

Exploring the Reform of a High-Quality “Analog Circuits” Course Based on the Outcome-Based Education Concept

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Abstract

Guided by the Outcome-Based Education concept, systematic teaching reforms have been implemented for the “Analog Circuits” course to address the shortcomings of the traditional teaching model. Key measures included restructuring course objectives, modularizing content, implementing competency-based assessments, and enhancing industry-education integration. Post-reform results showed significant improvements: student pass rates rose substantially, academic performance became more balanced, and students achieved notable success in engineering competitions. Teaching quality and student satisfaction also increased. The study demonstrates that OBE-based reform effectively strengthens both course quality and students’ comprehensive competencies.

Keywords

Analog Circuits Course, Outcome-Based Education, Teaching Reform, Student Competency Development

1. Introduction

“Analog Circuits” is a fundamental engineering course for undergraduate students in electronic information-related majors. This course primarily analyzes the fundamental working principles of analog unit circuits within electronic systems, investigates their basic laws and analytical methods. It enables students to independently complete tasks, such as parameter measurement, circuit analysis, data processing, and analog unit circuit design as required in experiments. Students

will gain not only a foundation in semiconductor devices but also the ability to analyze and experiment with analog circuits that utilize these components. These competencies provide a solid foundation for the students' subsequent coursework and professional endeavors in engineering technology and scientific research (Liu & Wu, 2024; Wu, 2025).

Outcome-Based Education (OBE) is an instructional philosophy driven by learning outcomes. It uses a reverse-design approach to plan curriculum and instruction based on the competencies students are expected to master. It enables students to apply theoretical knowledge to practical problems within complex engineering contexts, coupled with an innovative spirit and the ability for autonomous learning (Jiang et al., 2024; Ruan et al., 2025).

However, the traditional teaching model for analog circuits presents significant shortcomings:

- 1) Against the backdrop of the New Engineering Initiative and engineering education accreditation, the alignment between course objectives and graduation requirement indicators remains inadequately defined. There is a pressing need to systematically establish and enhance the clarity and measurability of these correlations.

- 2) To meet the "Golden Course" standard of being high-order, innovative, and challenging, the course content is designed to foster students' practical and innovative abilities.

- 3) The current assessment framework fails to adequately capture students' ability to solve complex engineering problems. There is a pressing need to develop diverse evaluation methods.

To address identified challenges in analog circuits education, the course has been systematically restructured in accordance with the national Emerging Engineering Education framework and engineering accreditation standards.

2. Reform Plan

2.1. Reconstructing the Course Objectives Framework

Under the guidance of the OBE educational philosophy and in close alignment with new engineering disciplines and accreditation standards, "Analog Circuits" course is transitioning from a traditional, theory-intensive foundation module into a modern, core professional course that equips students with applicable, skilled, and competent profiles (Li, 2025).

A clear and measurable linkage must be established between course objectives and graduation requirement indicators. Vague expressions like "master... knowledge" must be replaced by a correlation matrix. Course objectives should be constructed through backward design to ensure they underpin the graduation requirements, utilizing demonstrable action verbs (e.g., "can calculate," "analyze," "design," "apply").

The restructured course objectives articulate the connection between each instructional activity and the required graduate competencies, clarifying learning

purposes for students and sharpening teaching focus for instructors. By implementing objective-specific assessments, student proficiency across different competency dimensions can be precisely evaluated, providing robust evidence for the continuous improvement of teaching quality.

2.2. Restructure the Curriculum Teaching System and Course Content

Focusing on the development of the electronic information industry and its contribution to the local regional economy (Jiang et al., 2024), the course content is been restructured. We modularized the curriculum, replacing the linear structure of traditional textbooks with progressive and relatively independent teaching modules (Yu et al., 2025).

With the initial goal of designing “basic amplifier circuits”, this course explains the core operating mechanisms of PN junctions, diodes, and transistors from a semiconductor physics perspective. Then it proceeds to cover the analysis and design methods for basic transistor amplifier circuits, guiding students to understand the relationship between device models and physical reality, as well as the design principles of fundamental amplifier circuits. Subsequently, the working mechanism of field-effect transistors and their fundamental amplification circuits are introduced in parallel. This directly supports the graduation requirement indicator point for “establishing and solving mathematical models”.

The course establishes a pedagogical framework centered on architecting a complete operational amplifier, sequentially unifying core circuit modules. Students explore the functional partitioning and collaborative dynamics within an integrated op-amp, learning how to combine circuits to achieve desired system characteristics (e.g., high gain, low output impedance). This process rigorously develops their ability for system-level analysis and abstract modeling, providing direct support for the corresponding graduation requirement.

