Strategies for Improving Digital-Intelligent Teaching Competence of Engineering Teachers Driven by AI

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Abstract. The rapid development of artificial intelligence is profoundly reshaping the higher education landscape, making the digital-intelligent teaching competencies of university engineering faculty a critical variable in driving the digital transformation of education. Taking the smart teaching practice of the Electrical and Electronic Technology course as a case study, this paper systematically elaborates a smart teaching reform pathway centered on cloud-based course resource construction, multi-dimensional knowledge graph development, the application of AI teaching assistants and intelligent agents, smart learning analytics and learner profiling, as well as online-offline blended teaching models. On this basis, it proposes strategies for enhancing university engineering teachers' digital-intelligent teaching competencies from three dimensions: institution, teacher, and technology. The findings indicate that using course-level smart teaching reform as a practical vehicle and embedding teacher competency development into authentic teaching contexts represents an effective path for transitioning from "technical training" to "capacity generation."

Keywords: Artificial Intelligence, Digital-Intelligent Teaching Competence, Engineering Teachers, Electrical and Electronic Technology, Smart Teaching

1 Introduction

The rapid development of digital technologies such as artificial intelligence, big data and virtual reality is propelling higher education forward from digital transformation to digital-intelligent upgrading [1]. In 2025, the Ministry of Education issued the Notice on Organizing and Implementing the Initiative of Empowering Teacher Development through Digitalization, which clearly proposes to "establish a development path for teachers' digital literacy guided by digital literacy standards, supported by training and research, and characterized by application-driven practical improvement". The digital-intelligent teaching competence of university teachers refers to a comprehensive professional literacy that enables them to effectively integrate digital tools with teaching activities, optimize teaching procedures and innovate teaching modes within an education environment empowered by digital-intelligent technologies. This competence has become a decisive factor determining whether the national digital education strategy can be fully implemented [2].

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Engineering courses face particularly prominent challenges in the digital-intelligent transformation due to their highly abstract theories, high demands for practical operation, and rapidly updating knowledge [3]. As a core foundational course for mechanical engineering majors, Electrical and Electronic Technology covers multiple knowledge areas including circuit theory, alternating current, and electronic technology. In traditional teaching, there have long been pain points such as abstract knowledge, students' difficulty in spatial imagination, and disconnection between theory and practice. How to leverage artificial intelligence technology to empower course teaching while simultaneously enhancing teachers' digital-intelligent teaching competencies has become an urgent issue to be addressed.

2 Practical Challenges in Digital-Intelligent Teaching

Engineering faculty face three key issues in digital-intelligent competence: weak awareness—most equate technology with PPT/video, lack proactive exploration, and heavy workloads reduce motivation; superficial application—basic office skills exist but deep abilities like virtual simulation, learning analytics, and AI-assisted design are lacking, especially for courses like Electrical and Electronic Technology requiring knowledge graphs, simulation tools, and transforming abstract theory into interactive visuals, demanding high interdisciplinary literacy; and disconnect between teaching and technology—many use tools for their own sake without linking to objectives, e.g., simulations not integrated with inquiry-based learning, platform data not used for diagnostic adjustment, resulting in superficial application that fails to improve outcomes.

3 Exploratory Smart Teaching of the Electrical and Electronic Technology

As a core foundational course for mechatronics majors, Electrical and Electronic Technology builds circuit analysis thinking and engineering practice abilities [4]. To tackle traditional issues, the course team implemented systematic smart teaching reforms across five dimensions: resources, knowledge organization, AI tutoring, learning analytics, and pedagogy.

3.1 Construction of Three-Dimensional Cloud Curriculum Resources from Flat to Multi-Layered Forms

Traditional curriculum resources rely on printed textbooks and PPT courseware, featuring outdated content and monotonous formats. Relying on the Fanya cloud curriculum platform, the curriculum team built a three-dimensional digital resource library covering all knowledge points of the course, including micro-lecture videos, digital textbooks, courseware, exercise banks and engineering case libraries. Two core principles were highlighted during resource development: first, "precision over accumulation" — resources were carefully selected and stratified with difficulty indicators and

star ratings (★) marked according to the importance and complexity of knowledge points in each chapter to avoid overloading students with cognitive burden; second, "dynamic rather than static updates" — resource content was continuously revised in response to industrial technological advancements and teaching feedback.

The introduction of digital textbooks stands out as a key measure. Centered on printed textbooks, the team constructed three-dimensional digital textbooks via the combination of mobile terminals, internet and intelligent applications. Beyond conventional text and charts, these digital textbooks embed micro-lecture videos, animated demonstrations, interactive exercises and community discussion functions, enabling students to conduct fragmented learning and in-depth exploration anytime and anywhere.

3.2 Construction of Multi-Dimensional Knowledge Graphs from Discrete Points to Interconnected Networks

Electrical and Electronic Technology contains numerous interwoven knowledge points. Traditional discrete-point teaching often leaves students unable to grasp the overall knowledge framework. The curriculum team systematically built a four-in-one knowledge network integrating curriculum graphs, knowledge graphs, problem graphs and competence graphs, Figure 1.

