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Exploration on the Teaching of the "Analog and Digital Circuits" Course in the Context of Emerging Engineering Education

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Abstract

In this paper, to address the problem that the traditional assessment of the "Analog and Digital Circuits" course emphasizes results over process, this paper conducts teaching exploration of the course from three key dimensions—curriculum content integration, experimental project optimization, and curriculum assessment reform—while aligning with the core goal of Emerging Engineering Education, which is competence-oriented and focused on cultivating interdisciplinary engineering talents. By detailing the reform approaches, this paper aims to effectively enhance students' in-depth understanding of circuit principles and practical application capabilities within limited class hours, thereby laying a solid foundation for their subsequent professional courses.

Keywords

Emerging Engineering Education; Analog and Digital Circuits; Experiments.

1. Introduction

Against the core goal of emerging engineering education, which focuses on "being future-oriented, serving industries, and cultivating interdisciplinary engineering talents", Analog and Digital Circuits serves as a compulsory course for engineering majors such as Internet of Things, Intelligent Science and Technology, and Computer Science and Technology. The quality of its teaching directly influences the cultivation of students' engineering thinking, practical abilities, and innovative awareness [1, 2]. In traditional teaching of analog and digital circuits, there are problems such as "emphasizing results over processes" and "emphasizing experimental quantity over understanding depth", which are different from the concept of "student-centered and ability oriented" in emerging engineering education. This article focuses on the three core directions of "course content integration", "experimental project optimization", and "course assessment reform", and elaborates in detail on the reform path of analog and digital circuit teaching under the background of emerging engineering education. The aim is to explore whether it is possible to improve students' understanding and practical application ability of circuit principles within a limited number of class hours through precise adjustment of teaching strategies, and to build a solid bridge for the learning needs of subsequent professional courses.

2. Curse Overview

The course of Analog and Digital Circuits is a compulsory course for students majoring in Internet of Things, Intelligence, Artificial Intelligence, and Computer Science at the School of Information Technology and Engineering of Guangzhou College of Commerce. It is a fusion of two courses, Analog and Digital Circuits, but is only offered for one semester. The total number of class hours for the Internet of Things major at the School of Information and Technology is 64, including 48 class hours for theory and 16 class hours for experiments, and 48 class hours

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for the Computer Science and Technology major, including 32 class hours for theory and 16 class hours for experiments. The course involves a huge amount of content, and students need to complete the course learning in a relatively short period of time, which is a challenge for both teachers and students. During the teaching process, the following problems were found: 1. The knowledge points are scattered and wide-ranging, and many of the contents are not strongly related before and after, which makes it easy for students to forget during the learning process; 2. Most students in the major do not have a foundation in circuit analysis [3], and there is a knowledge gap when learning analog electronics, which significantly increases the difficulty of the course and results in poor learning outcomes for students. 3. There are a large number of experimental projects, and some students cannot keep up with the pace, resulting in a lack of understanding of the experimental principles. They only follow the experimental steps to connect the circuit and measure the data.

3. Prpblems and Content Integration of Course

3.1. Problems in the Course

Analog Circuits [4] studies continuously varying electrical signals, with core knowledge points including basic knowledge of semiconductors, amplifier circuits, feedback in amplifier circuits, integrated operational amplifiers (op-amps), sinusoidal oscillation circuits, and DC regulated power supplies. Digital Circuits [5], by contrast, focuses on discrete digital signals, covering core concepts such as Boolean algebra, gate circuits, combinational logic circuits, flip-flops, and sequential logic circuits. The two courses differ significantly in their ways of thinking and analytical methods. After integration, students who have just mastered the amplification principle of transistors must immediately switch to understanding the logical relationship of Logic gates, which creates great difficulty in thinking transition and easily leads to knowledge forgetting.

"Circuit Analysis" serves as the prerequisite course for Analog and Digital Circuits, encompassing core knowledge such as Kirchhoff's laws, Ohm's law, the concept of impedance, and transient analysis of RC circuits. However, in the training programs of emerging engineering majors—such as Computer Science and Technology, Internet of Things, and Intelligent Science and Technology—programming and algorithms are prioritized as core courses, resulting in the omission of "Circuit Analysis". Even for Artificial Intelligence majors where "Circuit Analysis" is retained, it is scheduled in the same semester as "Analog and Digital Circuits", leading to a knowledge gap when students learn Analog Circuits. Specific manifestations are as follows:

Inability to understand quiescent operating point calculation: The calculation of the quiescent operating point (Q-point) in Analog Circuits requires applying Kirchhoff's Voltage Law (KVL). Since students have not learned KVL, they cannot comprehend the derivation process and can only rely on rote memorization of formulas. When parameters change, they are unable to perform independent calculations.

Difficulty in analyzing AC amplifier circuits: The analysis of AC amplifier circuits involves equating transistors to linear models, including calculations of input resistance, output resistance, and voltage gain. All these require a foundation in the equivalent circuit method from "Circuit Analysis". Due to the lack of this foundation, students cannot understand why it is necessary to calculate the impact of input and output resistance on the load.

