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# *Transformations and Challenges Brought by Generative AI to the Teaching of "Electrotechnics and Electronics"*

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***Abstract:*** With the rapid development of generative AI, intelligent systems—represented by large language models—are profoundly influencing the pedagogical models and learning methods of higher education. As a critical foundational course for engineering majors, Electrotechnics and Electronics is characterized by abstract theories, extensive mathematical derivations, and strong practical requirements. Traditional teaching models have increasingly revealed shortcomings in stimulating student interest and meeting personalized learning needs. Generative AI demonstrates significant advantages in areas such as intelligent tutoring, automated content generation, experimental and simulation assistance, and learning assessment, providing new opportunities for curriculum reform. However, its application in teaching also faces a series of challenges, including academic integrity, increased student dependency, the shifting role of educators, and the reconstruction of evaluation systems. This paper systematically analyzes the application scenarios of generative AI in the teaching of Electrotechnics and Electronics, explores the pedagogical transformations and potential risks it brings, and proposes corresponding strategies to provide a reference for the reform of related engineering courses.

## 1. Introduction

In November 2022, the artificial intelligence research laboratory OpenAI officially released the conversational large language model, ChatGPT. As a representative application evolved from Generative Pre-trained Transformer (GPT) technology, ChatGPT leverages deep learning and reinforcement learning from human feedback. Based on pre-training with massive datasets, it has demonstrated exceptional capabilities in natural language understanding, knowledge expression, and content generation [1]. Compared to previous AI chat systems, ChatGPT exhibits significant advantages in maintaining continuous dialogue, proactive questioning for clarification, human-like linguistic expression, and contextual memory, rapidly sparking widespread global attention and in-depth discussion.

From the perspective of technical evolution, the widespread acclaim for ChatGPT is no coincidence. As early as 2020, GPT-3 was selected as one of the "10 Breakthrough Technologies" by MIT Technology Review, triggering sustained interest in the large-scale model paradigm across academia and industry [2]. Subsequently, the next-generation models based on the GPT-4 core achieved further leaps in multimodal understanding, complex reasoning, and cross-domain knowledge transfer, moving large model technology from laboratory research toward the stage of large-scale application. Based on the diffusion of innovations theory, this phase can be viewed as a critical node where large model natural language processing technology comprehensively moves into application scenarios—a period also referred to as the "post-ChatGPT era."

The rapid development of generative AI is reshaping the educational ecosystem with unprecedented depth and breadth. Generative AI tools, represented by ChatGPT, DeepSeek, DALL·E, and Codex, are breaking through multiple boundaries of traditional teaching in terms of time, space, and cognitive methods through their capabilities in natural language processing, multimodal content generation, and code analysis [3]. This not only changes the production logic of teaching resources and the design of learning paths but also presents a fundamental challenge to the long-standing teacher-centered "teaching-learning" boundary.

In the field of engineering education, the impact of generative AI is particularly pronounced. Electrotechnics and Electronics, a core foundational course for non-electrical engineering majors, covers various knowledge modules including circuit analysis, analog electronic technology, and digital electronic technology. It is characterized by high theoretical abstraction, complex mathematical derivations, and a strong dependence on engineering practice. For a long time, the teaching practice of this course has faced prominent issues such as difficulty in conveying theoretical depth, challenges in deepening practical experience, and a disconnect between student understanding and application, which have become significant bottlenecks restricting the quality of engineering talent cultivation [4].

The intervention of generative AI offers new possibilities for resolving these teaching dilemmas. On one hand, it can assist students in achieving a cognitive leap from conceptual understanding to problem-solving by automatically generating multi-level instructional texts, problem explanations, and personalized learning suggestions. On the other hand, it provides intelligent support for teachers in instructional design, case construction, and learning assessment, helping to drive a shift in teaching models from "experience-driven" to "data- and intelligence-driven." However, the extensive application of generative AI in teaching is accompanied by a series of potential risks, including technical dependence, academic integrity, the weakening of cognitive abilities, and ethical and governance issues; its application boundaries and regulatory frameworks require urgent and in-depth exploration [5]. Consequently, systematically analyzing the transformative opportunities and practical challenges brought by generative AI to the teaching of Electrotechnics and Electronics—and clarifying its empowerment paths and application boundaries—holds important theoretical significance and practical value for promoting innovation in foundational engineering courses, enhancing talent cultivation quality, and achieving the synergistic development of AI technology and higher education.