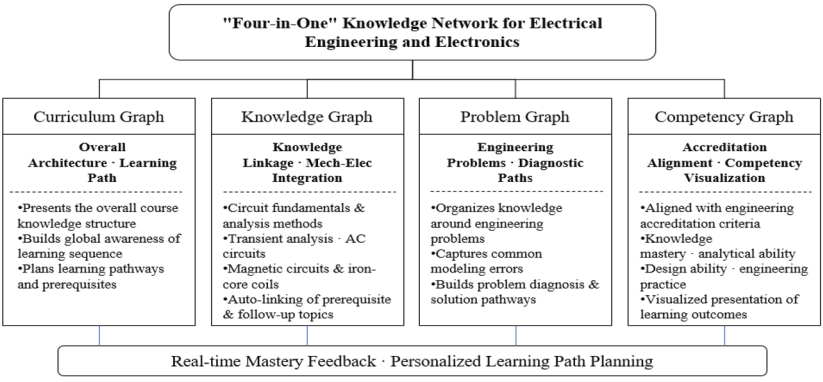


Fig. 1. "Four-in-One" Knowledge Network Structure Diagram

The curriculum graph presents the overall knowledge architecture and learning sequence of the course, helping students establish a holistic understanding of learning priorities and progression. The knowledge graph delves into individual knowledge points and builds horizontal connections between modules including fundamental circuit theory, circuit analysis methods, transient analysis, alternating current circuits, magnetic circuits and iron-core coil circuits, breaking disciplinary barriers between mechanical and electrical knowledge. For example, when teaching Thevenin's Theorem, the graph automatically links prerequisite knowledge such as Kirchhoff's Laws and Superposition Theorem, as well as subsequent application scenarios for complex circuit analysis. The problem graph organizes knowledge around engineering problems and

accumulates common modeling errors and diagnostic workflows. Aligned with the requirements of engineering education accreditation, the competence graph visualizes training objectives covering knowledge mastery, analytical capabilities, design skills and engineering practical competence [5].

Based on the knowledge graph, the system can provide real-time feedback on students' mastery rates of each knowledge point and formulate personalized learning paths. This graph-guided learning framework effectively addresses students' struggles of forgetting previous content while learning new chapters and fragmented knowledge, and also helps teachers accurately identify core teaching focuses and difficult topics.

3.3 Human-Machine-Human Collaborative Interaction Enabled by AI Teaching Assistants and Intelligent Agents

To resolve the problems of delayed after-class Q&A and insufficient learning support in traditional teaching, the curriculum team introduced an AI teaching assistant system built on large language models. Grounded in the course knowledge base, the AI teaching assistant provides 7×24-hour intelligent Q&A services for students. When students encounter confusing circuit analysis problems, they can submit natural language inquiries to the assistant, which matches relevant content via the knowledge graph and provides answers alongside targeted learning recommendations.

The value of AI teaching assistants extends far beyond replacing teachers' Q&A work; it enables a new human-machine-human collaborative teaching model. By analyzing frequently raised questions collected by the AI assistant, teachers can accurately identify common student difficulties and deliver targeted in-class explanations. Furthermore, based on students' learning behaviors and proficiency levels, the AI assistant recommends differentiated learning resources and practice tasks, shifting teaching from uniform mass instruction to personalized support.

3.4 Data-Driven Learning Assessment via Intelligent Learning Situation Analysis and Student Learning Portraits

In traditional teaching, instructors' understanding of student learning relies mainly on classroom observation and assignment grading, which suffer from lag and subjectivity. To address this, the course team employs the big data analytics engine of a smart teaching platform to dynamically track students' entire learning process. The platform automatically collects multi-source behavioral data from video viewing, online quizzes, discussion interactions, assignment submissions, and other activities, and uses machine learning to construct a "learner profile" for each student. These profiles contain not only mastery levels of knowledge points but also multidimensional information such as learning progress, preferences, participation, and cognitive abilities. Teachers can thus monitor overall class performance and individual difficulties in real time, precisely identify stuck points, and promptly adjust teaching strategies—for example, by adding case discussions and exercises for chapters with low mastery rates. Students, in turn, receive visual feedback that clearly reveals their weaknesses, enabling targeted self-

directed learning. This data-driven model turns individualized instruction from concept into practice [6].

3.5 Online-Offline Blended Teaching Model

The curriculum team designed a blended teaching workflow of "pre-class online self-study — in-class offline seminars — post-class online consolidation". Before class, students complete independent preview and diagnostic tests via the cloud curriculum platform; teachers adjust in-class teaching design according to learning situation feedback from the platform. During class, the BOPPPS framework (Bridge-In, Objectives, Pre-assessment, Participation, Post-assessment, Summary) is combined with PBL (Project-Based Learning) to carry out case discussions, group collaboration and semi-simulation experiments. Teachers transform from knowledge transmitters into designers and facilitators of learning activities. After class, students complete layered assignments, extended reading and project tasks on the platform, while teachers provide personalized tutoring and conduct teaching reflection via data tracking.

