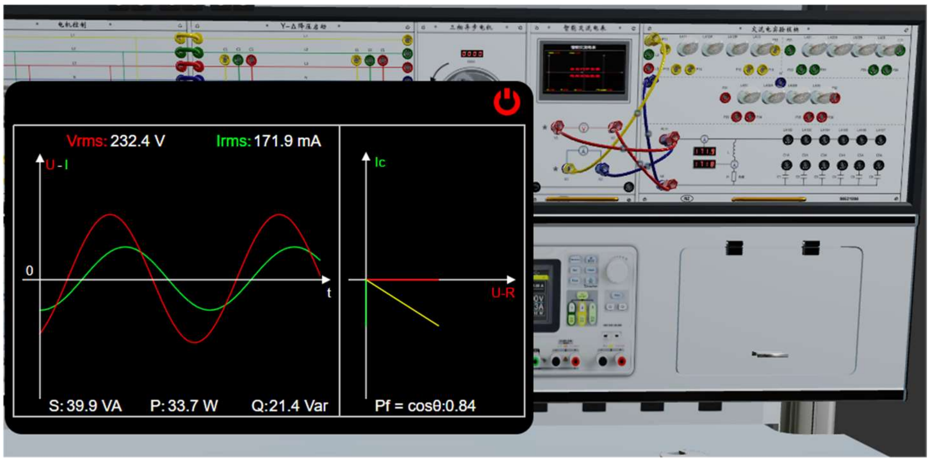

Fig. 1 Digital intelligent experimental platform

(1) Enriching experimental types and strengthening the cultivation of innovative capabilities: Digital virtual experiments can provide diversified experimental projects, including design-oriented and comprehensive innovative experiments. Unrestricted by physical equipment, these experiments can be updated and expanded at any time, offering students more abundant experimental resources and stimulating their innovative thinking. For example, the traditional "RC circuit verification experiment" can be upgraded to "custom filter circuit design and performance optimization," where students need to achieve specified amplitude-frequency characteristics through simulation and debugging.

(2) Breaking the mechanized teaching model and realizing flipped classroom pre-learning: Students complete the construction and simulation of basic circuits on the virtual experimental platform before class. During class, the focus shifts to discussions on complex issues (e.g., "Why is there a discrepancy between theoretical calculations and simulation results?"). Teachers transition from "demonstrators" to "guides." The virtual experimental platform supports multiple experimental forms, such as online simulation and remote operation, enabling students to participate more actively in the experimental process—transforming "mechanical verification" into "exploratory learning" and fostering their ability to proactively analyze and solve problems.

(3) Overcoming equipment limitations with one-to-one virtual environments: Each student can independently use virtual instruments (e.g., oscilloscopes, function generators), avoiding the "free-rider" phenomenon in group experiments.

(4) Avoiding equipment aging issues with no physical wear of virtual components: Students can repeatedly attempt complex wiring and debugging (e.g., cascading of multi-stage amplifier circuits) without worrying about equipment damage. This reduces psychological pressure and enhances their enthusiasm for trial-and-error.

(5) Automation of process-oriented evaluation: The digital experimental platform can real-time record and store key information such as students' experimental processes, start/end times of experiments, and types/frequencies of major errors. Teachers can review the recorded data online to identify students' mistakes and provide targeted guidance, eliminating the one-sidedness of traditional evaluation that relies solely on experimental reports. Additionally, the platform's automated testing system can quickly analyze and evaluate students' experimental results, allowing teachers to gain a more accurate understanding of each student's learning status and provide personalized guidance and suggestions.

(6) Operation preview mechanism: Students can first simulate the wiring process on the virtual platform to gain sufficient practice and understanding. Only after the system verifies the correctness of the simulation do they proceed to physical operations. This reduces the probability of accidents caused by blind operations.

