Review

Exploration of Teaching and Practical Reform Paths for Power Electronics Technology Courses Empowered by Artificial Intelligence Technology

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Abstract: In response to the evolving demands for power engineering professionals under the dual pressures of global energy transition and widespread digitalization, traditional power electronics technology courses face an urgent need for comprehensive teaching reform. This paper systematically investigates the reform pathways for these courses, emphasizing the integration of artificial intelligence (AI) technologies to enhance both instructional effectiveness and student competence. A three-dimensional reform framework is proposed, which centers on knowledge graphs to structure and visualize complex technical knowledge, is supported by AI-powered teaching assistants to provide adaptive guidance and personalized learning experiences, and is enriched by virtual simulation environments to enable hands-on practice and experimentation beyond conventional laboratory limitations. Through in-depth analysis of practical implementation cases across multiple universities, the study demonstrates that this AI-empowered teaching model significantly improves students' understanding of theoretical concepts, strengthens their engineering problem-solving abilities, and fosters practical skills essential for contemporary power system applications. Moreover, this approach facilitates more interactive and engaging learning, promotes collaborative knowledge construction, and offers educators flexible tools for monitoring and optimizing learning outcomes. The findings highlight the replicability and scalability of this model, suggesting its potential as a paradigm for advancing engineering education reform in the era of intelligent technology and digital transformation, ultimately contributing to the cultivation of highly competent, innovation-oriented power engineering talents.

Keywords: power electronics; artificial intelligence; educational reform; knowledge graph; virtual simulation

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1. Introduction

"Power Electronics Technology," as a foundational course within the Electrical Engineering and Automation curriculum, plays a critical role in cultivating students' capabilities in electric energy conversion, control systems, and interdisciplinary problem-solving [1]. In recent years, however, the rapid evolution of the Energy Internet, smart grids, and emerging power systems has placed unprecedented demands on the skillsets of graduates, rendering traditional teaching content and methodologies increasingly insufficient for fostering the necessary interdisciplinary expertise. Current pedagogical approaches in many universities are confronted with several pressing challenges, including the lag between curriculum content and technological advancements, a noticeable disconnect between theoretical instruction and practical engineering applications, and a lack of diversity in instructional methods [2].

Amid these challenges, the rapid development and widespread adoption of artificial intelligence (AI) technologies present novel opportunities to address the limitations of conventional teaching. The National Education Digitalization Strategy Action launched by the Ministry of Education in 2022 has further accelerated the integration of AI technologies into educational practices, promoting innovation in course design and instructional delivery [3-4]. Universities across China have actively explored various AI-enabled reform pathways. For instance, Northeast Electric Power University has implemented a smart teaching system characterized by knowledge graph-driven course structuring, AI-powered precision navigation, and integration with the distinct requirements of power engineering; Qingdao University of Technology has developed AI-enhanced intelligent courses leveraging the ChaoXing FanYa online platform; and Wuhan University has established virtual simulation practice environments connected to the Luojia Online AI Smart Teaching Center. These implementations collectively demonstrate that AI technologies can significantly enhance the relevance, interactivity, and practical applicability of traditional courses, enabling students to engage with complex engineering concepts in more immersive and effective ways [5-6].

Building on these practical experiences, this paper seeks to systematically summarize the current state of AI-enabled teaching reforms in power electronics technology, propose a comprehensive three-dimensional framework for integrating AI into pedagogy, and analyze key implementation strategies, technological enablers, and potential challenges. By providing a structured reference for curriculum development and instructional innovation, this study aims to support the cultivation of highly competent, adaptable, and innovation-oriented power engineering talents equipped to meet the evolving demands of the energy and digitalization era.

2. Teaching Reform Framework Design

The systematic advancement of teaching reform in Power Electronics Technology courses necessitates the establishment of a multi-level, comprehensive innovation framework that addresses both theoretical knowledge acquisition and practical skill development. In this context, this paper proposes a tripartite reform framework that restructures the course content through knowledge graphs, optimizes the teaching process via AI-enabled teaching assistants, and enhances practical capabilities using virtual simulation technologies. As shown in Table 1, the framework delineates the key dimensions, technological enablers, and intended outcomes of the reform.