## 2. Key Transformations in the Teaching of "Electrotechnics and Electronics" Empowered by Generative AI

Generative AI has brought profound transformations to the "Electrotechnics and Electronics" curriculum, encompassing teaching methodologies, learning resources, personalized learning paths, experimental simulations, and assessment mechanisms. By leveraging real-time interaction, dynamic resource generation, and individualized support, generative AI addresses the challenges of student diversity and limited experimental resources. Furthermore, AI facilitates a shift in learning assessment from result-oriented to process-oriented approaches, providing a more comprehensive evaluation of instruction. These transformations offer new opportunities to enhance teaching quality and cultivate student competencies.

### 2.1. Transition of Teaching Methods from "One-way Lecturing" to "Intelligent Interaction"

Traditional classroom instruction in "Electrotechnics and Electronics" predominantly employs a teacher-centered "one-way lecturing" model. The teaching process relies heavily on blackboard derivations or slide presentations, where students passively receive knowledge through listening and post-class exercises. While this model offers certain advantages in systematic knowledge transmission, its limitations have become increasingly apparent given the reality of diverse student backgrounds, varying paces of comprehension, and the growing demand for personalized learning. On one hand, limited classroom time makes it difficult for instructors to cater to varying levels of understanding regarding abstract theories and complex derivations. On the other hand, students' immediate confusion during the learning process often lacks timely and effective feedback, easily leading to knowledge gaps and a sense of frustration.

Generative AI can leverage natural language understanding and generation capabilities to respond to student inquiries in real-time. It can dynamically generate hierarchical and targeted explanations based on the student's phrasing, cognitive level, and contextual information [6]. For instance, in learning abstract topics such as Kirchhoff's Laws, phasor methods, and the operating principles of amplifier circuits, generative AI can provide supplementary explanations from multiple dimensions—including formula derivation, physical significance, and engineering examples. This supports students in conducting multi-round follow-up questions and iterative learning, creating a learning experience akin to "one-on-one tutoring." This interaction-centric approach significantly enhances feedback and engagement, driving the transition of classroom instruction from "teaching-centered" to "learning-centered." Consequently, the role of the teacher is evolving from a knowledge transmitter to a learning facilitator and instructional designer. By constructing a collaborative "Teacher-Student-AI" teaching model, the effectiveness and quality of the "Electrotechnics and Electronics" curriculum are further enhanced.

### 2.2. Transition of Learning Resources from "Static Textbooks" to "Dynamic Generation"

Traditional teaching resources for "Electrotechnics and Electronics" rely mainly on textbooks, problem sets, and fixed courseware. These resources suffer from long update cycles and singular presentation formats, making it difficult to adjust flexibly based on teaching progress or student differences. Furthermore, their ability to support abstract concepts such as electromagnetic field distribution and transient processes is limited. The introduction of generative AI provides a new technical pathway for reconstructing the supply model of learning resources. Based on course syllabi and student feedback, generative AI systems can dynamically generate exercises, case studies, and engineering scenarios at different difficulty levels, achieving an on-demand supply of instructional resources [7].

Depending on the format of the resource, generative AI enables the presentation of circuit operation processes, phasor variations, and field distributions through dynamic graphics or multi-level schematic forms, lowering the barrier to understanding abstract concepts. Meanwhile, leveraging the code-generation capabilities of models like Codex, circuit simulation resources can be rapidly constructed via natural language commands, significantly improving the generation efficiency and scalability of experimental resources.

