AI-Empowered Research on Teaching Reform and Innovation in Circuit Courses

Lingyan Wu[1], Gang Cai[2*], Hui Li[1], Xingang Feng[1], Juntao Zhu[1], Hao Wu[1]

[1]School of Intelligent Manufacturing and Materials Engineering, Gannan University of Science and Technology, Ganzhou, China
[2]The Department of Mathematics and Information Science, Science and Technology College Gannan Normal University, Ganzhou, China

*GangCai@gnnu.edu.cn

Abstract. Addressing prominent issues in traditional Circuit course teaching—such as theoretical abstraction, weak practical application, and monolithic assessment—this study responds to the demands of New Engineering and Education 4.0 for engineering talent development. Guided by constructivist learning theory, it achieves deep integration of AI with Circuit course pedagogy. By establishing a four-dimensional reform framework encompassing "objectives-content-practice-assessment", the study advances a new pedagogical paradigm for electrical and information engineering disciplines through four dimensions: developing personalized teaching resources, constructing an engineering-oriented practical system, organically integrating ideological and political elements, and innovating diversified assessment mechanisms. A three-year practice involving electrical and information engineering students from the 2022-2024 cohorts at Ganzhou University of Science and Technology demonstrates that postreform measures have significantly enhanced overall course pass rates, markedly increased awards in subject competitions, and achieved a 100% excellent rating in course evaluations. These findings provide an actionable pathway for the intelligent transformation of foundational engineering courses and offer valuable support for new engineering talent cultivation.

Keywords: AI-empowered, teaching reform, engineering practice, new engineering disciplines

1 Introduction

Both China's Education Modernization 2035[1] and relevant UNESCO reports emphasize AI's supportive role in education[2]. As a core foundational course for electrical and information engineering disciplines, Circuit Theory serves as the cornerstone for developing engineering thinking and bridging subsequent courses. Its teaching quality directly impacts the effectiveness of new engineering talent cultivation[3][4].Current Circuit teaching faces three challenges: core theorems and concepts remain abstract, with traditional methods failing to provide intuitive presentation, leading students to

A. Y. M. A. Islam et al. (eds.), *Proceedings of the 2025 International Conference on Educational Technology and Management Information Systems (ETMIS 2025)*, Advances in Computer Science Research 129,
https://doi.org/10.2991/978-94-6239-630-2_38

memorize formulas mechanically; practical sessions predominantly involve verification experiments, lacking training in independent design and troubleshooting, resulting in delayed engineering capability development; assessment relies heavily on end-of-term written examinations, unable to quantify innovation and collaborative skills[5]. Integrating AI to address these pain points has become a key pathway for enhancing teaching quality.

Existing AI-engineering education integration practices globally include: MIT's intelligent teaching assistant system enabling real-time circuit problem feedback, boosting learning efficiency by 35%[6]; Stanford's simulation platform identifying cognitive bottlenecks for targeted instruction[7]. Domestic scholars have also developed related intelligent teaching ecosystems[8], though existing research suffers from fragmented technology application, disconnect from industrial frontiers, and neglect of valuedriven leadership.

This paper centers on course characteristics, leverages technological empowerment, and targets competency development by integrating AI throughout the entire Circuit teaching process, constructing a theory-practice-industry linkage solution. Using electrical and information engineering students at Ganzhou University of Science and Technology as subjects, effectiveness is comprehensively evaluated through quantitative data (student grades, subject competition achievements) and qualitative materials (teacher development).

2 Theoretical Foundations and Core Framework

This paper employs a three-dimensional theoretical framework comprising constructivism[9], connectivism[10], and engineering education accreditation standards[11].

Embracing the learning by doing principle of constructivism, the course team leverages intelligent technologies to create virtual simulation scenarios and inquiry-based tasks, thereby achieving a profound integration of theory and practice within the Circuitry course. Connectivism focuses on the networked construction of knowledge. The team constructed a knowledge graph encompassing over 250 knowledge points based on the core course content, transforming circuit laws, theorems, and key application points into a visualized, interconnected knowledge system to assist students in forming a systematic cognitive framework. The outcome-oriented philosophy of engineering education accreditation guides teaching to focus on cultivating the ability to solve complex engineering problems. Guided by this philosophy, the course team has directed students to participate in subject competitions and research projects, achieving phased results.

