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The Analysis of Course Objective Achievement and Reform Practices for "Principles of Electric Circuits" under the Context of Engineering Education Accreditation

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Abstract: Under the context of engineering education accreditation, there is a strong emphasis on outcome-based education and competency-based education, with differentiated outcomes tailored to various disciplines. This paper takes the outcome-based educational reform and practical results of a 4-credit course "Principles of Electric Circuits" at a university in Shanghai as a case study. It analyzes the outcome-based teaching reform and practices for foundational courses in the electronic information major from three main aspects: objective formulation, course achievement analysis, and exploration of teaching reform practices.

1. Introduction

With the acceleration of global economic integration, competition among countries in fields such as science and technology and engineering has become increasingly intense, creating an urgent need for the cultivation of high-quality engineering talent to meet the rapidly changing market demands. China's initiatives, including the "Belt and Road" initiative, the "Yangtze River Economic Belt," and the "Coordinated Development of Beijing-Tianjin-Hebei" strategy, along with the "dual carbon" goals proposed in 2020, have led to the vigorous development of a new economy characterized by new technologies, new business formats, new models, and new industries, but it also raised the standards for engineering and technical talents as a result. Ensuring that graduates possess the necessary knowledge and skills has become a significant challenge faced by universities worldwide. In this context, university are aligning their teaching with international standards, guided by the unified engineering education accreditation standards established among countries. This alignment aims to deepen the reform and innovation of engineering education to ensure its quality and effectiveness, thereby enhancing the global competitiveness and comparability of engineering education.

The standards and requirements of engineering education accreditation aim to ensure that higher education institutions can cultivate high-quality engineering talent that meets societal and industry needs[1]. In June 2016, China became an official member of the Washington Accord, which signifies that engineering undergraduate degrees accredited by the China Engineering Education Accreditation Association (CEEAA) are recognized by all signatory countries, including the United States, the United Kingdom, and Australia[2][3]. By ensuring that engineering curricula align with industry demands through accreditation, universities can better adapt to the rapidly changing societal needs, produce high-quality engineering talent that meets these requirements, and improve students' employability. Furthermore, obtaining internationally recognized accreditation can enhance an institution's global reputation, attract more international students and academic exchanges, and promote the development of globalized education.

The course "Principles of Electric Circuits" is a crucial foundational course with strong practical applications for various programs in higher education, including Electrical Engineering and Automation, Automation, Electronic Information Science and Technology, Measurement and Control Technology and Instruments, Optical Information Science and Technology, and Biomedical Engineering. It serves as a supporting course for subsequent subjects such as Analog Electronic Technology, Digital Electronic Technology, Power System Analysis, Power Electronics Technology, and Motor and Drive Courses, playing a vital role in the cultivation of talent by bridging foundational knowledge and advanced applications. This paper takes the Electrical Power Systems and Automation program at the University of Shanghai for Science and Technology as a case study to examine the completion of the course objectives for "Principles of Electric Circuits" in recent years, alongside ongoing reforms. By analyzing the degree of achievement of the course objectives, this study explores practical pathways for the reform of foundational courses in the context of engineering education.

2. Course objectives and their supporting relationship with graduation requirements

The "Principles of Electric Circuits" course serves as a pivotal foundational component within the curriculum of Electrical Engineering programs. Grounded in the principles of Outcome-Based Education (OBE), this course employs a blended teaching approach that integrates both online and offline methods. It utilizes a diverse array of instructional strategies, including classroom lectures and discussions, video demonstrations of circuit simulation software, and collaborative group projects. Through these methodologies, students engage with fundamental concepts, laws, and analytical techniques related to direct current (DC) circuits, alternating current (AC) circuits, and transient circuits, thereby acquiring essential knowledge in circuit analysis. Moreover, the course is designed to cultivate students' abilities to analyze and address complex engineering problems within the electrical engineering domain. It emphasizes the importance of connecting theoretical knowledge with practical applications, thereby establishing a solid foundation for subsequent studies in circuit design and related disciplines. The alignment of the course objectives with graduation requirements is illustrated in Table 1, highlighting the course's integral role in the broader educational framework.