Overall, generative AI is driving the shift of learning resources in "Electrotechnics and Electronics" from "pre-compiled" static textbooks to "on-demand" dynamic services. This not only improves the flexibility and precision of resource supply but also provides strong support for individualized instruction and the implementation of engineering-oriented teaching models.

## 2.3. Personalized Reconstruction of Learning Paths

The personalized reconstruction of learning paths represents another key breakthrough brought by generative AI. Traditional courses are often constrained by a uniform teaching pace, leading many students to report a gap in understanding between theoretical derivation and engineering practice. By analyzing a learner's cognitive trajectory in real-time—including exercise accuracy, experimental reports, simulation operational paths, and knowledge retrieval records—generative AI can construct individualized "knowledge-competency" topological maps. For example, learners with a shallow understanding of Kirchhoff's Laws will receive a customized, progressive case package from the AI that spans from DC circuits to AC systems. Each case embeds error simulations, reinforcing cognitive mastery through "failure-based learning." Such adaptive learning systems improve average knowledge internalization efficiency by 60%, particularly helping to bridge the gap between theoretical calculation and engineering practice commonly found among engineering students.

## 2.4. Intelligent Upgrading of Experimental and Simulation Teaching

Experimental teaching in "Electrotechnics and Electronics" is heavily dependent on hardware equipment, lab space, and instructional time. It is often restricted by the number of lab benches, component losses, and potential safety risks, which limit students' practical opportunities and the depth of their experimentation. Furthermore, traditional experimental teaching focuses primarily on verification-based experiments, where processes and result analysis rely heavily on on-site instructor guidance, making it difficult to meet the needs for personalized practice and iterative testing.

The introduction of generative AI offers a new path for the intelligent upgrading of experimental and simulation teaching. By integrating generative AI with circuit simulation platforms, students can complete the entire experimental workflow—including circuit design, parameter configuration, operating condition switching, and result analysis—within a virtual environment. During the experiment, the AI system can identify abnormal phenomena in real-time based on the student's actions and simulation results, providing intelligent prompts for issues such as wiring errors, improper parameter settings, or unreasonable model assumptions. Additionally, generative AI supports the expansion of diverse experimental tasks. Beyond traditional verification, the system can guide students through parameter sensitivity analysis, extreme condition simulations, and typical fault injection experiments (e.g., short circuits, open circuits, or component parameter drift), enabling students to deeply understand circuit working mechanisms and failure characteristics without safety risks. Meanwhile, AI can perform comparative analyses of different experimental schemes, helping students understand engineering trade-offs and enhancing the comprehensive and exploratory nature of experimental teaching.

## 2.5. Transition of Learning Assessment from a "Result-oriented" to a "Process-oriented" Approach

In traditional pedagogical evaluation, student learning effectiveness is primarily measured through summative indicators such as midterm and final exams and lab reports. The focus is on the correctness of calculations and the completeness of experimental conclusions, with little attention paid to cognitive performance during conceptual understanding, reasoning paths, and problem-solving processes. This result-oriented approach fails to fully reflect a student's true learning state and hinders timely instructional adjustments by the teacher.

The development of generative AI provides technical support for shifting assessment from a result-oriented to a process-oriented model. It enables the comprehensive analysis of multi-source behavioral data, including homework text, problem-solving steps, experimental and simulation trajectories, and the questioning and correction process during human-AI interaction. This allows for a more systematic characterization of student performance in conceptual construction, logical reasoning, and problem-solving. Based on this, generative AI supports the implementation of formative assessment mechanisms. Teachers can use intelligent analysis to continuously monitor cognitive changes and competency development, identifying common issues and individual differences to make targeted instructional adjustments. Assessment standards are gradually shifting from "is the answer correct?" to "how did they think?", "do they understand?", and "can they transfer this knowledge?", guiding students to value the learning process itself.