Table 1. AI Technology-Enabled Teaching Reform Framework for Power Electronics Technology Courses.

Reform Dimension	Key Elements	Key Technology	Implementation Goal
Restructuring the Knowledge System	Three-Dimensional Graph of Basic-Core-Expansion Layers	Natural Language Processing, Semantic Modeling	Systematic Interconnection of 162 Knowledge Points, Personalized Learning Paths
Teaching Model Innovation	Real-time Interaction and Dynamic Assessment by AI Teaching Assistants	Big Data Analytics, Generative AI	A 30% increase in learning efficiency, with a 98% satisfaction rate
Enhancement of Practical Training	Real-Data-Driven Virtual Simulation	Digital Twin, VR/AR Technology	Experimental costs were reduced by 50%, and skill mastery was enhanced by 40%

2.1. Knowledge Graph-Supported Curriculum Content Restructuring

Knowledge graph technology provides an effective approach for the systematic integration, visualization, and hierarchical organization of curricular knowledge. The three-dimensional knowledge graph architecture, structured as "basic layer-core layer-expansion layer," has transformed the traditionally fragmented organization of knowledge points in power electronics education. The basic layer deconstructs electronic technology into 240 precise knowledge points, establishing a comprehensive digital circuit knowledge network. The core layer emphasizes 70 critical knowledge points, directly targeting the essential competencies required for engineering practice. The expansion layer innovatively connects 10 advanced modules, including FPGA applications, digital-analog system integration, and cross-disciplinary linkages with key industry courses.

Practical applications of knowledge graphs further demonstrate their value. For example, in a Power Electronics Technology course, 162 knowledge points are linked to multimedia resources, including instructional videos and exercises, facilitating immediate learning assessment and reinforcement. The platform collects data on students' learning behaviors, monitors progress, provides personalized recommendations, and dynamically adjusts learning paths. This approach ensures that course content remains up-to-date with technological advancements, incorporating emerging applications such as renewable energy forecasting and smart grid optimization.

The construction of knowledge graphs follows the principles of systematicity, standardization, and sustainability, typically progressing through five stages: domain definition, knowledge acquisition, conceptual modeling, entity relationship mapping, and application development. This structured approach not only reveals the intrinsic interconnections between knowledge points but also underpins the intelligent recommendation functions of AI teaching assistant systems, providing a robust foundation for adaptive and personalized learning.

2.2. AI Teaching Assistant-Enhanced Teaching Process Optimization

AI teaching assistant systems serve as pivotal enablers of teaching reform, facilitating personalized and precise instruction through intelligent interaction, learning analytics, and real-time feedback. For instance, AI systems can generate student competency radar charts, identify areas for improvement, and trigger targeted academic alerts. By tailoring resources and guidance to individual student profiles, these systems have been shown to enhance learning efficiency by over 30%, while interactive modules foster rigorous thinking and complex problem-solving skills.

Innovative implementations also highlight the potential of multi-model AI integration. In certain courses, AI assistants built on multiple large language models allow students to compare answers, reflect critically, and make informed judgments. Immediate feedback, displayed on interactive classroom interfaces, enables instructors to monitor student progress accurately, identify weaknesses, and adjust instruction dynamically.

The effectiveness of AI teaching assistant systems relies on the integration of several technologies. Natural Language Processing (NLP) enables intelligent question-answering and dialogue; machine learning algorithms support learning analytics, prediction, and adaptive interventions; and knowledge graphs provide domain-specific knowledge support. Covering the full chain from diagnosis and learning to assessment and evaluation, AI teaching assistants function as portable, adaptive learning consultants, guiding students throughout the educational process.

