Design of a Teaching Model for the Electrical and Electronic Technology Course Empowered by Generative Artificial Intelligence——From the Perspective of Three AI Agents

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Abstract. In the context of educational digital transformation, the traditional *Electrical and Electronic Technology* course faces challenges such as outdated teaching content, a lack of personalized guidance, and a disconnect between theory and practice. Using Activity Theory as an analytical framework, this paper positions generative AI as a core mediating tool for reshaping the teaching activity system and, based on this, proposes a "Three AI Agents" human–computer collaborative teaching model. The model subdivides AI into an AI Guidance Agent, an AI Experiment Agent, and an AI Evaluation Agent. The teaching process is designed around three phases—"intelligent pre-class preparation, in-class virtual-real integration, and post-class personalized expansion"—and potential problems and countermeasures are proposed. The model provides an operable practical reference for the intelligent transformation of electrical and electronic engineering courses.

Keywords: human–computer collaboration; AI agent; electrical and electronic technology; teaching model design

1 Introduction

With the in-depth advancement of Emerging Engineering Education, *Electrical and Electronic Technology*, as a core foundational course for electronic information majors, directly affects students' subsequent professional learning outcomes and the cultivation of their engineering practice abilities. However, in meeting the talent cultivation demands of the new era, traditional teaching models expose problems such as teaching content updates lagging behind technological iterations, support methods lagging behind student needs[1], and the practical component lagging behind engineering reality. These issues urgently require optimization and improvement through innovative educational technologies[2]. The rapid development of generative artificial intelligence offers a new technological pathway to address these dilemmas.

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2 Theoretical Foundation and Analytical Framework

2.1 Activity Theory and Its Implications

Activity Theory views human activity as a dynamic system composed of "subject, tool, object, community, rules, and division of labor"[3]. Introducing this theoretical framework into instructional design means that AI is no longer merely a technical tool external to teaching activities; instead, it is embedded as a "mediating tool" within the teaching activity system, reshaping the division of labor and interaction relationships, and deeply participating in teaching activities through a specialized division of labor. Specifically, within the teaching activity system of the Electrical and Electronic Technology course, the concrete meanings of each component are as follows:

Subject: Teachers and students constitute the dual subjects.

Tool: Generative AI serves as the core mediating tool.

Object: The comprehensive development of students' knowledge, abilities, and competencies.

Community: A collaborative community composed of teachers, students, and AI.

Rules: Teaching norms, AI usage boundaries, and academic ethics.

Division of Labor: Teacher-led, AI-assisted, student-active inquiry.

This framework provides the theoretical foundation for designing the three AI agents in this paper. As the "tool" element, AI requires internal differentiation (specialized division of labor among agents) to better act upon the "object" (student development). The teacher's role evolves from knowledge transmitter to human-computer collaboration designer and learning ecosystem coordinator, responsible for establishing operational rules and boundaries for AI agents, auditing content generation quality, handling emotional communication and value guidance, and performing human intervention and decision-making at key nodes.

2.2 Design Principles

Based on the above theoretical analysis, this paper proposes four design principles for generative AI-empowered course teaching:

First, the Human–Computer Collaboration Principle. This principle clarifies the role positioning where teachers lead decision-making and provide emotional support, while AI handles data and resources. AI does not replace teachers' professional judgment and value guidance.

Second, the Agent Specialization Principle. AI should be subdivided into agents with different functions, each undertaking professional tasks, rather than serving as a generic "AI teaching assistant"[4].

Third, the Context Embedding Principle. This involves using typical engineering problems in the electrical and electronic field as carriers to guide students in learning within authentic contexts.

Fourth, the Safety and Ethics Principle. This ensures the professional accuracy of AI-generated content, protects the privacy of teachers' and students' data, and clarifies the academic norms for student use of AI[5].

3 Construction of the Teaching Model

3.1 Overall Architecture

Based on the aforementioned theoretical framework, this paper constructs a "Three AI Agents" human–computer collaborative teaching model. This model upgrades AI from a "tool" to a "cognitive partner," endowing it with a clear role positioning and functional division of labor. Figure 1 illustrates the overall architecture of the "Three AI Agents" human–computer collaborative teaching model. The model centers on a shared student profile repository as the core data hub, around which three specialized AI agents are constructed—the AI Guidance Agent, the AI Experiment Agent, and the AI Evaluation Agent. These three agents collaborate through bidirectional data flow, jointly supporting personalized learning output, which is ultimately implemented in the three-stage teaching process of pre-class, in-class, and post-class.

