Research on the "Virtual Reality Integration" Hybrid Practical Teaching Mode of the Electronic Circuit Courses Group Based on CDIO

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Abstract. The electronic circuit courses group is fundamental courses for electronic engineering major, as well as communication engineering, automatic control, and other electrical majors. It plays a connecting role in the curriculum system of electrical majors. The current electronic circuit courses group mostly adopts traditional hardware practical teaching or virtual simulation practical teaching mode, without organically combining the two methods, which cannot meet the requirements of new engineering teaching construction. In view of the common problems existing in the teaching methods, based on the concept of CDIO, a new hybrid mode of "virtual and real integration" for the electronic circuit courses group is proposed in this paper, which is student-centered and outcome-based, so as to improve students' ability to solve complex engineering problems and cultivate students' engineering innovation consciousness.

Keywords: Electronic Circuit Courses Group, Virtual Reality Integration, Practice Teaching mode, CDIO.

1 Introduction

The electronic circuit courses group of the electronic engineering major mainly includes courses such as "fundamentals of circuit analysis", "analog electronic circuits", and "digital logic circuits". Through the study of these core courses, students can master the basic theoretical knowledge of circuits and electronic technology, basic circuit analysis and design methods and experimental skills, as well as the ability to engage in scientific research and comprehensive development and design work in the relevant field of information engineering. At the same time, it can lay a foundation for the study of subsequent courses such as "signals and systems", "communication principles", "high-frequency electronic circuits", "automatic control principles", and "integrated circuit design". In the context of the construction of new engineering disciplines, as a related major in the high-tech industry, the construction of engineering practice teaching mode reforms for the backbone courses group of electronic engineering major has become particularly urgent and important.

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The “CDIO” stands for Concept, Design, Implement, and Operate. It takes the product development to product operation life cycle as the carrier, allowing students to learn engineering actively, practically, and organically connected between courses.

[1][2]. The “virtual real integration” hybrid practical teaching mode is an emerging teaching mode that combines portable experimental hardware equipment with virtual instrument software.It can organically combine traditional hardware practice and virtual simulation practical teaching manner, and break through the limitations of time and space to carry out practice. A lot of universities around the world, especially in majors such as electronics, communication, and automatic control, are exploring this new mode of practical teaching. Many companies have also noticed the increasing popularity of “virtual real fusion portable laboratories” in universities and actively launched related product suites, such as NI's MyDAQ, Thunder Experiment platform“A+D Lab”, Hardwood Classroom“E-Lab”experimental platform[3][4][5], etc.

A relatively complete CDIO oriented practical teaching mode is extracted based on the actual teaching work of the electronic circuit courses group of electronic engineering major. The "virtual real integration" hybrid practical teaching software and hardware platform is also constructed, breaking the boundaries of courses within the course group and creating a miniature and portable electronic circuit laboratory for students. This not only meets the practical teaching needs of the electronic circuit courses group, but also serves as an independent innovation practice platform for flipped classrooms, comprehensive course design, graduation design, innovative practice, subject competitions, etc.

2 Existing Problems in the Practical Teaching of Electronic Circuit Courses Group

The current electronic circuit course group mostly adopts traditional hardware practical teaching and virtual simulation practical teaching mode separately, which faces some common problems as follows:

①**Traditional hardware practical teaching mainly focuses on verification, lacking case-based, design based experiments, and fixed experimental circuit boards or modules.** The fixed experimental process mainly focuses on verifying laws and theorems, lacking practical circuit design and application abilities such as designing and building circuits, selecting and arranging devices, analyzing module circuit functions, and determining parameter applicability. The experimental content is relatively simple and lacks comprehensiveness, which restricts students' divergent thinking and makes it difficult to stimulate their interest in independent research. It is also difficult to cultivate students' ability to solve complex engineering problems and innovative consciousness.

②**Virtual simulation practical teaching can lead to a lack of intuitive understanding of actual electronic circuits.** Although excellent simulation software such as Multisim and Pspice have been introduced, which do not consume devices and can adjust parameters at any time, it may lead to insufficient intuitive understanding of actual devices for students, which cannot exercise their actual hardware circuit connection and debugging abilities. Moreover, software simulation experiments are conducted under ideal conditions and cannot fully reflect actual measurement errors, actual system failures, and abnormal operating conditions, resulting in students lacking the ability to troubleshoot and correct practical problems.

③**There are still limitations in time and space in current practical teaching.** Large and single function experimental boxes and a large number of electronic measuring equipment are not allowed to be taken out of the laboratory. The limited opening time of the laboratory restricts the location and time for students to carry out practical activities. Sudden experimental ideas cannot be implemented and verified on the experimental equipment in a timely manner. The end of the experimental class will also force students to terminate their experimental plans.