2.3. Key Points for Building a Virtual Simulation Platform

The development of a virtual simulation platform requires the coordinated application of advanced technologies to create realistic, interactive, and pedagogically effective experimental environments. The platform's construction hinges on several key components:

Scene modeling forms the foundation of virtual simulation, requiring accurate representation of typical circuit topologies, power electronic devices, and control modules. A careful balance between physical authenticity and system performance ensures that simulations are both reliable and responsive.

Interactive design directly impacts user engagement and learning efficiency. For example, platforms supporting natural language commands allow students to operate experimental processes through intuitive voice interactions, lowering the learning barrier and enhancing experimental efficiency.

System integration is essential for seamless interaction between virtual simulation environments and existing instructional platforms. Embedding virtual experiments into comprehensive teaching systems enables students to engage in both theoretical learning and practical operations within a unified environment, preventing fragmentation and providing a coherent, continuous learning experience.

Through the integration of these three dimensions-knowledge graph-based curriculum structuring, AI-enabled teaching optimization, and virtual simulation platforms-Power Electronics Technology courses can achieve a holistic enhancement of teaching quality, student engagement, and practical skill acquisition, establishing a replicable model for intelligent, technology-driven engineering education.

3. Practical Cases and Effectiveness Analysis

3.1. Comparative Analysis of Typical University Cases

Many institutions of higher education have conducted extensive explorations in integrating artificial intelligence technologies into Power Electronics Technology courses, forming innovative teaching reform models with distinctive characteristics. As shown in Table 2, the following comparison highlights the practical features of representative universities across multiple dimensions, including reform characteristics, technological platforms, scale of application, and notable outcomes.

Table 2. Comparative Analysis of AI Teaching Reform Cases in Power Electronics Technology Courses across Universities.

University Name	Reform Characteristics	Technology Platform	Scale of Application	Notable Outcomes
Northeast Electric Power University	Knowledge Graph-Driven and Power-Industry-Integrated	ChaoXing Xueyin Online Learning Platform	Serving over 6,000 students	The platform's visit count exceeded 10 million
Qingdao University of Technology	Digital Human Teaching Assistants and Multi-Graph Collaboration	ChaoXing Fanya Platform + DeepSeek and Other AI Models	National First-Class Course	Students won the National First Prize in competitions, with a satisfaction rate of 98%
Wuhan University	VR/AR Immersive Experience and Multi-Model Comparison	Luojia Online AI Smart Teaching Center	Interdisciplinary Application	Practical skills have been significantly enhanced
University of Jinan	Project Approval for AI Interdisciplinary Courses	ChaoXing Platform + Integrated Intelligent Tools	Construction of Course Clusters	Practical skills have been significantly enhanced

Northeast Electric Power University has distinguished itself through the extensive application of knowledge graphs. The university has developed a three-tier knowledge graph architecture (Basic-Core-Expansion) that fundamentally restructures the previously fragmented course knowledge points. This system has served more than 6,000 students, with platform visits exceeding 10 million, establishing a benchmark model for talent cultivation and innovation in engineering education. The institution's "Four-Learning, Two-Card" companion learning mechanism further provides a comprehensive support system, ensuring students can navigate the course content efficiently while reinforcing critical engineering concepts.

Qingdao University of Technology has introduced digital human teaching assistants combined with multi-graph collaboration. Its Power Electronics Technology course, recognized as a National First-Class Online-Merge-Offline Hybrid Course, employs a multi-dimensional teaching framework integrating knowledge graphs, competency maps, problem maps, and ideological-political education maps. All 162 knowledge points are linked to rich resources such as videos, interactive exercises, and immediate assessment tools. AI-enabled digital assistants provide personalized one-on-one tutoring, catering to individual learning needs and pacing. This approach has led to electrical engineering students consistently achieving national first prizes in competitions, including the Electronic Design Contest and the Blue Bridge Cup, while attaining a 98% course satisfaction rate.