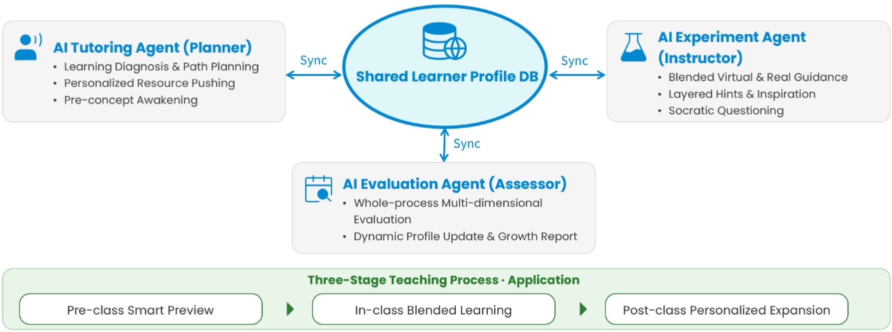

Fig. 1. Overall architecture diagram of the teaching model

3.2 AI Guidance Agent

The AI Guidance Agent is built on a fine-tuned open-source large language model. Based on a general model, it undergoes domain-specific fine-tuning using textbooks, problem banks, and student Q&A records from the Electrical and Electronic Technology course, equipping it with professional capabilities such as circuit knowledge Q&A, learning path planning, and metacognitive prompt generation. Serving as the planner for personalized learning, it is responsible for analyzing learning situations, planning paths, and pushing resources during the pre-class phase to achieve "one plan for one student." In this phase, through knowledge retrospective diagnosis, it assesses students' mastery of prerequisite courses; through pre-concept detection, it identifies existing cognitions related to new knowledge; and through learning style identification, it analyzes students' preferences and habits. This process generates a "Five-Dimensional Profile," the content of which is shown in Table 1.

Based on the student's learning profile, the AI Guidance Agent intelligently generates three differentiated learning paths: foundational, standard, and challenging. Each path includes adapted learning resources, detailed time allocation, and phased key milestones, presented according to the student's preferred learning style. Simultaneously, metacognitive prompts are embedded in the learning process to guide students in actively reflecting on, self-monitoring, and regulating their learning process.

Table 1. Composition of the Five-Dimensional Profile

Dimension	Diagnostic Content	AI Detection Method
Knowledge Base	Mastery of prerequisite courses	Automatic grading of pre-tests + knowledge point association analysis
Cognitive Level	Memory/Understanding/Application/Analysis/Evaluation/Create	Depth analysis of responses to open-ended questions
Learning Style	Visual/Auditory/Read-Write/Kinesthetic	Analysis of learning behavior trajectory
Interest Tendency	Theoretical/Applied/Innovative preference	Analysis of resource click preferences + question content
Metacognitive Ability	Planning/Monitoring/Regulation ability	Analysis of learning logs + self-reflection texts

3.3 AI Experiment Agent

Table 2. Steps of the experimental guidance model

Step	Student Behavior	AI Experiment Agent Behavior	Originality Description
①Plan Conception	Proposes experimental design ideas	Socratic questioning: "Why choose this parameter?" "Are there other possibilities?"	Guides thinking; does not provide direct answers.
②Virtual Rehearsal	Builds circuits on a digital twin platform	Real-time risk labeling: "Current at this node might be too high; recommend simulation first."	Predicts risks, not just post-hoc remediation.
③Physical Setup	Connects physical circuits	Visual recognition assistance: identifies connections via camera; prompts "Third pin might have poor contact."	Integrates computer vision, going beyond text interaction.
④Fault Diagnosis	Seeks help when encountering problems	Layered Hints Mechanism	Provides differentiated support based on student ability.
⑤Optimization Iteration	Completes basic functions	Exploratory questioning: "How could you modify this to reduce power consumption?" "What about improving stability?"	Guides in-depth inquiry; fosters innovative thinking.

The AI Experiment Agent adopts a dual-engine architecture combining a large language model with a digital twin platform. It connects to a SPICE simulation engine via API to perform circuit simulation and verification, while using computer vision to recognize hardware circuit connections and compare them with the intended topology. All physical conclusions are based on simulation calculations or visual recognition results to ensure accuracy. Serving as the guide for virtual-real integration, it is responsible for providing real-time guidance, fault diagnosis, and solution optimization suggestions during the in-class experimental phase, addressing the problem of students "following recipes rigidly" in traditional experiments. The "Five-Step Progressive" experimental guidance model is adopted during classroom implementation, with steps detailed in Table 2.

3.4 AI Evaluation Agent

The AI Evaluation Agent adopts a hybrid architecture combining a rule engine with a large language model. For quantifiable indicators, it uses preset rules and computer vision for automatic scoring; for qualitative judgment indicators, it employs the large language model for semantic analysis. Serving as a multi-intelligent assessor, it is responsible for comprehensive, multi-dimensional, and intelligent learning evaluation, achieving a transformation from "judgment by a single exam" to "continuous development profiling." The evaluation adopts a "Three-Dimensional Nine-Item" intelligent evaluation model, as shown in Table 3.