Inability to troubleshoot circuit faults: When encountering problems such as no waveform output or abnormal voltage measurements in experiments, students cannot use Kirchhoff's laws to identify faults. They have to rely entirely on teachers' guidance and are unable to solve problems independently.

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3.2. Curriculum Content Integration

To address the issue of large knowledge gaps, teachers restructure the integrated curriculum content. The core approach is to strengthen core knowledge points and add knowledge connection links. For example, after explaining the linear applications of operational amplifiers (op-amps), teachers briefly introduce voltage comparators, helping students understand how op-amps convert analog signals into digital signals (high/low levels) when operating in the non-linear region.This ensures the logical coherence of knowledge between analog and digital circuits.

To tackle students' weak foundation in Circuit Analysis, solutions are designed from three dimensions: pre-class supplementation, in-class adaptation, and post-class reinforcement. This ensures students make up for foundational gaps and keep up with the course progress.

Pre-class stage: Teachers remind students to preview on Xuexitong (a domestic educational platform) and upload video materials to the corresponding chapters. The content focuses on essential foundational knowledge required for learning Analog Circuits, such as Kirchhoff's Voltage Law (KVL), Kirchhoff's Current Law (KCL), Ohm's Law and resistive circuit analysis, and the equivalent circuit method. Students are required to watch these videos before learning the corresponding Analog Circuits knowledge points to lay a foundation for analyzing amplifier circuits. Meanwhile, teachers assign test questions on Xuexitong to check students' learning outcomes, ensuring students enter the classroom with foundational knowledge.

In-class stage: For core foundational content—such as the calculation of quiescent operating points (Q-points) in Analog Circuits and the simplification of Boolean algebra in Digital Circuits—teachers adopt a unified teaching approach of "slow pace and multiple examples" to ensure all students understand. For instance, when explaining Q-point calculation, teachers first explain KVL using simple series circuits, then derive loop voltage equations, helping students with weak foundations keep up.

Post-class stage: Teachers assign homework on Xuexitong for consolidated practice. They grade the homework, check each student's knowledge mastery one by one, and provide focused explanations in the next class for common foundational issues students encounter in their homework. If students face problems while completing homework, they can also watch videos on relevant knowledge points on Xuexitong or seek online answers from teachers.

4. Current Status of Experiments and Optimization of Experimental Projects

In the experimental teaching of Analog and Digital Circuits, the course was initially designed with 8 experimental projects. These projects cover the use of electronic instruments and meters, common-emitter amplifier circuit, emitter follower, sinusoidal oscillator, integrated operational amplifier, verification of gate circuit logic functions, combinational logic circuit design, and counter design . However, in actual teaching, it was found that the total experimental class hours are only 16, with each experiment allocated merely 2 class hours. To complete their lab reports, students often rush through the procedures and record data, resulting in their understanding of experimental principles remaining superficial. This makes it difficult to integrate theory with practice. Among these experiments, the teaching contradictions in the common-emitter amplifier circuit experiment are the most prominent, thus becoming the breakthrough point for optimizing experimental projects.

4.1. Current Status of Experiments—Taking "Common-Emitter Amplifier Circuit" as an Example

The common-emitter amplifier circuit is a core content of Analog Circuits experiments, covering key knowledge points such as adjustment of the transistor's quiescent operating point

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(Q-point), measurement of voltage gain, and analysis of waveform distortion. However, in the initial arrangement of 2 class hours, the teaching process is severely compressed, with specific issues manifested in three aspects:

Tight operation time: Within 2 class hours (80 minutes), students need to complete circuit wiring, adjustment of the quiescent operating point, connection of the oscilloscope and signal generator, calculation of voltage gain, waveform observation, and data recording. They have almost no time for thinking and can only perform mechanical operations according to the steps in the experimental guide. There are even cases where they power on the circuit without checking the wiring, or forget to power off when measuring the resistance of the sliding rheostat.

Weak understanding of principles: Most students can adjust the potentiometer step by step to change the quiescent operating point, but when asked questions like "Why does an excessively high quiescent operating point cause saturation distortion?" or "What is the relationship between voltage gain and collector resistance/load resistance?", only a small number of students can give vague answers. After the experiment, some students still do not understand "why the quiescent operating point must be measured before measuring voltage gain", indicating that the core logic remains ungrasped.

Lack of expansion ability: The experimental guide specifies circuit parameters (e.g., load resistor RL=4.3kΩ), so students do not need to think about the significance of parameter selection. When teachers temporarily request "changing RL to ∞ and observing the change in voltage gain", 80% of students cannot predict the result nor know how to verify the theory through data, reflecting the problem of disconnection between practice and theory.

4.2. Optimization of Experimental Projects

In response to the above issues, after discussions among the course team's teachers, it was decided to remove experiments with high similarity or secondary importance, focus on in-depth teaching of core knowledge points, and concentrate class hours on core experiments—enabling students to thoroughly complete and understand each one.