## 3. Key Challenges of Implementing Generative AI in Teaching

While generative AI presents broad application prospects for education, its deep integration into teaching practice faces a series of practical challenges [8]. Currently, defining the boundaries of academic integrity, the potential erosion of student initiative, and the reconfiguration of teacher roles within the context of technological integration have become prominent issues requiring urgent attention and resolution.

### 3.1. Issues of Academic Integrity and Learning Authenticity

Generative AI possesses the capability to rapidly generate homework solutions, experimental reports, and technical descriptions. While this enhances learning efficiency, it also poses challenges to academic integrity and the authenticity of learning [9]. In the "Electrotechnics and Electronics" curriculum, many calculation and analysis problems, as well as lab reports, follow standardized solution patterns. If students use tools like ChatGPT to directly generate answers, they may bypass the necessary thinking and derivation processes, thereby weakening the internalization of knowledge. Without clear usage guidelines and process-oriented supervision, generative AI could be used as a substitute for completing learning tasks, leading to academic misconduct such as plagiarism and contract cheating. This undermines the fairness of course assessments and the credibility of evaluation results. Consequently, defining the reasonable boundaries of AI assistance while safeguarding the authenticity of the learning process is a critical issue that must be addressed.

### 3.2. Students' Over-reliance on Artificial Intelligence

The high efficiency of generative AI in problem analysis and step-by-step derivation may lead some students to view it as an "instant problem-solving tool" rather than a learning aid. In "Electrotechnics and Electronics," the development of skills such as circuit modeling, formula derivation, and parameter analysis relies on iterative thinking and independent reasoning. If students rely excessively on AI for direct solutions when facing difficulties, their ability to analyze the essence of problems may be weakened, hindering the cultivation of engineering mindsets and systemic modeling capabilities. Chronic over-reliance on AI may compromise students' independent problem-solving capacities in isolated environments. This creates a critical "knowledge-application gap" where learners master tool proficiency at the expense of grasping fundamental engineering principles. Therefore, guiding students to use generative AI as a "cognitive scaffold" rather than a "mental substitute" is a vital challenge in its pedagogical application.

### 3.3. Pressures Arising from the Transformation of Educator Roles and Competency Frameworks

The deep integration of generative AI into the teaching process imposes new requirements on educator roles and competency structures. In traditional "Electrotechnics and Electronics" instruction, educators primarily handle knowledge lectures and grading. In the context of widespread generative AI application, educators must shift toward designing learning tasks, facilitating the learning process, and monitoring educational quality. This transition requires not only strong curriculum reconfiguration and instructional design skills but also basic AI literacy to understand the capabilities, boundaries, and potential risks of generative AI. For many educators, completing this role transition, mastering relevant technologies, and effectively integrating them into practice within a limited timeframe presents significant pressure, placing new demands on university teacher training and support mechanisms.

### 3.4. Rising Complexity in Assessment-Goal Alignment

The participation of generative AI in learning activities significantly increases the complexity of educational evaluation. On one hand, students may use AI tools to varying degrees during assignments, experimental analysis, and report writing, making it difficult for traditional result-oriented evaluation methods to accurately reflect their true proficiency. On the other hand, the "Electrotechnics and Electronics" curriculum typically carries the responsibility of foundational competency cultivation within the Engineering Education Accreditation system, which has clear requirements for knowledge mastery, engineering analysis, and problem-solving skills. Constructing an evaluation system that allows for the reasonable use of AI while effectively distinguishing between "AI assistance" and "genuine student capability"—and ensuring alignment with course objectives and accreditation standards—remains an essential problem to be explored and resolved [10].

## 4. Response Strategies and Suggestions for Teaching Reform

While generative AI enhances efficiency and personalization in 'Electrotechnics and Electronics' instruction, it necessitates a shift in addressing academic integrity and competency development. Educators must position AI as a pedagogical assistant rather than a substitute for cognition. Instructional designs must be restructured to emphasize process-oriented assessment and critical thinking, thereby reducing excessive reliance on AI. Simultaneously, education on information literacy and academic norms should be strengthened to ensure the responsible use of intelligent tools and educators should apply generative AI appropriately to curriculum design and instructional reflection. Through these strategies, the integration of generative AI and teaching can be effectively achieved, nurturing versatile engineering professionals who possess both a solid engineering foundation and the ability to apply intelligent tools.

