Article

Digital and Intelligent Teaching Reform Path of Basic Electrical and Electronic Courses

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Abstract: Against the backdrop of advancing national strategies for modern educational digitalization and deepening New Engineering initiatives, Basic Electrical and Electronic Courses-an essential cornerstone for nurturing engineering talents-have exposed numerous pressing issues in traditional teaching. These include knowledge renewal failing to keep pace with industrial transformations, a clear disconnect between theoretical instruction and engineering practice, and difficulties in implementing personalized education models. Drawing on the mainstream trend of integrating "AI + Education" and referencing the teaching reform experiences of universities such as Guangzhou University and Southeast University, this study delves into feasible pathways for the digital-intelligent transformation of Basic Electrical and Electronic Courses from six core dimensions: renewing teaching concepts, reconstructing curriculum systems, innovating teaching models, upgrading practical platforms, enhancing faculty capabilities, and optimizing evaluation mechanisms. This research aims to establish a digital-intelligent education system supported by technological empowerment, centered on student development, oriented toward competence cultivation, and focused on continuous improvement. It provides referential theoretical insights and practical examples for fostering high-quality engineering and technical talents capable of meeting the demands of industrial digitalization.

Keywords: basic electrical and electronics; digital-intelligent teaching; educational reform; path exploration; new engineering construction

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1. Introduction

Basic Electrical and Electronic Courses encompass core subjects such as Circuit Analysis, Analog Electronics, and Digital Electronics. As a crucial link connecting fundamental disciplinary knowledge with practical engineering applications, the quality of instruction in these courses directly influences the development of students' engineering mindsets and technological innovation capabilities. However, with the rapid adoption of emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and smart hardware, the limitations of the traditional teacher-centered, lecture-based model have become increasingly apparent. Current teaching content often emphasizes abstract theoretical derivations and formula calculations, which may diverge from the practical requirements of modern industrial scenarios. Instructional methods are frequently restricted to slide presentations and blackboard demonstrations, lacking the diversity needed to stimulate active student exploration. Furthermore, practical training is often constrained by physical space, equipment availability, and scheduling, resulting in laboratory sessions that remain largely at a basic verification level. Assessment methods typically rely on final closed-book examinations, which may not fully or accurately reflect students' comprehensive competencies or engineering practice skills.

National strategic guidelines and policy opinions regarding the digital transformation of education have clearly advocated for the construction of an intelligent education system, providing explicit guidance for the digital-intelligent reform of basic electrical and electronic curricula [1,2]. Within this policy and technological landscape, the digital-intelligent transformation of these courses is no longer optional but an essential requirement of the current era. Leveraging core technologies such as AI, Big Data, and Knowledge Graphs, digital-intelligent instruction facilitates a fundamental shift from knowledge transmission to competency cultivation by restructuring educational elements, optimizing instructional processes, and innovating teaching models. This approach offers a novel solution to many long-standing issues in traditional teaching. Research on optimizing electrical and electronic course groups within the context of smart education has indicated that digital-intelligent tools are central to breaking down instructional barriers between courses and enhancing overall educational quality [3]. Based on these perspectives and the reform experiences of various institutions, this paper systematically explores implementation paths for the digital-intelligent teaching of Basic Electrical and Electronic Courses, providing a reference for the high-quality construction of similar curricula.

2. Core Connotation and Practical Significance of Digital-Intelligent Teaching Reform for Basic Electrical and Electronic Courses

2.1. Core Connotation

The digital-intelligent reform of Basic Electrical and Electronic Courses is not merely the integration of digital tools into traditional classrooms as auxiliary components. Rather, it utilizes digital-intelligent technologies as a core driving force to facilitate a comprehensive and profound reconstruction of all educational elements, including instructional concepts, curriculum structures, teaching models, practical platforms, and evaluation mechanisms. Research on the construction of smart courses in electrical and electronics has implemented teaching practices with AI and Knowledge Graphs as dual engines, verifying the significant role of full-element reconstruction in improving the quality and efficiency of engineering courses. These results provide important support for clarifying the core connotation of digital-intelligent teaching reform [4].

Specifically, the core essence of the reform can be summarized into three dimensions. Regarding instructional logic, there is a fundamental shift from a traditional knowledge-oriented concept to a competency-oriented approach, integrating the cultivation of engineering practice capabilities and innovative thinking throughout the entire educational process. In terms of technological application, a multi-dimensional support system comprising AI, Knowledge Graphs, and virtual simulation is established to promote refined, personalized, and intelligent instructional processes. Finally, regarding the educational model, a tripartite collaborative ecosystem of "teacher-AI-student" is constructed, breaking the traditional dual structure of instruction to achieve an organic unity between large-scale education and personalized training, thereby ensuring that each student receives a learning experience tailored to their specific needs.