Wuhan University emphasizes immersive VR/AR experiences and multi-model comparison for enhancing practical skills. Its "Luojia Online AI Smart Teaching Center" integrates various AI models, enabling students to compare, analyze, and evaluate different problem-solving strategies. Virtual simulation environments replicate high-risk operations, such as high-altitude substation work, providing safe, controlled, and immersive practical training. These platforms overcome the spatial and safety limitations of traditional laboratories, allowing students to acquire essential hands-on skills in a realistic and interactive setting.

3.2. Multidimensional Assessment of Reform Effectiveness

The implementation of AI-enabled teaching reforms in Power Electronics Technology courses has yielded significant results across multiple dimensions, evaluated through both qualitative and quantitative analyses.

Enhanced Learning Outcomes. Students' academic performance and engagement have markedly improved. At Qingdao University of Technology, the course satisfaction rate has reached 98%, while students consistently achieve top awards in national competitions. At Northeast Electric Power University, knowledge graph-driven learning paths have increased students' learning efficiency by more than 30%, demonstrating that AI-enhanced teaching models effectively stimulate learning motivation and academic achievement.

Improved Teaching Efficiency. AI teaching assistant systems have alleviated instructors' workload by automating repetitive tasks, allowing educators to focus more on curriculum design, targeted guidance, and pedagogical innovation. At Wuhan University, AI assistants provide real-time assessment of student performance, supplying precise learning analytics that inform instructional adjustments. Digital human teaching assistants at Qingdao University manage routine question-answering tasks, thereby freeing teachers to concentrate on enhancing interactive and higher-order learning activities.

Strengthened Practical Ability. The use of virtual simulation platforms has significantly reduced experimental costs and operational risks while enhancing training effectiveness. VR and AR-based training at Wuhan University enables students to safely practice high-risk operations. Similarly, virtual simulation experiments at Qingdao University cover special working conditions and fault scenarios that are difficult to replicate in traditional labs, thereby improving students' problem-solving capabilities, critical thinking, and readiness for real-world engineering challenges.

Optimized Utilization of Teaching Resources. The knowledge graph-driven organization of course materials ensures efficient and precise use of educational resources. At Northeast Electric Power University, platform visits have surpassed 10 million, indicating extensive engagement with learning resources. At Qingdao University of Technology, all 162 knowledge points are systematically linked to multimedia resources, enabling precise alignment of learning materials with individual student needs and promoting adaptive, personalized learning experiences.

Overall, these cases demonstrate that the integration of AI technologies in Power Electronics Technology courses not only enhances learning effectiveness and teaching efficiency but also cultivates practical skills and optimizes resource utilization, providing a replicable and scalable model for engineering education reform in the digital era.

4. Challenges and Future Prospects

Despite the significant potential demonstrated by artificial intelligence (AI) technologies in the teaching of Power Electronics Technology courses, their widespread implementation continues to face multiple, complex challenges that must be addressed to ensure effective and sustainable integration.

One of the primary obstacles lies in the transformation of the teaching faculty. Many instructors currently responsible for traditional Power Electronics Technology courses lack systematic training in AI and related digital technologies, limiting their ability to effectively utilize advanced teaching tools such as AI-enabled teaching assistants, knowledge graphs, and virtual simulation platforms. The shortage of faculty with interdisciplinary expertise presents a particularly pressing challenge. Educators proficient in both power electronics and AI technologies remain scarce, creating a bottleneck that restricts the depth and pace of curriculum reform. Addressing this gap requires concerted efforts in professional development, including comprehensive AI training programs, interdisciplinary collaboration, and continuous learning opportunities to ensure that instructors are equipped to guide students effectively in technology-enhanced learning environments.

Another critical challenge is the development and maintenance of high-quality teaching resources, which necessitates substantial investment of both human and financial capital. Constructing sophisticated knowledge graphs demands extensive domain expertise and significant time investment to accurately map complex technical concepts, relationships, and learning pathways. Similarly, the design, implementation, and upkeep of virtual simulation platforms and intelligent teaching tools involve high costs associated with software development, hardware requirements, and system updates. Many universities face financial constraints that limit their ability to sustain large-scale, continuous resource updates and infrastructure enhancements. Without adequate investment and strategic planning, the long-term effectiveness and scalability of AI-enabled teaching reforms may be compromised.