### 4.1. Positioning Artificial Intelligence as a Pedagogical Assistant

In the "Electrotechnics and Electronics" curriculum, generative AI must be positioned strictly as a pedagogical assistant designed to augment comprehension, rather than a substitute for independent thinking and calculation. To achieve this, universities should specify the boundaries of AI tool usage within course syllabi to ensure applications remain within a supplementary scope. For example, instructors may designate AI tools to help students grasp complex circuit analysis concepts or generate multi-level exercises to consolidate knowledge, but they must prohibit students from using them as "direct problem-solvers." Furthermore, educators must prioritize independent analytical reasoning in engineering problem-solving to ensure students maintain intellectual autonomy and gain authentic experience during knowledge construction. Through such regulations, generative AI can maximize its utility without undermining students' autonomous learning abilities.

### 4.2. Reconstructing Instructional Design and Assessment Methods

To better adapt to the application of generative AI in teaching, instructional design and assessment methods require a comprehensive reconstruction. Traditional assessments that use the "correct answer" as the sole criterion can no longer fully reflect a student's learning process or depth of thought. Therefore, curricula should increase the proportion of classroom discussions, experimental designs, open-ended questions, and formative assessments to reinforce active thinking and innovation. Especially for engineering courses like "Electrotechnics and Electronics," the assessment of experimental design and practical problem-solving skills is vital. By designing open-ended problems, educators can encourage proactive exploration and analysis, avoiding simple reliance on AI-generated solutions and promoting the cultivation of critical thinking and engineering practice skills. Additionally, formative assessment allows for the tracking of learning trajectories, helping educators identify weak points in real-time for personalized guidance and dynamic instructional adjustments.

### 4.3. Strengthening Student Education on Information Literacy and Academic Norms

With the widespread application of generative AI, educating students on academic norms and information literacy has become particularly important. First, students should be guided to correctly recognize both the advantages and limitations of generative AI. While generative AI can provide real-time feedback and help students quickly understand complex concepts, it cannot replace their own thought and practice. Educators should use case studies and seminars to guide students in using AI tools correctly, preventing them from becoming "shortcuts" that hinder deep learning. Second, strengthening academic integrity education is crucial. Students must clearly understand the risks of academic misconduct when using AI for assignments or lab reports and recognize the negative impact such behavior has on personal growth and academic development. By cultivating an awareness of the responsible use of intelligent tools, educators can enhance students' ethical standards in both academic and professional contexts, laying the foundation for nurturing high-quality electrical engineering professionals.

### 4.4. Enhancing Educators' AI Literacy and Pedagogical Capabilities

The effective application of generative AI depends on educators' profound understanding and reasonable use of the technology. Thus, improving educators' AI literacy and pedagogical capabilities is a key step in current educational reforms. Universities should utilize teaching seminars, specialized training, and online learning to help faculty understand the basic principles, development trends, and application methods of AI in curriculum design. Additionally, educators should use practical cases to learn how to utilize AI tools for instructional design, learning behavior analysis, and pedagogical reflection. For instance, educators can use generative AI to assist in answering difficult student questions or utilize intelligent analysis of homework data to understand learning progress in real-time, providing a basis for subsequent teaching adjustments. Enhancing educators' AI literacy not only helps educators adapt to new teaching models but also, through their leadership, improves the overall AI application proficiency of students, driving the systemic transformation toward intelligent education.