2.2. Practical Significance

Firstly, it is a specific measure to respond to the national educational digitalization strategy. The digital-intelligent teaching reform is an important practice to implement the plan for building a powerful education country. By promoting the in-depth integration of technology and education and teaching, it leads Basic Electrical and Electronic Courses to develop in the direction of high quality and intelligence, providing a replicable and promotable typical model for the digital transformation of higher engineering education.

Secondly, it is an effective means to solve the problems of traditional teaching. Relying on digital-intelligent technologies, we can specifically address many pain points in traditional teaching: connect fragmented knowledge points into a systematic knowledge network through Knowledge Graphs, break the temporal and spatial limitations of practical teaching with the help of Virtual Simulation technology, and realize accurate judgment of students' learning status and personalized guidance through Big Data analysis, fundamentally solving prominent problems such as the disconnect between theory and practice and the single evaluation method.

Finally, it is a key grasp to adapt to the needs of industrial development. At present, electrical and electronic technology has been widely applied in many fields such as smart devices, new energy, and the IoT, with an accelerating pace of technological iteration. The digital-intelligent teaching reform can timely integrate cutting-edge industrial technologies, new processes, and new standards into the curriculum content, realizing the synchronous resonance between curriculum teaching and industrial needs, and effectively improving the adaptability of talent training to market demands.

3. Practical Dilemmas of Digital-Intelligent Teaching Reform for Basic Electrical and Electronic Courses

3.1. Lagging Teaching Concepts Behind Digital-Intelligent Development

Some educators still adhere to traditional teaching concepts, simply equating digital-intelligent technologies with auxiliary tools such as courseware production and online answering, failing to recognize their transformative value in reshaping the education ecosystem. They have an insufficient understanding of the core connotation of technology empowering education, making it difficult to give full play to the core role of AI, Big Data and other technologies in personalized teaching and precise evaluation. At the same time, the deep-rooted concept of "valuing theory over practice and knowledge over competence" is not in line with the requirements of New Engineering construction for cultivating students' engineering literacy and innovation capabilities, becoming an ideological barrier that hinders the smooth progress of digital-intelligent reform.

3.2. Disconnected Curriculum System from Digital-Intelligent Needs

The prevailing curriculum structure remains predominantly discipline-centered, maintaining distinct boundaries between subjects such as Circuit Analysis, Analog Electronics, and Digital Electronics. Consequently, knowledge points are often presented in a fragmented manner, which can hinder the development of a comprehensive and integrated knowledge system for students. Research indicates that traditional textbooks in this field tend to emphasize mathematical derivations and formula proofs, often resulting in prolonged content update cycles [5]. Modern technical elements, such as intelligent sensing and drive control, may not be integrated into the curriculum in a timely fashion, leading to a gap between instructional content and the rapid evolution of contemporary electrical and electronic technologies [5]. This disconnect can result in an insufficient link between academic theories and practical engineering applications. Without the support of authentic project cases, it becomes difficult for students to effectively translate theoretical knowledge into professional practice. Scholars have suggested that dismantling disciplinary barriers and prioritizing an engineering-oriented focus are essential strategies for addressing these challenges, providing a clear foundation for the subsequent reconstruction of the curriculum system [6].

3.3. Insufficient Innovation in Teaching Models

Most classrooms still adopt the traditional model where instructors lecture and students listen, leaving students in a passive role with limited opportunities for active exploration and interaction. Although some institutions have introduced digital resources such as Massive Open Online Courses (MOOCs) and online assignments, a comprehensive, full-cycle digital-intelligent teaching loop covering pre-class, in-class, and post-class stages has not yet been established. The integration of online resources with offline instruction often remains insufficient, causing blended learning models to become a mere formality. This makes it challenging to provide personalized learning paths and real-time feedback, preventing digital-intelligent technologies from reaching their full potential. Research on the reform of electrical and electronic technology instruction has shown that this superficial digital integration is a widespread issue. The core problem lies in the absence of a systematic reconstruction of instructional models rather than a lack of technological application [7].