(7) Reducing laboratory maintenance costs: Virtual wiring replaces physical operations, and wiring practice for complex circuits can be completed on the virtual platform—significantly reducing plug-and-pull wear of physical equipment and extending the service life of instruments. Fault simulation incurs zero cost: the virtual system can artificially set various faults (e.g., component cold soldering, power supply short circuits), enabling students to learn fault diagnosis methods without damaging real equipment. Teachers can easily update experimental content (e.g., changing the traditional "discrete component amplifier circuit" to "integrated operational amplifier application experiment") by modifying virtual component parameters or replacing experimental modules via software. This realizes rapid iteration of experimental projects without purchasing new equipment. Furthermore, virtual experiments eliminate the need for physical consumables such as wires, resistors, capacitors, and chips-reducing consumable costs to zero and significantly lowering long-term laboratory expenses.

3.2. Reforming Experimental Teaching Content

In the reform of digital experimental teaching, experimental teaching content and methods should be optimized to meet the needs of talent cultivation in the new era. Centering on the teaching objectives of "solid foundation, strong competence, emphasis on practice, and promotion of innovation," the experimental teaching content should be systematically restructured and optimized to shift from "single verification" to "comprehensive application" and "innovative design."

(1) Constructing a multi-level and modular experimental teaching system: Retain some classic basic experiments (e.g., verification of Kirchhoff's laws, construction of basic amplifier circuits). Set up comprehensive experimental projects that integrate multiple knowledge points and skill requirements, such as "design of integrated operational amplifier application systems" and "construction of motor control systems." Strengthen students' overall grasp of the knowledge system and practical application capabilities. Encourage students to use virtual simulation to conduct exploratory and open design experiments based on mastering basic principles, thereby cultivating their abilities in independent thinking, scheme design, and problem-solving.

(2) Integrating engineering practice elements to enhance students' engineering literacy: Experimental teaching content should be closely aligned with industrial development needs and engineering practices to enhance students' engineering awareness and practical capabilities. In traditional experimental teaching of Electrical and Electronic Technology, experimental projects often focus on basic theoretical verification and lack close integration with practical engineering applications. To improve students' engineering literacy and practical abilities, a series of experimental projects closely related to engineering practice can be added in the virtual environment. These projects can cover circuit design, system integration, fault diagnosis, and other aspects. Without increasing the hardware investment in laboratories, students can experience the entire process of engineering projects through practical operations, thereby deepening their understanding and application of theoretical knowledge.

(3) Using digital means to enrich experimental forms and content update mechanisms: The digital experimental platform provides strong support for the diversified presentation and dynamic update of experimental teaching content. Based on technological development and teaching feedback, teachers can flexibly adjust experimental parameters, replace experimental modules, or add new experimental projects without purchasing new equipment-greatly improving the efficiency of curriculum updates.

3.3. Optimizing Experimental Teaching Methods

(1) Pre-class: Independent learning and task-driven approach

In traditional curriculum teaching, due to the lack of teacher guidance, students face problems such as low subjective initiative and unclear preview goals during independent learning. This leads to perfunctory pre-class preparation, making it difficult to form a basic understanding of experimental content and affecting in-class efficiency. With the digital experimental platform, teachers issue preview task lists that specify experimental objectives, key steps, and thinking questions. Students are required to complete pre-class tasks such as virtual circuit construction, experimental parameter adjustment, and virtual instrument testing to familiarize themselves with experimental steps and expected results. Meanwhile, the platform provides automatic scoring, problem feedback, and recording mechanisms to enhance the effectiveness of pre-class preparation.

(2) In-class: Interactive exploration and competence improvement

The traditional teaching model is mechanized, with students passively receiving knowledge and lacking in-depth thinking. By adopting flipped classrooms, group collaboration, and problem-oriented approaches, students' enthusiasm for hands-on practice and thinking exploration is stimulated—realizing the transformation from "verification-based learning" to "inquiry-based learning." Instead of repeatedly explaining basic knowledge, teachers focus on discussing common problems encountered by students during pre-class preparation, guiding them to analyze error sources and the rationality of circuit design, and cultivating their critical thinking. Students are divided into groups, with each group independently completing tasks such as circuit construction, debugging, and data collection. Role assignments (e.g., main wiring operator, recorder, presenter) are set to ensure the participation of every student. Teachers use the digital platform to real-time monitor students' experimental progress and errors, providing timely guidance when necessary. They also pay attention to individual differences and offer targeted support to students at different levels.