## 5. Typical Case Studies in "Electrotechnics and Electronics"

In the process of empowering the "Electrotechnics and Electronics" curriculum with generative AI, the following typical cases demonstrate its specific role in enhancing teaching effectiveness and cultivating student competencies:

**Case 1: Generative AI-Assisted Circuit Analysis Instruction**

To address issues such as unclear modeling logic and non-standardized analytical processes encountered by students in complex circuit analysis, generative AI is introduced as a supporting tool for both in-class and after-school learning. Students are required to use generative AI to self-check and reflect on their logic for node selection, loop partitioning, and equation formulation before solving problems, rather than simply obtaining numerical results. Practice shows that this approach effectively guides students to focus on the logical process of circuit analysis, reduces conceptual errors, and significantly improves circuit modeling and systemic analysis skills, successfully transitioning learning from a "result-oriented" to a "process-oriented" model.

**Case 2: Generative AI-Supported Analog Electronic Circuit Design**

In the teaching of electronic technology, generative AI is introduced to assist students with circuit scheme demonstration and parameter sensitivity analysis for common-emitter amplifiers and operational amplifier applications. By assigning open-ended design tasks, students are guided to use generative AI to compare performance differences between various circuit architectures and analyze the impact of parameter variations on gain, bandwidth, and stability. Teaching practice demonstrates that this model helps strengthen students' understanding of electronic circuit mechanisms, enhances engineering design thinking and scheme evaluation capabilities, and reduces the rote application of formulas.

**Case 3: Integrating Generative AI into Experimental Teaching**

In the experimental teaching phase, generative AI is integrated into the pre-experiment preparation and post-experiment analysis stages. Before experiments, students use generative AI for self-testing on experimental principles and outlining operational procedures. After experiments, it is used to assist in analyzing the sources of experimental error and the rationality of results, rather than directly generating the report. Results indicate that this model effectively improves classroom efficiency, deepens students' understanding of experimental phenomena, reduces the rate of identical reports, and promotes an overall improvement in experimental teaching quality.

These typical cases demonstrate that generative AI can effectively support key components of the "Electrotechnics and Electronics" curriculum, including circuit analysis, electronic design, and experimental teaching. Under the premise of reasonable and standardized use, positioning generative AI as a "tool for learning guidance and competency promotion" helps drive the curriculum's transformation toward a core focus on skill cultivation and the shaping of engineering mindsets.

## 6. Conclusions

The rapid development of generative AI has brought significant transformations to the "Electrotechnics and Electronics" curriculum, enhancing teaching efficiency, supporting personalized learning, and strengthening the interactivity of experimental and simulation teaching. Generative AI tools are steering education from a simple 'tool-assisted' model toward a 'smart symbiosis' model. This shift drives systemic innovation in teaching methods, learning resources, learning paths, and assessment mechanisms." However, this evolution also presents issues such as academic integrity risks, the potential weakening of student skill development, and a lack of adaptability in teaching evaluation systems. How to ensure educational equity and foster students' thinking skills while fully leveraging the advantages of Generative AI has become an urgent challenge for the contemporary educational community.

In the post-generative AI era, the teaching of "Electrotechnics and Electronics" requires a reconstruction of the three-dimensional objective system—integrating "theory, simulation, and practice"—to include AI ethics, human-AI collaboration, and engineering practice skills as core curriculum goals. Higher education institutions should actively respond to this transformation by developing a hybrid curriculum that integrates virtual simulations with physical experiments. Furthermore, it is essential to refine the usage standards for AI tools, clarifying their role as pedagogical aids and defining their application boundaries to ensure the authenticity and fairness of the teaching process. Meanwhile, generative AI should serve as an empowering tool for education rather than a replacement for the primary educators. Future instruction in "Electrotechnics and Electronics" should leverage human-AI collaboration to facilitate a deeper understanding of the essence of electrotechnical theories, engineering mechanisms, and practical laws. Only by promoting technological innovation while upholding the core values of engineering education—the cultivation of practical ability and critical thinking—can we achieve a healthy integration of generative AI and curriculum instruction. This approach is essential to nurturing a new generation of electrical engineering professionals who possess both engineering literacy and intelligent mindsets.

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