By introducing typical engineering cases such as “audio power amplification” and “EEG signal amplification”, students learn to design complete signal processing systems using integrated operational amplifiers and related components. This approach strengthens their system integration awareness and supports the learning objective of “functional circuit design and system integration”.

Modular reorganization enables students to structure previously disconnected knowledge into a logical “components-to-systems” progression. This fosters a system-level perspective on circuit functions and enhances systems thinking skills. By embedding theory within project-based learning, the course sparks student engagement and inquiry, equipping them with adaptable circuit analysis and design skills transferable to novel problems.

2.3. Implementing a Competency-Oriented Multifaceted Assessment Framework

A diversified assessment framework has been established, integrating formative

and summative evaluations with an emphasis on competency development. The overall grade distribution has been restructured as follows: Formative Assessment (40%) + Final Examination (60%). The formative component comprises two multi-unit quizzes (20% total) and one midterm assessment (20%).

The final exam has been substantially redesigned to shift focus from rote memorization and formulaic application toward complex, open-ended problems requiring synthesis, design, and analytical reasoning. This revised format evaluates students' grasp of core conceptual models and their capacity to analyze and resolve complex engineering challenges. By aligning assessment with sustained learning, the reform discourages last-minute cramming and encourages consistent academic engagement throughout the course. These diversified evaluation methods prompt students to employ critical thinking, systematic analysis, and creative design, thereby fostering the advanced cognitive abilities essential for addressing multifaceted engineering problems.

2.4. Deepening Industry-Education Integration

To meet the requirements for graduates' comprehensive competencies under the new engineering discipline development and engineering education accreditation, the course must deepen industry-education integration to cultivate students' innovative thinking and patriotic spirit. When analyzing device characteristics and calculating circuit parameters, emphasis is placed on data objectivity and precision, fostering a rigorous, pragmatic, and meticulous scientific attitude. Centered on the core technology of "chips", the course introduces the development trajectory and gaps in the global semiconductor industry. By sharing stories of Chinese scientists and enterprises striving for excellence, it inspires students' sense of mission to serve the nation through science and technology.

3. Effectiveness of Reform Implementation

3.1. Improvement in Student Achievement and Competency Attainment

Through a comparative analysis of student outcomes in the Analog Circuits course before and after the teaching reform, the effectiveness of the new approach is evident (**Figure 1**). The reform has led to substantial improvements in overall learning outcomes: the average course score increased significantly from 53.3 to 65.3, while the pass rate surged from 30.3% to 71.11%. These results demonstrate that the reforms have successfully strengthened students' mastery of core course content. Moreover, the grade distribution has become more balanced. Prior to the reform, 69.7% of students failed the course, reflecting a polarized academic performance pattern. In contrast, post-reform overall grades now approximate a normal distribution, indicating that the improvements have benefited a broad range of students and effectively reduced the rate of academic underachievement. These positive changes are likely attributable to specific initiatives such as increased instructional hours and optimized teaching and learning processes.