3.4. Need for Upgrading Practical Teaching Conditions

Traditional practical teaching is constrained by venues, equipment, funds and other factors. Experimental projects have a high repetition rate and insufficient innovation, mostly focusing on verification experiments, which are difficult to effectively cultivate students' engineering innovation capabilities. Although some universities have built Virtual Simulation platforms, most of them only provide single-function simulation operations, with insufficient in-depth integration with physical experiments, unable to create a real engineering environment. At the same time, the practical teaching resource sharing mechanism is not perfect. High-quality Virtual Simulation projects and experimental teaching resources are difficult to circulate efficiently among different universities and majors, further widening the gap in practical teaching levels between universities.

3.5. Uneven Digital Literacy of Faculty

There is an obvious "technological divide" among the faculty: middle-aged and elderly teachers lack systematic training in AI tools, Knowledge Graph construction, Virtual Simulation design and other technologies, making it difficult for them to independently design and implement digital-intelligent teaching plans; young teachers, although having a certain technical foundation, lack practical experience in the in-depth integration of technology and teaching. In addition, most teachers lack work experience in frontline industry and have an insufficient understanding of the development trend of industrial digitalization, leading to a disconnect between teaching content and engineering practice and affecting the implementation effect of digital-intelligent reform.

3.6. Lack of Digital-Intelligent Support in Evaluation Mechanisms

Traditional evaluation methods mainly rely on final closed-book exams, focusing on assessing students' mastery of theoretical knowledge, while ignoring the evaluation of students' comprehensive literacy such as engineering practice capabilities, innovative thinking, and teamwork capabilities. The sources of evaluation data are single, limited to homework and exam scores, lacking the collection and analysis of multi-dimensional data throughout the whole process of students' pre-class preparation, in-class participation, experimental operations, and project design. It is difficult to form a comprehensive and objective digital portrait of students, and it is impossible to provide scientific data support for teaching optimization.

4. Implementation Paths of Digital-Intelligent Teaching Reform for Basic Electrical and Electronic Courses

4.1. Innovate Teaching Concepts and Establish Digital-Intelligent Education Orientation

Renewing teaching concepts is the basic premise for promoting digital-intelligent transformation. It is necessary to guide teachers to break through traditional thinking stereotypes, establish a teaching concept of "technology empowerment and competence orientation", deeply understand the core role of digital-intelligent technologies in reshaping teaching models and improving teaching quality, and deeply integrate AI, Big Data and other technologies into the entire teaching process to realize the fundamental transformation from "knowledge transmission" to "competence cultivation". Adhere to the student-centered and individualized teaching principle, use digital-intelligent tools to analyze students' learning styles, knowledge gaps and ability levels, design personalized learning paths for students at different levels, and realize "one-on-one precise teaching". At the same time, strengthen the concept of "industry-education integration and the unity of knowledge and practice", closely connect with the digitalization development needs of the electrical and electronic industry, integrate cutting-edge industrial technologies and real engineering projects into the teaching process, build a trinity education framework of "theory-practice-innovation", and realize the organic connection between classroom learning and engineering practice.

4.2. Reconstruct Curriculum System and Build Digital-Intelligent Content Framework

The curriculum system is the core carrier of digital-intelligent teaching reform. Drawing on the practice of constructing the "four-dimensional map" for digital-intelligent courses at Guangzhou University, build a multi-dimensional map framework integrating Knowledge Graphs, Problem Graphs, Competence Graphs and ideological and political views, connecting more than 300 core knowledge points in series and integration according to logical levels, effectively solving the problem of knowledge fragmentation. In accordance with the evolution logic of "component-circuit-module-link-system", integrate the curriculum content into modular units such as Circuit Analysis, Electronic Design, Intelligent Control, and Engineering Practice, realizing the systematic construction of the knowledge system. In terms of content update, timely integrate emerging technologies such as intelligent sensing, Embedded Systems, and the IoT, and eliminate outdated theories and redundant content; refer to the practice model of Southeast University, take autonomous driving electric vehicles as a unified engineering carrier, design progressive engineering tasks, and allow students to master knowledge and improve abilities simultaneously in the process of completing projects. At the same time, deeply explore the ideological and political elements of the curriculum, integrate content such as "China's Intelligent Manufacturing", the "Dual Carbon Strategy", and engineering ethics into teaching, and realize the synchronous resonance of value guidance and knowledge transmission. Break the inherent barriers between courses, build cross-semester, high-credit, theory-practice integrated course groups, realize the seamless connection between Basic Electrical and Electronic Courses and subsequent professional courses, and effectively implement the requirements of engineering orientation and systematic education.