By fostering critical thinking and problem-solving skills, the "Principles of Electric Circuits" course not only prepares students for advanced coursework but also equips them with the competencies necessary for successful careers in engineering. The ongoing assessment and refinement of the course objectives about industry demands underscore the importance of continuous improvement in engineering education, ensuring that graduates are well-prepared to meet the challenges of an evolving technological landscape.

Table 1: Correspondence between Observation Points and Course Objectives.

Course objectives	Graduation requirement indicator point support ratio	Corresponding graduation requirements observation points	Supporting graduation requirements
1. Master the basic concepts, laws, and analysis methods in DC circuits.	0.35	1.2 Ability to apply the above knowledge to solve complex engineering problems in the field of electrical engineering.	1. Engineering knowledge: able to apply mathematics, natural sciences, engineering fundamentals, and professional knowledge to solve complex engineering problems in the field of electrical engineering.
2. Master the basic concepts, laws, and analysis methods of single-phase AC circuits, coupled circuits, and three-phase AC circuits.	0.4		
3. Master the three-element analysis method and complex frequency domain analysis method based on the characteristics of transient circuits.	0.25		

3. Analysis of the achievement of the objectives of the 2019 course

3.1. Scoring criteria

The evaluation of each stage of this course is conducted on a percentage scale (converted into excellent grades: 90-100 points, good grades: 80-89 points, medium grades: 70-79 points, passing grades: 60-69 points, failing grades:<60 points, absent grades: 0 points). The grading standards for each stage are as follows:

Table 2: Scoring Criteria for Circuit Principles Homework.

Course objectives	Scoring Criteria				weight(%)
	90-100	80-89	60-79	0-59	
1.Ability to apply circuit knowledge to analyze DC circuits.	Excellent homework and able to accurately apply circuit knowledge to analyze DC circuits	Good homework and able to apply circuit knowledge reasonably to analyze DC circuits	The homework basically meets the requirements and can apply circuit knowledge to analyze DC circuits	Poor homework quality and conceptual errors in circuit analysis.	35%
2.Ability to apply circuit knowledge to analyze and communicate circuits.	Excellent homework, and able to accurately apply circuit knowledge to analyze and communicate circuits	Good homework and able to apply circuit knowledge reasonably to analyze and communicate circuits	The homework basically meets the requirements and can apply circuit knowledge to analyze and communicate circuits	Poor homework quality and conceptual errors in circuit analysis.	40% (20%+ 20%)
3.Ability to apply circuit knowledge to analyze transient circuits.	Excellent homework and able to accurately apply circuit knowledge to analyze transient circuits	Good homework and able to apply circuit knowledge reasonably to analyze transient circuits	The homework basically meets the requirements and can apply circuit knowledge to analyze transient circuits	Poor homework quality and conceptual errors in circuit analysis.	25%

(1) Homework grading criteria

The scores from four assignments will be included in the final grade at a ratio of 40%, with support for the three-course objectives accounting for 35%, 40% (20%+20%), and 25% respectively. The scoring criteria for circuit principle homework are shown in Table 2.

(2) Final Exam Scoring Standards

The main assessment focuses on the analysis methods of DC circuits, AC circuits, and transient circuits. DC circuit analysis scores 36 points, AC circuit analysis scores 38 points, and transient circuit analysis scores 26 points. The total score of the paper is 100 points, and 60% of the paper score will be included in the final grade. The scoring criteria for final exam assessment items are shown in Table 3.

Table 3: Scoring Criteria for Final Exam Assessment Items.

Course objectives	Basic requirements	Evaluation criteria					Proportion
		90~100	80~89	70~79	60~69	<60	
1	Analyze DC circuits using Kirchhoff's voltage/current law, equivalent transformation of power sources, mesh method, node voltage method, superposition theorem, Thevenin's theorem, and other methods.	Can be used very accurately.	Can be accurately utilized.	Can be utilized more accurately.	Can be basically utilized.	Cannot be utilized.	36%
2	Using the phasor method to analyze single-phase AC circuits, coupled circuits, and three-phase AC circuits.	Can be used very accurately.	Can be accurately utilized.	Can be utilized more accurately.	Can be basically utilized.	Cannot be utilized.	38%
3	Use the three-factor analysis method and complex frequency domain analysis method to analyze first-order and second-order dynamic circuits.	Can be used very accurately.	Can be accurately utilized.	Can be utilized more accurately.	Can be basically utilized.	Cannot be utilized.	26%