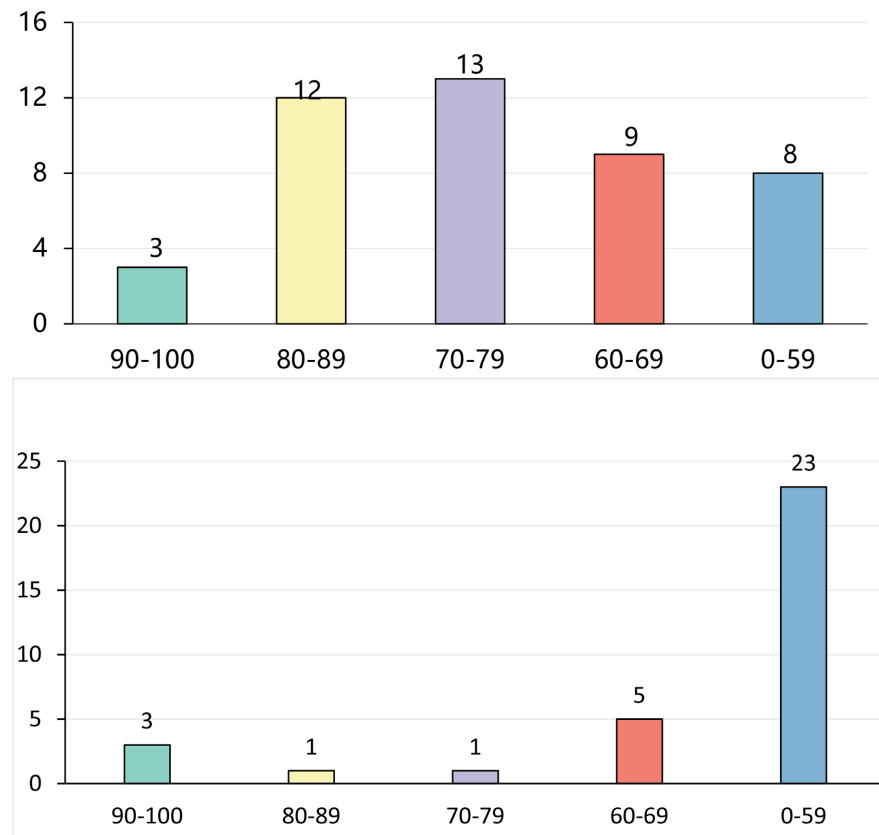


Figure 1. Comparison of student performance before and after reform.

3.2. Student Competence Enhanced in Engineering Practice and Innovation

Project-driven modular teaching and comprehensive experimental design have strengthened students' ability to independently execute circuit design, simulation, and system analysis. These methods have significantly boosted student motivation and initiative. Students now demonstrate greater exploratory skills in post-class seminars and project reports. In recent years, more students from this course have earned provincial or higher awards in prestigious competitions such as the National Undergraduate Electronic Design Contest and the "Challenge Cup". These awards comprise 2 national bronze medals; and 7 provincial-level awards (4 first prizes and 3 second prizes). Their engineering competence and innovative thinking have gained broad recognition from industry and society.

3.3. Optimization of Teaching Evaluation and Feedback Mechanisms

A multi-dimensional evaluation system integrating formative assessments and summative examinations has been established to support continuous improvement in teaching quality. Analysis of formative assessment data enables instructors to promptly identify weaknesses in instruction and common student learning difficulties. This facilitates timely adjustments in teaching strategies and precise

interventions. Furthermore, the inclusion of comprehensive and design-oriented questions in final examinations effectively directs student learning toward knowledge integration and practical application.

Table 1. Student feedback on teaching.

Academic Year/Semester	Course Name	Instructor	Evaluation Score	Number of Respondents	Response Rate
Fall Semester of 2024-2025	Analog Circuits	Jianxiu Li	96.40	30	63.83%
Fall Semester of 2023-2024	Analog Circuits	Jianxiu Li	90.88	16	48.48%

The feedback was gathered from anonymous open-ended survey questions at the end of each semester. Student feedback on teaching is shown in **Table 1**. Based on two years of student evaluation data for the “Analog Circuits” course, the teaching reforms have yielded both quantitative and qualitative improvements in instructional quality. Student participation in course evaluations increased significantly from 48.48% in 2023 to 63.83% in 2024, indicating enhanced student engagement and evaluation willingness. Concurrently, the average course evaluation score rose markedly from 90.88 to 96.40 points, reflecting substantially improved student satisfaction with the teaching quality. These elevated evaluation results are further corroborated by the observed concurrent improvements in student academic performance and a notable rise in pass rates, collectively demonstrating the substantial impact of the teaching reform on overall educational effectiveness.

Students reported positive teaching outcomes, noting that “course objectives were clear and content highly practical”, and that “teaching methods effectively stimulated learning interest”. The course was described as “rich in content” and “enhancing the ability to analyze and debug circuits”.

3.4. Synchronized Development of Team Teaching Competency

Through the implementation of teaching reforms, the instructional team has consistently refined its educational philosophy and enhanced teaching competencies. These efforts have yielded significant outcomes, including the approval of university-level teaching reform projects and awards, demonstrating a virtuous cycle of mutual development between teaching and learning. Since the reform initiative launched in 2023, the team has achieved recognition as a university-level blended online-offline first-class undergraduate course and published two academic papers on blended learning innovations in analog circuits education.

4. Conclusion

Guided by the OBE philosophy, the Analog Circuits course has undergone comprehensive teaching reform. We have systematically restructured the course objectives and optimized teaching content. The assessment mechanisms have been

innovated to better evaluate learning outcomes. Integration of ideological education and industry collaboration has been deepened. These reforms have significantly improved teaching quality. Students show notable progress in both knowledge acquisition and skill development. Their engineering literacy and value recognition have been enhanced. This comprehensive development provides solid foundation for future professional studies and career development. The teaching team remains committed to continuous innovation. We will further refine the teaching system to enhance the course's advanced nature. The challenge level will be progressively elevated to foster deeper learning. Looking forward, the teaching team will continue to deepen pedagogical innovations and refine the instructional system. These efforts aim to further enhance the course's advanced nature and academic rigor, fostering sustained educational excellence.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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