

Research on the Construction of the Principles of Electric Circuits Textbook Based on National First-Class Course Standards

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Abstract

The construction of national first-class undergraduate courses serves as a pivotal initiative to deepen reforms in higher education and fulfill the fundamental mission of "cultivating virtue and nurturing talent." As the core medium for delivering course content and the foundational guide for teaching implementation, the quality of textbooks directly determines the effectiveness of first-class course development and the caliber of talent cultivated. This study takes Principles of Electric Circuits, a foundational engineering course, as its research focus, addressing the challenges faced by traditional textbooks in the new era. It systematically explores advanced principles, implementation pathways, and innovative directions for textbook construction. The paper proposes adhering to a construction philosophy centered on "cultivating virtue and talent, student-centered learning, outcome-oriented education, and interdisciplinary integration." It advocates following a construction approach that emphasizes "restructuring the content system, deeply integrating information technology, strengthening practice-based education, and establishing a robust evaluation and feedback mechanism." Furthermore, it calls for comprehensive innovation in "content modalities, learning pathways, capability empowerment, and evaluation mechanisms," aiming to build a new-generation Principles of Electric Circuits textbook system that supports the cultivation of higher-order thinking skills and meets the demands of the digital and intelligent era.

Keywords: national first-class course, principles of electric circuits, textbook construction, obe concept, new-generation textbook, digital resources

1. Introduction

Principles of Electric Circuits serves as a foundational course for disciplines such as electrical engineering, electronic information engineering, and automation, undertaking the fundamental mission of cultivating students' circuit analysis capabilities, engineering modeling thinking, and scientific literacy. With the in-depth advancement of technological revolutions and industrial transformations epitomized by artificial intelligence, the Internet of Things, and new energy, the "New Engineering" initiative has set unprecedented standards for the knowledge structure, competencies, and innovative spirit of China's future engineering talent[1].

Therefore, leveraging the significant opportunity presented by the construction of national first-class undergraduate courses, it is imperative to undertake a profound and systematic reform of the Principles of Electric Circuits textbook. This reform is not only an intrinsic requirement for the course itself to achieve "higher-order thinking, innovation, and challenge" but also a necessary choice to embody modern educational philosophies centered on "student-centricity, outcome-oriented education, and continuous improvement,"[2] thereby nurturing exceptional engineers capable of addressing future challenges.

2. Core Philosophies Guiding Textbook Construction

Philosophies serve as the vanguard of action. To develop a first-class textbook, it is essential to first establish advanced, aligning guiding principles that correspond with its objectives.

2.1 *Cultivating Talent with Moral Integrity: The Deep Integration of Value Inculcation and Knowledge Transmission*

Textbooks serve as the primary frontline for "teaching and nurturing talent." First-class course textbooks must transcend their mere function as repositories of knowledge and evolve into dynamic vehicles for value-led education. In the development of the Principles of Electric Circuits textbook, "ideological and political education integrated into courses" (Curriculum-Based Political and Moral Education) should be consistently woven throughout as a unifying thread. Specifically, this can be achieved through the following approaches:

(1) Promoting Scientific Spirit and Patriotic Commitment

When introducing core principles such as Ohm's Law and Kirchhoff's Laws, vividly narrate the stories of scientists' relentless pursuit of truth, thereby cultivating a rigorous and pragmatic scientific spirit. In the introduction and relevant chapters, highlight China's major engineering achievements in ultra-high-voltage power transmission, smart grids, 5G communication, and new energy vehicles to inspire students' national pride and a sense of mission to contribute to technological advancement for the nation.

(2) Fostering Engineering Ethics and Responsibility Awareness

When covering topics like electrical safety, circuit reliability design, and electromagnetic compatibility, integrate case studies on engineering ethics to encourage students to reflect on the potential societal, environmental, and ethical implications of technological applications. This approach aims to instill a responsible mindset in engineering design.

2.2 Student-Centered Approach: Balancing Cognitive Patterns and Learning Experience

The logical framework of textbook development must shift from "teacher-convenience" to "learner-effectiveness." It is essential to fully respect the cognitive traits and learning habits of post-2000s college students as "digital natives." [3]

(1) Adhering to Cognitive Patterns: Employ a progressive narrative strategy that moves "from concrete to abstract, and from simple to complex." Extensively utilize everyday analogies (e.g., comparing electric current to water flow, voltage to water pressure, and resistance to pipe friction) to demystify abstract foundational concepts and reduce cognitive barriers for learners.

(2) Stimulating Intrinsic Motivation: Replace rigid and formal narrative tones with a more approachable, guiding language style. Incorporate interactive elements such as "Problem Mysteries," "Pause & Reflect," and "Exploration Corners" to transform the textbook into a dialogue with readers, shifting from passive knowledge reception to active thinking and knowledge construction.