For practical teaching, the team independently developed a series of experimental demonstration boards and semi-simulation circuits to create a classroom model integrating learning, critical thinking and hands-on operation. Semi-simulation experiments convert abstract electrical engineering theories into interactive practical tasks that require students to think actively and operate hands-on, effectively cultivating engineering thinking and problem-solving capabilities.

4 Strategies for Improving Digital-Intelligent Teaching Competence of University Engineering Teachers

The smart teaching practice of Electrical and Electronic Technology shows that improving teachers' digital-intelligent competencies must be embedded in authentic teaching contexts, achieving a spiral ascent of "learning by doing and doing by learning" through course development and reform. Accordingly, this paper proposes enhancement strategies from three dimensions: institution, teacher, and technology.

4.1 Institutional Level, Establish Hierarchical, Classified Training Systems and Long-Term Safeguard Mechanisms

At the institutional level, it is essential to build a tiered and categorized training system alongside long-term support mechanisms. Given the diverse ages, technical backgrounds, and disciplinary orientations among engineering faculty, differentiated training should be implemented: junior faculty focus on hands-on AI tool operation, intelligent course design, and knowledge graph construction; mid-career faculty develop advanced skills in digital resource development, blended teaching, and learning analytics; program leaders concentrate on strategic areas such as digital-intelligent program construction and industry-education integrated curriculum restructuring. A blended online-offline learning platform should also be established—online micro-courses and case

libraries facilitate just-in-time learning, while offline workshops and salons promote experience sharing, with the six-step smart course development framework (environment setup, multi-agent collaboration, content and knowledge graph presentation, activity design, process evaluation) serving as a methodological guide. Furthermore, sustainable incentive and support mechanisms are needed: special teaching reform projects reward outstanding achievers, digital-intelligent competencies are incorporated into performance reviews and promotion criteria, and dedicated technical support teams provide one-on-one assistance for course building and knowledge graph creation—all ensuring the training system remains effective and responsive over time [7].

4.2 Individual Teacher Level, Strengthen Cognitive Motivation and Reflective Practice

At the teacher level, strengthening cognition-driven and reflective practice requires three actions. First, enhance the perceived value of digital-intelligent technologies, transforming capacity improvement from an external requirement into an internal motivation. Second, learn by doing in real teaching contexts—through task-driven activities such as course development, knowledge graph construction, and AI teaching assistant training—which naturally builds skills far more effectively than decontextualized technical training. Third, establish a reflective practice cycle: use multidimensional data (learning profiles, interaction records, test scores) to evaluate outcomes, identify problems, and refine instructional design, forming a closed loop of "teaching – data – reflection – improvement" that continuously elevates teachers' digital-intelligent competencies.

4.3 Technological Level, Deepen Full-Process Integration of AI Tools and Teaching Activities

At the technical level, advancing the deep integration of AI tools into the entire teaching process requires embedding AI into every stage—pre-class, in-class, and post-class: before class, it collects materials, generates syllabi and slide frameworks, and analyzes student data; during class, it enables real-time interaction and feedback; after class, it automates grading and provides personalized suggestions, thereby enhancing both efficiency and teacher competency. For engineering courses, which combine abstract theory with hands-on practice, technologies such as circuit simulation, intelligent interpretation, and knowledge graphs turn trial-and-error into inquiry-based learning, while generative AI is explored for case generation and experiment design. Meanwhile, a human-AI collaborative ecosystem should be built, where AI serves as a cognitive partner, embedded in workflows like test generation, micro-lecture production, and learning analytics—reducing teachers' administrative load so they can focus on instructional design and value guidance. This leverages AI's data-processing strengths while preserving teachers' irreplaceable roles in pedagogy and emotional engagement, thus achieving comprehensive deep integration at the technical level.

5 Conclusions

Improving the digital-intelligent teaching competence of university engineering teachers driven by artificial intelligence constitutes a systematic project involving conceptual renewal, skill acquisition and institutional guarantee. Taking the smart teaching reform of Electrical and Electronic Technology as a case, this paper reveals an effective pathway to boost teachers' digital-intelligent competence: relying on curriculum-based smart teaching reform as the carrier, teachers achieve competence advancement through "learning by doing and doing while learning" in authentic teaching scenarios including cloud curriculum resource construction, multi-dimensional knowledge graph development, AI teaching assistant application, intelligent learning situation analysis and blended teaching model innovation.

Curriculum reform practice indicates that the improvement of teachers' digital-intelligent teaching competence cannot be achieved through isolated technical training alone. A trinity collaborative mechanism integrating institutional top-level design, proactive teacher practice and in-depth technological integration must be established. Universities provide hierarchical classified training systems and long-term safeguard mechanisms; teachers strengthen cognitive motivation and carry out reflective practice; technologies facilitate full-process deep integration of AI tools and teaching. Coordinated efforts from all three dimensions enable the fundamental shift from "technical training" to "competence cultivation".

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