3.2. Method for calculating the degree of achievement of course objectives

Taking the scores of all students in each assessment stage of this course, if the total number of students is N, the achievement degree of the *i*-th course objective based on the performance assessment method is expressed as:

$$k_i^c = \frac{\sum_{j=1}^{N}(\sum(\text{Course objective } i \text{ Assessment section score} \times \text{ Proportion of final grade}))_j}{\text{N} \times (\sum \text{ Course objective } i \text{ Assessment phase objective score} \times \text{ Proportion of final grade})}$$

3.3. Achievement and Analysis of Course Objectives

3.3.1. Course Objective 1

Figure 1 records the achievement level of course objective 1. Comparative analysis of course objective attainment between the 2018 and 2019 cohorts reveals a slight decline in performance. Specifically, the achievement levels for Objective 1 in the 2019 cohort were recorded at 0.78, 0.47, and 0.59, respectively. Following the introduction of an additional in-class quiz, there was a noticeable improvement in the first objective's attainment; however, approximately five students continued to submit assignments of subpar quality, indicating an overall satisfactory performance yet room for enhancement.

A review of examination responses highlighted a significant number of deductions on questions related to the application of the Maximum Power Transfer Theorem, a concept that necessitates a complex direct current (DC) analysis involving the calculation of input resistance and open-circuit voltage. The challenges faced by students in mastering this topic can be attributed, in part, to the reduced opportunities for in-class practice due to the disruptions caused by the pandemic.

In response to these findings, the circuit education team plans to implement regular in-class assessments aimed at reinforcing students' understanding of fundamental DC circuit concepts and analytical methods and laying a solid foundation for subsequent communication and transient circuit analysis.

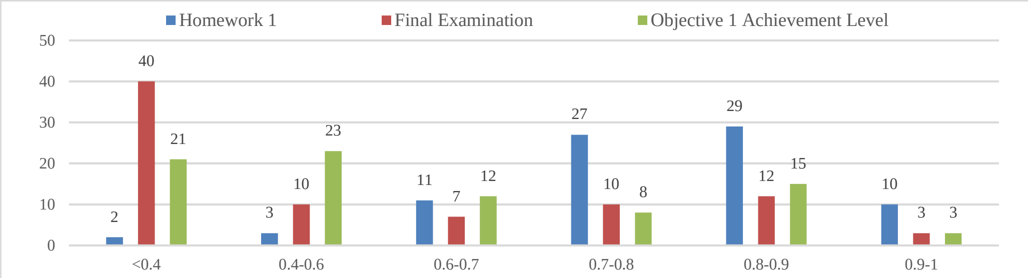

Figure 1: Distribution of Achievement of Course Objective 1.

3.3.2. Course Objective 2

Figure 2 records the achievement level of course objective 2. In a comparative analysis of student performance between the 2018 and 2019 cohorts, it was observed that the attainment levels for Objective 2 decreased across four key metrics, with scores recorded at 0.78, 0.78, 0.33, and 0.51, respectively. The analysis of alternating current (AC) circuits emerged as a significant challenge within the Principles of Electric Circuits course, with approximately 46 students exhibiting low scores on related assessments. This indicates a pressing need to enhance understanding and performance in the areas of single-phase AC circuits, three-phase AC circuits, and coupled circuits.

The complexity of AC circuit analysis arises from the fact that each variable possesses not only magnitude but also direction, coupled with a variety of expression forms and non-unique circuit calculation formulas. In response to these challenges, the circuit education team plans to employ graphical analysis techniques to facilitate deeper comprehension of AC circuit dynamics, thereby alleviating students' apprehension towards this subject matter.

Additionally, the teaching team will focus on refining the presentation of classical problem-solving methods, emphasizing the synthesis and summarization of key concepts. This initiative aims to clarify the thought processes involved in AC circuit analysis, enabling students to develop a more structured approach to problem-solving. Through these concerted efforts, the course seeks to bolster students' confidence and competence in AC circuit analysis, ultimately enhancing their overall performance and understanding of electrical engineering principles.