2.3 Outcome-Based Education (OBE): Precise Alignment of Knowledge Systems with Competency Objectives [4]

All textbook designs must ultimately serve the achievement of course learning outcomes. The cultivation of students' integrated competencies must be the core criterion for content selection and organization.

(1) Defining a Competency Map: Focus on core competencies such as "circuit analysis, calculation, design, application, and solving complex engineering problems." Break down chapter- and section-specific competency objectives into measurable outcomes, clearly listed at the beginning of each chapter.

(2) Theory-Practice Integration: Completely transform the fragmented "theory-first, application-later" model, and take engineering application cases and technical backgrounds as the "anchors" for theoretical explanation. For instance, when explaining resonant circuits, directly associate them with radio station selection or wireless charging technologies; when elaborating on filters, integrate them with audio processing or anti-interference design in communication systems. This ensures that students clearly understand "why to learn" and "how to apply" the knowledge.

2.4 Cross-disciplinary Integration: Co-evolution of Classical Theories and Cutting-edge Technologies

Modern engineering challenges increasingly exhibit multidisciplinary characteristics. [5] Textbooks must break down disciplinary barriers and demonstrate the foundational and bridging roles of circuit principles as a core discipline.

(1) Strengthening Classical Foundations: Consolidate classical fundamentals: Streamline core content in linear resistive circuits, dynamic circuit analysis, and sinusoidal steady-state analysis by retaining essential theories, refining derivations, and emphasizing physical principles and universal applicability.

(2) Integrating Frontier Perspectives: Add specialized "Interdisciplinarity and Application" modules or extended reading boxes. For example, introduce the applications of circuit theory in fields such as on-chip interconnects of integrated circuit chips (IBIS models), power electronic converters (switching transient processes), biomedical sensing (equivalent circuit models), and artificial intelligence hardware (foundations of in-memory computing). This enables students to perceive the strong vitality of basic theories.

3. Systematic Approach to Textbook Development

Guided by Advanced Principles, a Clear and Actionable Implementation Pathway Is Needed to Translate Blueprints into Reality.

3.1 Reconstructing the Content Framework: Building a "Modular, Hierarchical, and Contextualized" Knowledge System

(1) **Modular Design:** The textbook content is divided into three modules: the "Core Foundation Module", "Specialized Direction Linkage Module", and "Frontier Extension Module". The Core Foundation Module covers fundamental theories that all students must master; the Specialized Direction Linkage Module (e.g., focusing on power systems, electronic technology, or communications) provides discipline-specific cases and emphasis areas; and the Frontier Extension Module introduces content intersecting with emerging technologies. This design facilitates needs-based learning for students of different majors and academic levels, while also supporting instructors in organizing teaching activities effectively.

(2) **Hierarchical Progression:** Within each core knowledge unit, the content unfolds in the hierarchy of "concept introduction → laws and theorems → analytical methods → typical examples → engineering cases → exploratory questions". This structure forms a complete closed loop, guiding students from knowledge comprehension to competence enhancement, and aligns with the cognitive law of progressive mastery of disciplinary knowledge and skills.

(3) **Scenario-Based Introduction:** Each chapter opens with an engaging "engineering scenario" or "daily-life scenario". For instance, scenarios such as "How to design an efficient battery management system for electric vehicles?" or "How does the touchscreen of a smartphone detect the position of a finger?" are used to situate the knowledge to be learned in this chapter within a realistic and interesting problem-solving context. This approach stimulates students' cognitive engagement and helps them establish the connection between abstract theoretical knowledge and practical application scenarios.

3.2 Deepening the Integration of Digitalization and Intelligence: Developing New-Form Textbooks with "Paper-Digital Integration"

Actively leverage information technology to construct a dynamic, open, and interactive learning resource ecosystem.

(1) **Streamlining of Main Textbooks:** Print textbooks focus on expounding core concepts, logical frameworks, key conclusions, and high-quality illustrations, ensuring concise content, clear logic, and reader-friendliness.

(2) **Enrichment of Digital Resource Libraries:** Develop high-quality micro-courses and animated videos for all key points, difficult topics, and abstract concepts (e.g., the geometric significance of phasor methods, the physical connotation of convolution integrals, electromagnetic wave propagation). These resources visualize processes that are "invisible and intangible," making abstract knowledge more intuitive and perceivable.

(3) **Online Exercise and Adaptive Assessment Systems:** Establish a hierarchical and classified question bank (covering basic consolidation, competence enhancement, and comprehensive innovation) and equip it with an intelligent problem-solving system. Students can take online self-assessments, and the system provides real-time feedback. Furthermore, it pushes relevant learning materials and practice questions targeting students' weak areas, enabling the guidance of personalized learning paths.

3.3 Strengthening Practical Education: Implementing an Integrated Competence Chain of "Theory-Simulation-Design"

Elevate the cultivation of practical competence from a subordinate role to a core position parallel to theoretical learning.