There are two selection criteria for removing experiments: first, knowledge point repetition, i.e., whether the core principles involved in the experiment are already covered in other experiments; second, practical necessity, i.e., whether the experiment content serves as a core foundation for subsequent professional courses (such as microcontrollers [6] and embedded systems).

Ultimately, the number of experimental projects was reduced from 8 to 6, with specific adjustments as follows: 6 experiments were retained, including "the use of electronic instruments and meters, common-emitter amplifier circuit, integrated operational amplifier, verification of gate circuit logic functions, combinational logic circuit design, and counter design"; 2 experiments were removed, namely "emitter follower" and "sinusoidal oscillator". Meanwhile, the class hours of the removed experiments were reallocated to core experiments: the class hours for the common-emitter amplifier circuit were increased from 2 to 4, and those for combinational logic circuit design were also increased from 2 to 4. This ensures that core experiments have sufficient time for students to think, operate, and discuss.

Merely adjusting in-class experimental hours is still insufficient to meet students' individualized needs: students with weak foundations may require additional time to review operations, while students with surplus learning capacity may wish to conduct independent exploration. To address this, the college has implemented a measure to open laboratories at night, extending experimental teaching from in-class sessions to after-class independent time, thus forming a closed loop of "in-class in-depth teaching + after-class free practice".

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5. Reform of Curriculum Assessment

To address the phenomenon of "emphasizing results over processes" in traditional assessment, establishing a curriculum assessment and evaluation system that can objectively and fairly evaluate students' learning outcomes is a key link in achieving teaching objectives [7]. Combining the curriculum assessment characteristics of emerging engineering education and the features of the "Analog and Digital Circuits" course, a diversified assessment system is proposed. This system consists of two parts: process-oriented scores and summative scores. The specific assessment methods and the proportion of each item are shown in Table 1.

Table 1. Composition of Course Scores

Score composition	Assessment content	Score proportion	Proportion in the total course score
Process-oriented scores	Attendance, In-class performance	25%	40%
	Homework, Quizzes	25%	
	Lab assessment	50%	
Summative scores	Closed-book examination	100%	60%
Total course score		100%	

As shown in Table 1 Composition of Course Scores, process-oriented scores account for 40% of the total course score. These scores include four components: attendance, in-class performance, regular homework, quizzes and lab assessment. This design not only enhances students' learning enthusiasm and in-class teaching efficiency but also clarifies lab assessment as a key part of the assessment content. It focuses on students' knowledge and skills in analyzing, calculating, assembling, wiring, and testing basic circuits, as well as in fault analysis, identification, and troubleshooting.

In the teaching of Analog and Digital Circuits, lab assessment is a core component for testing students' practical abilities and a key means to guide them to value the experimental process. The previous assessment method required students to randomly select one experimental project, complete the operation within a specified time, and then the teacher would check the results and ask questions. While this method can test students' ability to adapt to changes, it has obvious limitations: students with weak foundations may fail to complete the assessment if they select a difficult project; top students may struggle to fully demonstrate their abilities if they select an easy one. Furthermore, it cannot truly reflect students' actual proficiency, which is not conducive to objective evaluation.

To address this, based on student feedback, reforms to the experimental operation assessment have been implemented as follows:

Experimental assessment projects are classified into three levels by difficulty, with each level corresponding to clear ability requirements and score ranges. This ensures that students at different proficiency levels can find suitable goals for themselves.

Students can independently choose experimental assessment projects based on their usual academic performance. Additionally, after completing the assessment of their chosen level, students are allowed to challenge higher-level projects and improve their scores by re-taking, which stimulates their motivation for active learning.

The assessment focuses on process and comprehension. During the assessment, teachers not only check whether the operation results are correct but also pay more attention to whether students understand the principles behind the operations. They assess the depth of students' comprehension through questions (e.g., "How to adjust a transistor from the amplification state

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to the cut-off state?" or "What is the logical relationship of a NAND gate?"), avoiding the situation where students get scores by merely memorizing steps.

For emerging engineering-oriented scientific course assessment, this system can monitor students' learning process from multiple dimensions and accurately evaluate their learning quality. While fully stimulating students' learning enthusiasm, it also promotes teachers to continuously optimize teaching design and improve their teaching quality.

6. Conclusion

Based on the current status of the "Analog and Digital Circuits" course and aligned with the talent cultivation requirements for computer-related majors under the background of emerging engineering education, this paper explores reforms in the course's teaching and experimental sessions. By streamlining curriculum content, deepening experimental projects, and diversifying assessment methods, the reform not only addresses practical issues such as limited class hours and students' weak foundational knowledge but more importantly, cultivates students' engineering literacy—including their ability to gain an in-depth understanding of principles and solve problems independently.In the future, we will continue to explore teaching models that adapt to the requirements of emerging engineering education, contributing to the cultivation of more high-quality engineering talents.

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