Accordingly, this paper constructs a four-dimensional implementation framework comprising "objectives—content—practice—evaluation". The objectives layer relies on student data to enable tiered setting; the content layer reorganizes resources based on principles of systematization, engineering, and personalization; the practice layer establishes a three-stage progressive training pathway encompassing virtual, physical, and project-based components; the evaluation layer emphasizes multi-dimensional assessment prioritizing both process and outcomes, forming a closed-loop improvement mechanism that systematically drives course enhancement and competency attainment.

3 Implementation Pathways

3.1 Optimising Knowledge Systems through Multimodal, Systematic, and Intelligent Approaches

As shown in Fig. 1, this course provides a foundational knowledge framework through the text modality, helps visualize abstract concepts via the visual modality, employs immersive VR learning, enhances student engagement through interactive smart classrooms, and fosters curiosity through the algorithmic modality.

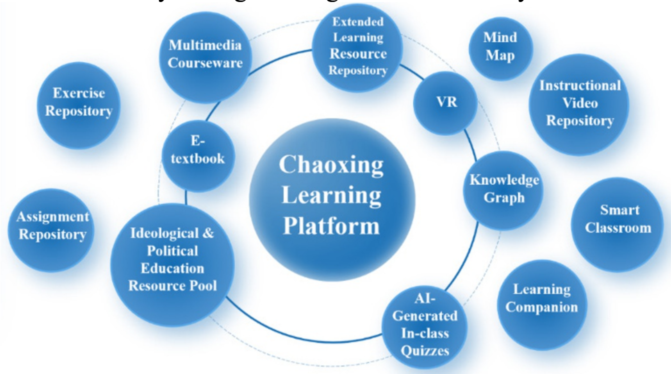

Fig. 1. Multimodal Integrated Teaching Resources

Employing "knowledge graph" technology to construct a visualized knowledge system, forming a systematic content framework that assists students in transitioning from fragmented knowledge to systematic thinking. Reorganize the knowledge and relationships within the "Circuits" course, presenting the whole picture through mind maps. This resolves the issue of isolated knowledge points, establishes a coherent knowledge system, and prevents students from "seeing the trees but not the forest".

Integrating Jimeng AI digital avatars, such as Mr Kirchhoff introducing himself while engagingly explaining Kirchhoff's laws, as shown in Fig. 2. Utilizing the AI workbench enables 24/7 self-service Q&A via AI assistants, personalized learning path recommendations, intelligent generation of teaching objectives and key/difficult points per chapter, automatic creation of in-class quizzes, and AI-driven learning progress analysis.

Fig. 2. AI Digital Avatar

3.2 Employment-Oriented Approach: Blending Virtual and Real-World Experiences, Promoting Learning Through Competitions to Enhance Practical Skills

Proactively guide career development by introducing knowledge points through real-life case studies to spark student interest. Integrate engineering practice projects to boost learning motivation and cultivate comprehensive competencies.

The incorporation of virtual simulation software such as Proteus and Multisim into experimental teaching enables virtual design and debugging prior to physical operation, thereby enhancing efficiency and safety. Students undertake projects in groups under continuous faculty supervision, covering scheme design, component selection, circuit assembly, and programme debugging to cultivate practical skills and teamwork.

Stimulate student interest by ensuring robust support for extracurricular practical activities and encouraging participation in diverse subject competitions. Faculty maintain connections with industry and society, utilizing external projects to hone student skills while encouraging applications for undergraduate innovation and entrepreneurship schemes to conduct research and publish academic papers.

Strengthen innovation and entrepreneurship platforms, including competition platforms, experimental facilities, corporate partnerships, and maker spaces. Deepen inter-institutional and industry-academia collaborations while establishing an innovation and entrepreneurship mentor network. The core focus of innovation education lies in enhancing educational quality, addressing developmental gaps, fostering synergistic educational approaches, and achieving educational objectives.