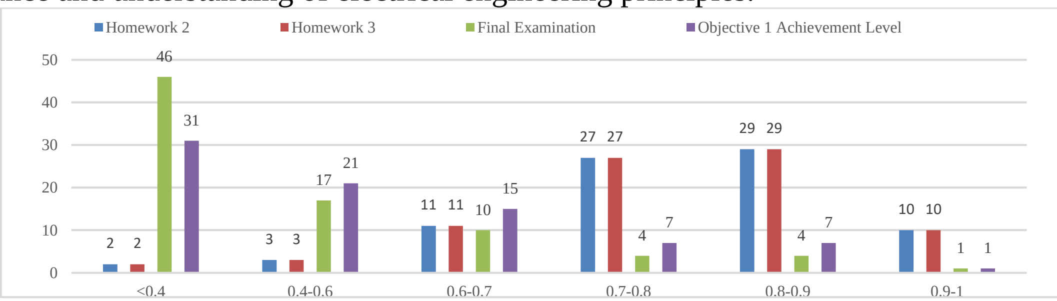

Figure 2: Distribution of Achievement of Course Objective 2.

3.3.3. Course Objective 3

Figure 3 records the achievement level of course objective 3. In a comparative evaluation of the curriculum between the 2018 and 2019 cohorts, the 2019 syllabus has clearly defined the process-based assessment content that can achieve Goal 3. It has also put forward higher requirements for this goal point. However, the achievement levels for Objective 3 in the 2019 cohort were recorded at 0.78, 0.31, and 0.49. This indicates a decline in proficiency across these metrics.

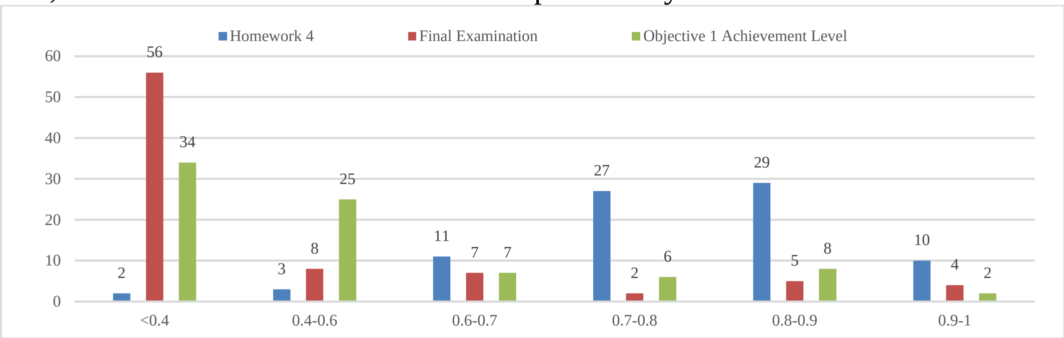

Figure 3: Distribution of Achievement of Course Objective 3.

The analysis of transient circuits presents greater abstraction compared to steady-state circuits, compounded by the complexities associated with the Laplace transform and the analysis of circuits in the complex frequency domain. These factors contribute to the lower attainment levels observed in this area. In response, the instructional team plans to enhance the curriculum by elaborating on circuit simplification techniques following circuit switching, focusing on the operational circuit representations of components such as capacitors, inductors, and power sources.

Furthermore, the teaching team will actively incorporate simulation videos and real-life phenomena, such as the operation of ceiling lights, to reinforce students' understanding of transient circuit processes. This approach aims to bolster students' analytical skills in transient circuit analysis, facilitating a deeper comprehension of the underlying principles and enhancing overall academic performance in the field of electrical engineering. Through these targeted interventions, the course seeks to address the identified gaps and improve student outcomes in complex circuit analysis.

3.3.4. The overall objective of the course

The distribution of achievement of course objectives is shown in Figure 4. In evaluating the curriculum outcomes for the 2019 cohort, a significant decline was observed, with an achievement level of 0.53 compared to 0.66 for the 2018 cohort. This decrease can be attributed to multiple factors, including the impact of the COVID-19 pandemic, which has led to diminished student motivation and engagement. Additionally, the shift to online instruction has adversely affected the quality of course delivery, resulting in a reduction in the attainment of course objectives.

In response to these challenges, the education team has identified critical issues within the three main course objectives and is implementing various means to enhance student learning outcomes. This strategy includes the utilization of online platforms, the incorporation of in-class assessments, and the dissemination of representative problem sets. These measures aim to strengthen students' analytical skills in direct current (DC) circuits, alternating current (AC) circuits, and transient circuits, while also equipping them with the competencies necessary to devise effective solutions for complex engineering problems.