4.3. Innovate Teaching Models and Create Digital-Intelligent Teaching Closed Loop

Innovating teaching models is the key grasp of digital-intelligent reform. Break through the traditional dual teaching structure, build a tripartite collaborative teaching model of "teacher-machine-student", and integrate AI teaching assistants into the entire teaching cycle: pre-class assess students' learning preparation status through pre-tests, and intelligently push personalized preview resources and learning paths; in-class real-time capture students' participation status with the help of intelligent sensing equipment, dynamically adjust teaching strategies, carry out interactive and inquiry-based teaching, and stimulate students' enthusiasm for active learning; post-class generate personalized learning reports, push targeted review materials and extended tasks, forming a complete teaching closed loop of "pre-class diagnosis-in-class interaction-post-class optimization". Adopt Southeast University's integrated "research-learning-practice-competition" model, design progressive project tasks around real engineering problems, guide students to independently complete the entire practical process including demand analysis, scheme design, circuit construction, testing and optimization, transform cutting-edge academic research results into inquiry topics, and cultivate students' innovative thinking and scientific research capabilities. Deepen the reform of "online-offline integration and virtual-physical combination" teaching, build an integrated smart teaching platform, integrate online resources such as MOOCs, Virtual Simulation, and live lectures, and realize the organic combination of independent online learning and in-depth offline interaction. Use Augmented Reality/Virtual Reality (AR/VR) technology to create immersive teaching scenarios, simulate complex circuit debugging processes through VR technology, carry out high-risk and high-cost experiments with the help of Virtual Simulation platforms, make up for the deficiencies of physical laboratories, realize the complementary collaboration between virtual experiments and physical experiments, and expand the boundaries of practical teaching.

4.4. Upgrade Practical Teaching Platforms and Build Digital-Intelligent Practice System

Practical teaching platforms serve as vital support for enhancing students' engineering capabilities. In 2023, a five-in-one virtual-physical integrated practice platform featuring guided research, basic training, comprehensive design, engineering practice, and innovation and entrepreneurship was pioneered. This system integrates multiple resources, including virtual simulations, physical experiments, and innovation-driven training, to facilitate the progressive cultivation of students from basic skills to advanced innovative capabilities. These reform achievements have established a replicable and typical model for engineering education [8]. To further support the high-quality development of smart courses in higher education, inter-university resource-sharing alliances should be established. Such alliances facilitate the cross-institutional circulation of high-quality digital textbooks, virtual simulation projects, and AI-driven instructional tools. Implementing these sharing mechanisms helps narrow the gap in practical teaching standards across different institutions. Furthermore, deepening school-enterprise cooperation through industry-education integration bases with leading enterprises allows for the introduction of advanced technologies and real-world projects into the curriculum. By developing enterprise-specific digital resources, such as intelligent agents and cloud management systems, students can be immersed in authentic engineering environments, significantly improving their practical skills and professional adaptability.

4.5. Strengthen Faculty Construction and Improve Digital-Intelligent Teaching Capabilities

The faculty is the core guarantee for the effective implementation of digital-intelligent reform. Implement the faculty digital literacy improvement plan, carry out special training on AI technology, Knowledge Graph construction, Virtual Simulation design, etc., organize digital-intelligent teaching seminars and workshops, and promote experience exchange and ability improvement among teachers. Relying on multidisciplinary advantages, set up interdisciplinary teaching teams composed of teachers majoring in Electrical Engineering, Automation, Computer Science, etc., absorb enterprise technical experts and industry leaders to participate in teaching, build a collaborative education mechanism of "university teachers + enterprise experts", and make up for the shortage of university teachers' industrial practice experience. Improve the teacher incentive and evaluation system, include the effectiveness of digital-intelligent teaching reform into teacher assessment indicators, commend and reward teachers who have made outstanding achievements in digital-intelligent curriculum construction and teaching innovation; support teachers to carry out research on digital-intelligent teaching reform, apply for teaching reform projects and achievement awards, and fully mobilize teachers' enthusiasm and initiative to participate in the reform.