3.3 Ideological Guidance, Prioritising Quality, Embracing AI, Cultivating Professional Competence

In accordance with the teaching content framework, refine corresponding course-based ideological and political objectives, ideological and political elements, and teaching materials to establish a comprehensive course-based ideological and political teaching system. Integrate ideological and political elements organically into course delivery to achieve dual objectives: knowledge transmission and value guidance.

Through smart classrooms, facilitate interactive modalities such as selecting participants for questioning, rapid response, voting, thematic discussions, and group deliberations. Employ diverse teaching formats to encourage active student engagement, honing collaborative problem-solving and teamwork ethos while cultivating communication competencies and interpersonal skills.

While guiding students to uphold their original aspirations, it is equally vital to foster a critical mindset, ensuring the judicious use of AI without excessive reliance. Employing AI for verifying exercise conclusions allows diverse, even unconventional solutions to emerge from different AI systems, stimulating thought, broadening perspectives, and honing students' innovative capabilities. However, as AI's expansive thinking may also generate illusions or errors, students must independently validate and evaluate AI outputs, thereby cultivating critical thinking.

3.4 Process-Oriented, AI-Assisted Assessment: Multi-Pronged Approach to Constructing Diverse Evaluation

In pedagogical reform, the course leverages the Chaoxing Learning Pass platform to establish a comprehensive learning task system, enhancing student engagement and agency. Pre-class activities activate independent inquiry through guided discussions and resource distribution, laying foundational knowledge. During sessions, AI assessments and smart classroom tools enable dynamic diagnostic feedback, allowing real-time adjustment of teaching pace and emphasis. Post-class arrangements are practice-oriented, integrating experimental tasks with both objective and subjective assignments to transform theoretical knowledge into practical problem-solving skills. The weighting of end-of-term assessments is reduced, shifting focus to systematic evaluation of higher-order competencies such as knowledge integration, comprehensive analysis, and innovative application.

The overall assessment framework shifts from summative, singular evaluations to formative assessments that span the entire learning journey through diverse formats. This transformation encompasses not only knowledge acquisition but also prioritizes cognitive development, practical competencies, and collaborative skills, thereby advancing teaching objectives from knowledge transmission towards a multidimensional cultivation of innovative capabilities. The assessment process emphasizes comprehensive observation from multiple dimensions and perspectives. Evaluation outcomes form a continuous teaching feedback loop, enabling the ongoing refinement of instructional strategies. This achieves a spiral of improvement in both teaching and learning quality, ultimately realizing the systematic empowerment of the course-based educational model.

4 Teaching Innovation Outcomes and Reflections

4.1 Innovation Outcomes

Academic performance has steadily improved, with enhanced initiative in learning and over 90% of students expressing interest in the course. Daily self-directed study time increased by 1.2 hours on average, with 85% of students affirming that personalized resources effectively addressed learning challenges. Practical innovation capabilities stand out, with the teaching team guiding students to secure 35 national and provincial awards in subject competitions over the past two years, as shown in Table 1. They have also supervised students in completing three provincial-level undergraduate innovation and entrepreneurship projects and publishing five academic papers.

Table 1. Summary of Academic Competition Awards in the Past Two Years

Subject Competition Events	Level	2023	2024	Total
Blue Bridge Cup National Software and Information Technology Talent Competition	National	2	4	6
	Provincial	8	7	15
Siemens Cup China Intelligent Manufacturing Challenge	National	0	1	1
	Provincial	4	3	7
National University Student Intelligent Vehicle Competition	National	0	0	0
	Provincial	2	4	6
Total		16	19	35

As shown in Table 2, the course achieved a 100% excellent rating in teaching evaluations and was recognised as a university-level exemplary project for course-based ideological and political education. The lead lecturer received a provincial second prize in the 2025 Teaching Innovation Competition. The teaching team published two papers on educational reform, with two members recognized as provincial dual-qualified teachers. They spearheaded multiple provincial teaching reform projects and Ministry of Education industry-academia collaborative education initiatives, establishing a virtuous cycle of "teaching-research-translation". AI-assisted teaching has effectively enhanced instructional efficiency, enabling lecturers to focus more on personalized guidance and pedagogical innovation.