Through these targeted interventions, the teaching team seeks to address the identified gaps in student performance and foster a more robust understanding of circuit analysis principles. By leveraging diverse instructional methods, the course aims to improve student engagement and learning outcomes, ultimately enhancing their preparedness for real-world engineering challenges.

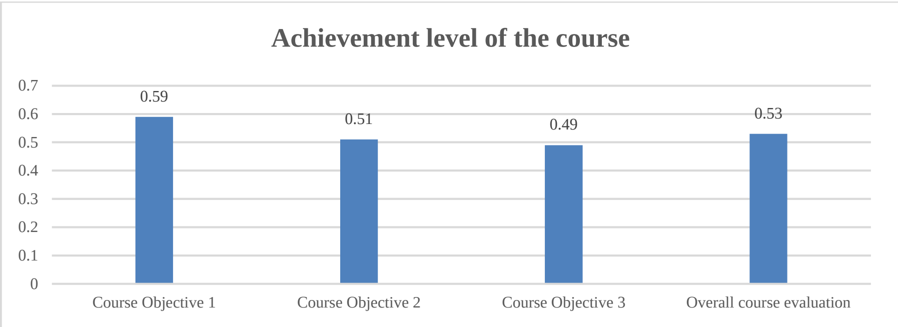

Figure 4: Distribution of Course Goal Achievement

4. Continuous improvement

The achievement levels for Course Objectives 2 and 3 are notably low, indicating that students demonstrate a limited understanding of fundamental concepts such as first-order transient analysis, phasor methods, and sinusoidal steady-state circuits. This situation reflects not only a general deficiency in content knowledge but also variability among students regarding their comprehension of the theoretical framework and mastery of research methodologies. To address these challenges, it is imperative to adjust assignment structures and integrate more engineering practice cases into theoretical instruction. Such an approach will facilitate students' ability to connect theoretical knowledge with practical applications, thereby enhancing their analytical skills and problem-solving capabilities in real-world contexts.

Moreover, there is a critical need to strengthen the procedural assessment components of the curriculum. Clearly defining the assessment criteria, which should assignment quality, in-class tests, and project practice, is essential. By focusing on student performance and effort throughout the learning process, educators can provide timely feedback and guidance, enabling students to identify and address their areas for improvement.

In terms of pedagogical enhancements, the incorporation of more interactive teaching methods is necessary. Techniques such as group discussions and the sharing of multiple solutions approach to typical problems will deepen students' understanding of circuit principles and promote active engagement. Regular classroom quizzes and assignment feedback will facilitate the timely identification and resolution of learning challenges. Additionally, establishing dedicated office hours will allow instructors to address students' difficulties encountered during their studies.

Furthermore, leveraging online platforms, in-class assessments, organized presentations, and the dissemination of representative problem sets will be instrumental in encouraging student attendance and improving assignment quality. Emphasizing the application of mathematical and physical principles, along with foundational knowledge in electrical engineering, will strengthen students' abilities to DC circuits, AC circuits, and transient circuits. Ultimately, these strategies aim to enhance students' capacity to analyze complex engineering problems and develop effective solutions, thereby improving the overall attainment of course objectives.

5. Conclusion

This study has calculated and analyzed the achievement levels of the "Principles of Electric Circuits" course within the context of engineering education accreditation, providing a framework for ongoing improvement in teaching practices. The analysis of course objective attainment reveals significant discrepancies, particularly noting that the average achievement level for Course Objective 3 is markedly lower than that of Objectives 1 and 2, with an average score of only 0.49.

This finding underscores the necessity for enhanced focus on Objective 3 through targeted exercises, such as the introduction of representative problem sets, to bolster students' abilities to analyze complex engineering problems effectively.

The role of engineering education accreditation is pivotal in enhancing educational quality and ensuring the effectiveness of talent cultivation. However, it is essential to recognize that curriculum reform is not a one-time effort but a continuous process that requires regular assessment and feedback. This iterative approach is vital for adapting to the evolving demands of engineering education and industry standards. By implementing the recommendations derived from this analysis, universities can better align their curricula with the needs of the profession, ultimately fostering a more competent engineering workforce.

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