(1) **Guiding Theoretical Learning through Simulation:** Prior to formal theorem exposition, instructors employ computational simulations to manifest disciplinary phenomena, thereby inducing students to engage in phenomenological observation, problematic questioning, and subsequent deductive-theoretical analysis.

(2) **Driving Comprehensive Application with Design Projects:** In the middle and later stages of the course, small-scale design projects are introduced—such as designing a simple DC voltage regulator, an audio filter, or a light-controlled switch. Students are required to comprehensively apply the knowledge they have learned to complete a miniaturized engineering practice process that includes requirement analysis, scheme design, simulation optimization, and report writing.

3.4 Improving Evaluation and Feedback: Establishing a "Comprehensive, Multidimensional, and Diagnostic" Learning Assessment System

To replace the traditional one-time, high-stakes final evaluation, assessment should be integrated throughout the entire learning process.

- (1) Formative Evaluation: Students' performance in virtual experiments, completion rate and accuracy in online self-assessments, and the quality of simulation reports should all be incorporated into the overall course grade with appropriate weighting.
- (2) Multidimensional Competency Assessment: Exercises and exam questions should not be limited to computational problems. Open-ended tasks such as circuit design, phenomenon interpretation, solution evaluation, and error analysis should be included to assess students' higher-order thinking abilities.
- (3) Learning Diagnosis and Feedback: By utilizing data analytics from the online learning platform, teachers can access a "class learning dashboard" that clearly presents students' mastery of each knowledge point. This provides precise data support for instructional intervention and promotes the continuous improvement of teaching quality.

4. Core Innovations in Textbook Development

The innovation of this textbook lies in its multidimensional breakthroughs and reconstruction of the traditional textbook paradigm.

4.1 Innovation in Content Modality: From "Static Text and Images" to a "Dynamic and Interactive Knowledge System"

The fundamental innovation of this textbook lies in its transformation of form. It is no longer a static printed book, but a dynamic, interactive knowledge body that seamlessly integrates printed pages with digital resources through technologies such as QR codes and augmented reality (AR). By scanning circuit diagrams, students can visualize 3D models of components and animations of current flow; by scanning example problems, they can access instructional videos; and by scanning exercises, they can enter simulation environments for verification. This "scan-and-learn, learn-and-practice" experience greatly enriches the information dimension, enhancing both learning efficiency and engagement.

4.2 Innovation in Learning Pathways: From "Uniform and Linear" to "Personalized and Nonlinear"

Traditional textbooks require all learners to follow a single, linear learning path. Supported by modular content design and intelligent learning systems, this textbook allows students to choose different learning paths based on their backgrounds, interests, and professional orientations. Advanced learners can explore frontier extension modules; students interested in specific application areas can focus on relevant professional linkage modules; and those with weaker foundations can review core micro-lectures and practice exercises recommended by the system. This design truly embodies personalized education and learning according to individual aptitude.

4.3 Innovation in Competency Empowerment: From "Knowledge Comprehension" to "Early Cultivation of Design Thinking"

The textbook significantly advances and normalizes the cultivation of design-oriented thinking—a high-order competency traditionally reserved for later stages of study. Rather than postponing design exposure until the final project, it introduces simulation-based inquiry tasks and micro design challenges throughout the learning process. Students are encouraged to think critically—"If I want to achieve a certain function, how should I design the circuit parameters?" or "Why is this solution better than the other?"—thereby gradually developing their design thinking, optimization awareness, and decision-making ability through problem-based exploration.

4.4 Innovation in Evaluation Mechanisms: From "Outcome Assessment" to "Process-Oriented, Data-Driven Learning Companion"

Through deep integration with an online platform, the textbook transforms from a passive assessment medium into an active learning companion. It continuously records students' learning behavior data—such as video engagement time, number of simulation attempts, and patterns of errors—and generates personalized learning reports and recommendations. This not only helps students monitor and adjust their own learning processes but also provides teachers with unprecedented insight into class-wide learning dynamics. Teaching feedback thus shifts from experience-driven to data-driven, forming a positive "evaluation–feedback–improvement" cycle that promotes continuous enhancement of teaching quality.

5. Conclusion

The development of the Circuit Principles textbook based on the standards of national first-class courses is a systematic and innovative endeavor. It requires us to adhere to the fundamental mission of fostering virtue through education, adopt a student-centered and outcome-oriented approach, and construct a new-type textbook system that integrates value orientation, scientific rigor, frontier relevance, interactivity, and practicality. Through comprehensive innovation in educational philosophy, structural design, and implementation methodology, this

textbook will better serve the teaching practice of first-class courses, effectively stimulate students' learning potential, and cultivate solid engineering foundations, innovative thinking skills, and strong humanistic qualities.

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