Table 2. Teaching Evaluation Results for the 'Circuits' Course (2022–2024 Cohorts)

Semester Taught	Teaching Hours	Classes Taught	Course Evaluation
2023-2024 D1	64	Telecom 221, 222	excellent
2024-2025 D1	64	Telecom 231, 232	excellent
2024-2025 D1	76	Electrical Engineering 231, 232	excellent
2024-2025 D2	64	Electrical Engineering 241, 242	excellent

4.2 Shortcomings and Reflections

Reform continues to face challenges: Firstly, some senior teaching staff exhibit limited AI application capabilities, necessitating the establishment of a faculty development system combining online training with offline workshops. Secondly, the quantitative precision of AI assessment in evaluating innovative thinking requires enhancement, necessitating collaboration with educational experts to refine the model. Thirdly, resource development costs remain relatively high, necessitating collaboration with other universities to establish a shared platform. Future advancement will focus on three areas: deepening industry-education integration by jointly developing AI-based circuit design systems with enterprises; refining evaluation models to enhance precision in assessing higher-order competencies; and establishing a provincial-level "AI+Circuit" resource-sharing platform to reduce application costs.

5 Conclusion

Guided by constructivist theory and engineering education accreditation standards, this paper constructs a four-dimensional AI-empowered teaching framework for "Circuits" encompassing objectives, content, practice, and assessment. Through content restructuring, pedagogical innovation, and practice reinforcement, it achieves full-process integration of technology and curriculum. Practice demonstrates that this approach effectively addresses traditional teaching challenges, significantly improving students' academic performance, practical skills, and innovative literacy while simultaneously advancing teacher development and course quality enhancement. The research findings provide a replicable practical pathway for the intelligent transformation of foundational engineering courses, holding significant value for driving engineering education reform within the context of the New Engineering initiative.

Acknowledgment

The research of this thesis is supported by the Jiangxi Provincial Department of Education Teaching Reform Research Project (Nos. JXJG-23-36-8, JXJG-23-36-1) and the Basic Education Research Foundation of Jiangxi Provincial Department of Education (No. SZUGKWL2023-1103). It also received funding from the 2025 Undergraduate Innovation Training Programme Project of Gannan University of Science and Technology (X202513434021), and Science and Technology Research Project of Jiangxi Provincial Department of Education (No. GJJ2404503).

References

1. Ministry of Education. Modernization of Chinese Education 2035 [Z]. Beijing: People's Publishing House, 2019.
2. World Economic Forum. Future of School: Defining New Education Models for the Fourth Industrial Revolution [R]. Geneva: World Economic Forum, 2020.

3. Department of Higher Education, Ministry of Education. Guidelines for New Engineering Education Development (2024 Edition) [Z]. Beijing: Higher Education Press, 2024.
4. Wang Songwu, Li Zhenshuang. Teaching Reform and Practice of Circuit Analysis Course under the New Engineering Paradigm [J]. Journal of Electrical and Electronic Education, 2021, 43(3): 6-9.
5. Wang Zhuping. Classroom Teaching Reform and Practice in University Circuit Courses [J]. Chinese Higher Education Research, 2005, (06): 83.
6. MIT. AI-Assisted Learning in Electrical Engineering: A Case Study of Circuit Course [R]. Cambridge: MIT Press, 2022.
7. Ryu, Kwangsoo; Shi, Miao. Generative Artificial Intelligence Empowering Digital Transformation in Higher Education: An Analysis Based on Stanford University. Research in Higher Engineering Education, 2025, (02): 176–181+188.
8. Shen Liyan, Zhang Jianping. Building an AI-Based Smart Teaching Ecosystem in Higher Education: A Case Study of Zhejiang University [J]. Modern Educational Technology, 2022, 32(12): 85-92.
9. Zhong Qiqian. The Essence and Challenges of Constructivist Learning Theory [J]. Educational Research, 2020, 41(7): 43-52.
10. Yang Yang, Chen Li. Learning Pathway Mining and Representation in Connectivist Learning [J]. Journal of East China Normal University (Educational Science Edition), 2025, 43(10): 84-98.
11. Li Zhiyi, Pan Chao. Transversal Competence Development in Higher Engineering Education for Industry 4.0 [J]. Research in Higher Engineering Education, 2024, (02): 12-17.