④**The practical teaching of the main courses in the electronic circuit course group is separated from each other.** The use of different experimental box products has invisibly severed the knowledge links between the main courses, and the related practical teaching links lack orderly connection and effective integration, making it difficult for students to establish a complete knowledge system for the electronic circuit course group.

⑤**The evaluation system for practical teaching in courses is not perfect enough.** The composition of course grades lacks formative evaluation and personalized design evaluation, and most of them do not have independent and detailed grading standards. The final experimental report submitted by students is the main grading basis, which lacks comprehensive and reasonable evaluation of students' practical process, as well as incentive guidance and evaluation measures for students' personalized design.

3 "Virtual Reality Integration" Hybrid Practical Teaching mode of the Electronic Circuit Courses Group Based on CDIO

3.1 Teaching Process Based on CDIO

A teaching mode based on four practical stages of conceptualization, design, implementation, and operation has been constructed[6][7]. A comprehensive and diversified assessment system has been established to evaluate the practical process and student learning outcomes. The evaluation results can provide a basis for continuous improvement and form a closed loop. Based on this, a mixed practice teaching mode combining virtual and reality, theory and practice, and simulation and practical operation has been studied, which to some extent solves the limitations of practical teaching in terms of time and space. The specific implementation plan is shown in Figure 1:

① **"Concept" stage:** In this stage, teachers use projects as a carrier to reconstruct the knowledge system of the electronic circuit course group. Through projects, they set up "simulated scenarios" to carry out practical teaching. The published projects provide indicator requirements for different difficulty levels, guiding students to establish a knowledge system of the course group that connects analog circuits and digital circuits in the process of completing tasks.Students form teams for discussion, conduct topic analysis, conduct data retrieval, and ultimately select a circuit design scheme. In the process of conceptualization, students learn independently and cultivate their ability to apply basic knowledge.

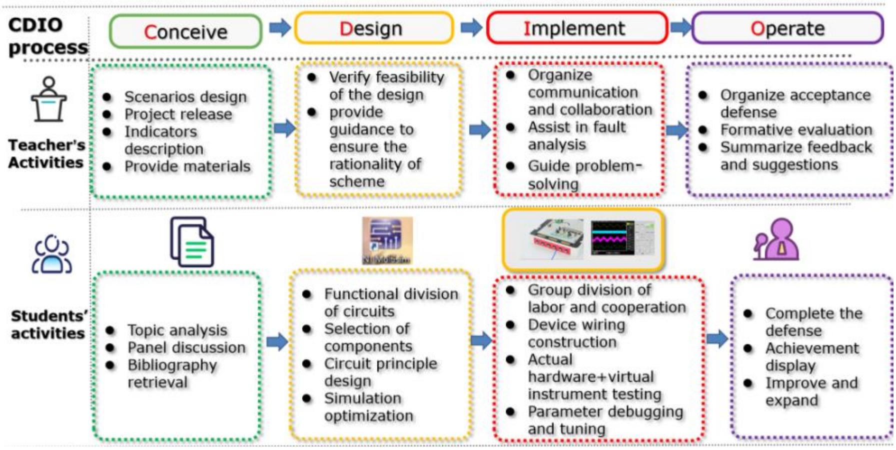

Fig. 1. CDIO Practical teaching process

② **“Design” stage:** In this stage, students divide the circuit functions based on the topic and indicators, corresponding to the relevant knowledge points in the course, select the required components, design the circuit, and optimize the design through simulation software such as Multisim. Teachers assist in verifying the feasibility of the design plan and provide individual guidance to ensure the rationality of the plan. In the design process, students independently design and cultivate their innovative consciousness and comprehensive design ability.

③ **“Implement” stage:** In this stage, student teams divide their work and collaborate to layout and connect physical components, independently build the entire experimental circuit, apply actual hardware combined with virtual instrument practice platform for circuit testing, and adjust parameters according to the circuit status. Teachers organize student communication and collaboration, assist students in fault analysis, and guide students to find solutions to problems. In the implementation process, students' ability to solve complex engineering problems and teamwork skills is cultivated.

④**“Operate” stage:** In this stage, students will showcase the results of their collaborative projects, conduct a defense and acceptance, make improvements or further expand their functions based on teacher feedback, and submit experimental reports. Teachers conduct testing and acceptance of students' achievements, comment on the defense situation, and summarize feedback suggestions. They provide formative evaluations of the entire process of students' project conception, scheme design, specific implementation, teamwork, report writing, and final project operation.