4.6. Optimize Evaluation Mechanisms and Realize Digital-Intelligent Precision Evaluation

Optimizing evaluation mechanisms is an important link to ensure the effectiveness of the reform. Break through the single exam evaluation model, establish a three-dimensional evaluation index system covering knowledge and skills, engineering capabilities, and comprehensive literacy, which not only assesses students' mastery of theoretical knowledge, but also attaches importance to the evaluation of practical operations, innovative thinking, teamwork and other capabilities; integrate ideological and political evaluation elements, strengthen value orientation, and realize the trinity evaluation goal of "knowledge-ability-literacy". Adopt the whole-process dynamic evaluation method, rely on the smart teaching platform to collect real-time multi-dimensional data of students' pre-class preparation, in-class participation, experimental operations, project design, after-class homework, etc., conduct data analysis through AI technology, generate students' personal digital portraits and class ability matrices, replace the traditional model of "one exam determines everything", and realize the whole-process tracking and dynamic evaluation of the learning process. Establish a closed-loop "evaluation-optimization" mechanism, take evaluation data as an important basis for teaching optimization, adjust teaching content and methods according to students' common shortcomings, and provide personalized guidance for students; regularly review evaluation results, summarize the effectiveness and deficiencies of the reform, continuously optimize the digital-intelligent teaching system, and form a virtuous cycle of "data collection-intelligent analysis-teaching optimization-effect improvement".

5. Reform Effects and Prospects

5.1. Reform Effects

Practice explorations in multiple universities have shown that the digital-intelligent teaching reform of Basic Electrical and Electronic Courses has achieved remarkable results. In terms of teaching quality, the integrated application of Knowledge Graphs and AI has increased students' systematic mastery of knowledge by more than 30%, and their ability to solve engineering problems has been significantly enhanced. This result is highly consistent with the data obtained from similar teaching reforms in relevant universities, further verifying the actual effect of technology empowering teaching. In terms of practical innovation, the construction of the virtual-physical integrated practice platform has increased the experimental opening rate by 40%, greatly stimulating students' enthusiasm for participating in discipline competitions and innovation and entrepreneurship projects, with various innovative achievements emerging continuously. In terms of talent training, the employment rate and job adaptability of graduates have both been significantly improved, gaining wide recognition from industries and enterprises. Among them, through digital-intelligent reform, Southeast University integrated 7 related courses into cross-semester project-based courses, which not only reduced class hours by 35%, but also significantly improved students' comprehensive innovation capabilities, successfully practicing the concept of course group optimization; the digital-intelligent education system built by Shandong University of Technology has achieved outstanding results, having been selected into 6 national first-class undergraduate courses, and its teaching team has won the first prize in the National University Teachers' Teaching Innovation Competition many times with this reform achievement, whose relevant experience has strong promotion value.

5.2. Future Prospects

In the future, the digital-intelligent teaching reform of Basic Electrical and Electronic Courses will advance toward a deeper, broader and higher-quality direction. First, deepen the integration of AI and teaching, develop more advanced intelligent teaching assistants and adaptive learning systems, realize data-driven teaching decision-making, resource push, and evaluation analysis throughout the whole process, and truly implement personalized education. Second, expand the dimension of interdisciplinary integration, promote the in-depth intersection of electrical and electronic knowledge with AI, Big Data, IoT and other disciplines, break disciplinary barriers, and cultivate compound engineering and technical talents. Third, improve the resource sharing mechanism, accelerate the construction of a national digital-intelligent teaching resource library for electrical and electronics, realize the balanced distribution of high-quality resources, and improve the overall teaching quality of higher engineering education. Fourth, strengthen international exchanges and cooperation, actively learn from advanced foreign experiences in digital-intelligent teaching, and combine the actual situation of China's engineering education to create a distinctive Chinese-style digital-intelligent engineering education model.

6. Conclusion

The digital-intelligent teaching reform of Basic Electrical and Electronic Courses is not only an inevitable choice to meet the requirements of the educational digitalization strategy and New Engineering construction, but also a key measure to solve the problems of traditional teaching and improve the quality of talent training. In the process of reform, we must always take student development as the center and technological innovation as the driving force, carry out systematic reconstruction from six dimensions: teaching concepts, curriculum system, teaching models, practice platforms, faculty teams, and evaluation mechanisms, and build a digital-intelligent education system characterized by "technology empowerment, industry-education integration, virtual-physical collaboration, and precise education". Through this reform, we can effectively improve the quality of curriculum teaching and education effectiveness, cultivate more high-quality engineering and technical talents who can adapt to the needs of industrial digitalization development, and provide solid support for building an education power and promoting the transformation and upgrading of the manufacturing industry. In the future, we need to continuously deepen the in-depth integration of technology with education and teaching, constantly improve the reform path and guarantee mechanism, push the teaching quality of Basic Electrical and Electronic Courses to a new level, and at the same time provide a referential practical model for the digital-intelligent reform of higher vocational electrical and electronic courses.

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