(3) Post-class: Strengthening consolidation and expansion to promote reflection and innovation

In traditional experimental teaching, students consider their tasks completed once they submit experimental reports-lacking in-depth reflection on the experimental process and further exploration. To address this, open and comprehensive innovative topics are extended from the experimental content, such as "How to use this circuit to realize another function?" and "How will performance change if a certain component is replaced?" Students are encouraged to independently design experiments and use the digital experimental platform for simulation verification. Additionally, based on the experimental process data and report content recorded by the platform, teachers provide detailed comments and individual feedback, pointing out students' strengths and weaknesses.

3.4. Improving the Evaluation System

The traditional experimental teaching evaluation method mainly relies on paper-based experimental reports and teachers' subjective judgments, which has problems such as delayed feedback, one-sided evaluation, and difficulty in quantification. Against the background of digital experimental teaching reform, a new experimental teaching evaluation system should be constructed—with data-driven evaluation as the core, combining process-oriented and result-oriented evaluation, and supported by multiple evaluation subjects. This system can not only accurately reflect students' learning outcomes but also provide teaching feedback for teachers to promote the continuous optimization of teaching strategies.

(1) Establishing a full-process and multi-dimensional evaluation mechanism

The digital experimental platform can real-time record key data such as students' operational behaviors, experimental processes, error types, and modification frequencies—providing a foundation for full-process evaluation. The new evaluation system should cover the following dimensions: experimental operation ability, problem analysis and solving ability, experimental result and data analysis ability and innovative design and expansion ability.

(2) Combining process-oriented evaluation and summative evaluation

Process-oriented evaluation focuses on evaluating students' experimental learning process, including pre-class preparation, in-class participation, performance during experimental operations, and problem-solving abilities. Based on the full-process information tracked and recorded by the digital experimental platform, automatic evaluation is conducted on the integrity of the experimental process, students' autonomy in experiments, and the accuracy of data-providing references for teachers to comprehensively assess experimental scores.

Summative evaluation is conducted at the end of the experimental course to comprehensively evaluate students' experimental learning outcomes through methods such as experimental operation assessments, experimental report reviews, and project defenses. Summative evaluation should comprehensively consider multiple aspects, including students' experimental operation ability, experimental report writing ability, innovative thinking, and teamwork ability.

(3) Application of evaluation results and teaching improvement

The digital experimental platform can promptly feed back evaluation results to both students and teachers. For students, this helps them understand their learning status and clarify directions for improvement. For teachers, it provides teaching feedback to support the adjustment of teaching strategies and methods-including updating experimental teaching content, improving experimental teaching methods, and optimizing the functions of the digital experimental platform. This ensures that the experimental teaching system can adapt to the needs of talent cultivation in the new era.

4. Conclusion

The digital-based reform of Electrical and Electronic Technology experimental teaching serves as a crucial approach to enhancing the quality of experimental teaching and fostering students' innovative capabilities. By implementing measures such as constructing digital experimental platforms, optimizing experimental teaching content and methods, and improving evaluation systems, the problems existing in traditional experimental teaching can be effectively addressed, thereby promoting the comprehensive upgrading of experimental teaching.

In the future, with the continuous advancement of digital technology, the reform of Electrical and Electronic Technology experimental teaching will exhibit a more diversified and intelligent trend. Universities should keep pace with the times, continuously innovate experimental teaching concepts and methods, and provide strong support for cultivating high-quality talents in the field of Electrical and Electronic Technology.

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