3.2 Software and Hardware Platform for Practical Teaching of "Virtual Real Integration"

The software and hardware platform requires integrated circuit design, data acquisition, data processing, and virtual instrument technology to achieve a "virtual real integration" hybrid practical teaching mode that combines actual hardware experiments, software simulation, and virtual instruments. Simply install the virtual instrument software and simulation software which are compatible with the device on a personal PC to create a portable electronic circuit courses group laboratory for students. The e-Lab product EPI-EWB204+/302 of "Hardwood Classroom" has been selected to build a "virtual real Integration" hybrid practical teaching software and hardware platform for the electronic circuit courses group, as shown in Figure 2:

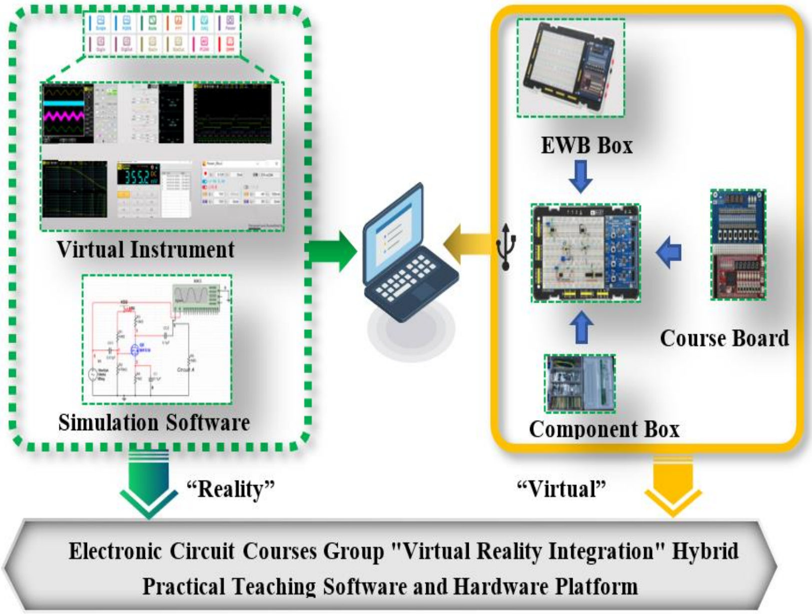

Fig. 2. "Virtual Real Integration" hybrid practical teaching software and hardware platform

The virtual instrument software supporting the experimental platform includes commonly used electronic measuring instruments such as digital multimeters, oscilloscopes, signal sources, spectrometers, amplitude frequency characteristic testers, logic analyzers, pulse signal generators, etc. The miniaturized and modular electronic circuit course group "virtual real integration" hybrid practical teaching software and hardware platform highlights portability and configurability, greatly breaking through the time and space limitations of traditional laboratories. The platform modules can be configured according to different course experimental requirements to cover the practical teaching needs of the vast majority of electronic circuit courses group.

3.3 Optimization of Assessment for CDIO Practical Teaching Mode

In the CDIO teaching mode, even if the same project is chosen, each student's experimental plan and steps may be different, and there may be personalized differences in design ideas and extended functions. Therefore, the assessment and evaluation of students cannot simply copy traditional experimental teaching mode, and only focus on the consistency between experimental results and standard answers. Assessment and evaluation observation points are set from the four CDIO practice stages of Concept, Design, Implementation, and Operation, as shown in Table 1:

Table 1. CDIO oriented practical teaching assessment and evaluation.

CDIO process	Assessment and evaluation observation points
Concept	Is the task topic analysis appropriate? Is the selection of experimental plan reasonable?
Design	Whether the circuit function division and component selection are appropriate? Is the circuit principle design reasonable? Does simulation optimize design? Does the design have innovation and expanded function?
Implementation	Is the layout and wiring of electronic components reasonable? Can this student identify faults, analyze and troubleshoot them? Can this student observe the circuit status and debug parameters? Can this student communicate and cooperate with team partners?
Operation	Whether the acceptance results meet the requirements of the indicators? Can this student accurately answer the defense questions? Participation rate in group work. Is the report written with standardized graphics and text?

4 Conclusion

The modular and layered "virtual real integration" hybrid practical teaching software and hardware platform provides students with a portable and micro virtual laboratory environment that can be independently designed. Students can not only build and debug actual electronic circuit hardware, but also integrate multiple virtual instruments to test and analyze circuits using the platform, breaking through the limitations of traditional electronic circuit experimental teaching with fixed time, location, and content. The practical platform connects analog circuits and digital circuits, weakens the boundaries within the electronic circuit courses group, and enables students to integrate and form a global view of electronic circuit systems through practice.

The new CDIO oriented practical teaching mode is student-centered and outcome-based. The implementation plan for the CDIO practical teaching process is designed in reverse, including the design of practical projects, optimization of teaching organizational forms and assessment methods under the new mode. A semi-open projects library is designed, and a diversified assessment system is established for the entire CDIO engineering practice process to cultivate students' ability to apply basic knowledge, innovative consciousness, comprehensive design ability, ability to solve complex engineering problems, and teamwork ability.

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