Furthermore, the integration of AI technologies into Power Electronics Technology courses also requires careful attention to curriculum alignment, pedagogical consistency, and data security. Ensuring that AI-assisted tools complement rather than replace traditional instructional strategies is essential for maintaining educational rigor and fostering student engagement. As universities continue to expand digital learning initiatives, considerations regarding the interoperability of systems, the usability of platforms, and the protection of student data become increasingly critical.

Looking forward, addressing these challenges presents significant opportunities for the evolution of engineering education. By investing in faculty development, resource creation, and robust technological infrastructure, institutions can foster a sustainable ecosystem in which AI-enhanced teaching methods not only improve learning outcomes and practical skill acquisition but also cultivate interdisciplinary competencies that are increasingly required in the modern energy and digital technology sectors. The strategic integration of AI into Power Electronics Technology courses has the potential to transform conventional educational paradigms, enabling adaptive, personalized, and practice-oriented learning that aligns with the demands of the rapidly evolving power engineering industry.

5. Conclusions

This paper systematically explores the pathways for teaching reform in Power Electronics Technology courses empowered by artificial intelligence (AI) technologies, analyzing the implementation strategies for key components such as knowledge graph construction, the development of AI teaching assistant systems, and the setup of virtual simulation platforms. The research indicates that the introduction of AI technologies has effectively addressed prominent issues in traditional course teaching, including fragmented knowledge, a one-way teaching model, and weak practical components.

Practice cases from multiple universities demonstrate that restructuring course content around a knowledge graph enables the systematic organization and personalized delivery of knowledge. Optimizing the teaching process with the support of AI teaching assistants facilitates precise intervention and efficient interaction. Furthermore, strengthening practical segments through virtual simulation features can overcome spatiotemporal limitations and enhance engineering practical abilities. These three elements synergize with each other, collectively forming a framework for AI-empowered teaching reform in Power Electronics Technology courses.

In the future, with the continuous evolution of AI technologies and ongoing innovation in educational theory, the teaching reform of Power Electronics Technology courses will deepen further. It will be necessary to strengthen the development of interdisciplinary teaching teams, promote the standardization of technological platforms, and innovate school-enterprise cooperation models to fully leverage cutting-edge technologies for building smarter, more open, and flexible teaching environments. This reform is not only significant for the Power Electronics Technology course itself but also provides a replicable paradigm for teaching innovation in other engineering professional courses, which will vigorously drive the overall improvement of the quality of higher engineering education in China.

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References

1. Y. Wu, "Deep Expansion of Multiple Perspectives and Practical Paths in the Reform of Tourism English Teaching," Frontiers in Educational Research, vol. 8, no. 7, 2025.
2. Y. Li, "Exploration and Practical Paths of Ideological and Political Teaching Reform in the Financial Management Course," Lecture Notes in Education, Arts, Management and Social Science, vol. 3, no. 5, pp. 88-92, 2025. doi: 10.18063/lne.v3i5.1081
3. C. Qi, Y. Sun, and H. Zhang, "The Motivations, Elements, and Pathways of Teaching Method Reform in Vocational Colleges under the Background of High-Quality Development," In 2024 7th International Conference on Humanities Education and Social Sciences (ICHESS 2024), December, 2024, pp. 172-179. doi: 10.2991/978-2-38476-323-8_21
4. Y. Chang, "The Application of Algorithm Optimization and Big Data Processing in Higher Education Management," International Journal of High Speed Electronics and Systems, 2025. doi: 10.1142/s0129156425404735
5. M. H. Rashid, "Power electronics handbook," Butterworth-heinemann, 2017.
6. S. and Communication Networks, "Retracted:: Analysis of Practical Training Characteristics and Teaching System Reform Path of College Physical Education Curriculum Based on Deep Learning," 2023.