Table 3. "Three-Dimensional Nine-Item" intelligent evaluation model

Dimension	Evaluation Indicator	Data Source	AI Evaluation Method
Knowledge Mastery	Accuracy of knowledge recall	Quizzes, assignments	Automatic grading + knowledge graph pinpointing weak areas
	Depth of concept understanding	Open-ended questions, class Q&A	Semantic analysis to determine the level of understanding
	Knowledge transfer ability	Comprehensive projects, case analyses	Analyzes ability to apply knowledge to new situations
Practical Ability	Operational standardization	Experimental process recordings	Computer vision recognition of operational norms
	Fault diagnosis ability	Records of help-seeking during experiments	Analyzes frequency of help requests and problem complexity
	Solution innovation ability	Design proposal texts	Compares with historical solution database to assess innovation
Core Competencies	Collaboration & communication	Group discussion records	Analyzes speech frequency, response quality, and contribution
	Critical thinking	Questioning and adoption of AI suggestions	Analyzes depth of student-AI dialogue
	Metacognitive ability	Learning reflection logs	Analyzes depth of reflection and self-monitoring awareness

In the evaluation model described above, the core knowledge base and evaluation standards used for assessment are pre-defined by the teaching team and strictly aligned with course teaching objectives. All evaluation results are subject to final review and confirmation by the instructor to ensure accuracy.

4 Teaching Process Design Based on the Three Agents

Pre-class, the AI Guidance Agent conducts precise guidance in three stages. It activates students' existing cognitions and updates learner profiles by pushing pre-concept awakening packages. Based on the profiles, it pushes differentiated pre-class resources embedded with metacognitive prompts to learners at different levels. Then, using pre-class diagnostic tests, it achieves automatic grading and learning analysis, synchronizing class-wide learning situation heatmaps to the teacher's lesson preparation system, providing data support for instructional decisions.

In-class, the 45-minute classroom activity is divided into three phases: the first 15 minutes are led by the teacher, focusing on core concept explanation and typical problem-solving, with AI generating problem variants in real time and synchronously displaying relevant cases and dynamic simulations; the middle 15 minutes are led by the AI Experiment Agent, conducting virtual simulation inquiry and guiding students' in-depth thinking through Socratic dialogue; the final 15 minutes are led by the teacher for Q&A and summary, with AI providing class-wide learning data to support the teacher in addressing common problems.

Post-class, driven by the AI Evaluation Agent, continuous development is achieved through phased task design and role division, organically connecting knowledge consolidation, in-depth reflection, and continuous development. This constructs a closed-loop learning support mechanism characterized by "AI multi-agent synergy."

The three AI agents achieve synergy by sharing the student profile repository, forming a "diagnosis-guidance-evaluation-re-diagnosis" closed loop. The implementation process is shown in Figure 2.

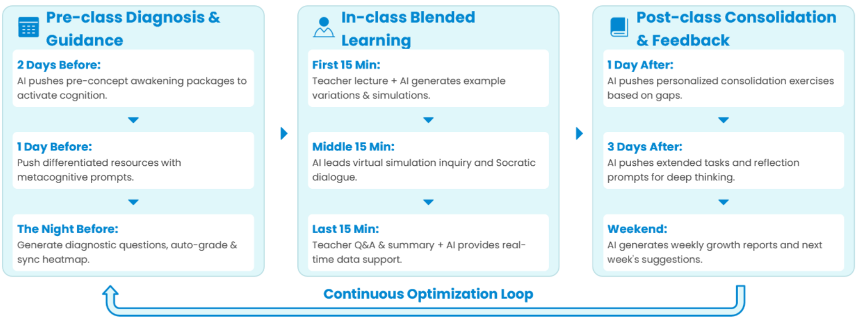

Fig. 2. AI-Enabled Teaching Process Design

Through preliminary system trials and feedback, students generally recognized the pedagogical value of the AI agents. They noted that the AI Experiment Agent's guided fault diagnosis strategy facilitated the development of engineering thinking, while the AI Guidance Agent and AI Evaluation Agent provided personalized learning paths and intuitive growth reports respectively, reducing learning pressure and improving efficiency. Participating teachers reported that after AI agents took over repetitive Q&A and grading tasks, they had more time and energy to focus on in-depth guidance and inspiration for students' individualized questions.

5 Potential Problems and Countermeasures

While integrating AI agents into teaching activities promotes better learning outcomes, it also potentially introduces issues such as student over-reliance on AI, AI-generated content "hallucinations," and differences in teacher acceptance. This requires avoiding students' excessive dependence on AI by clarifying the boundaries of AI usage, designing high-order thinking exploratory tasks, and encouraging critical questioning of AI output during the application of AI technology. By establishing a dual verification mechanism of "teacher review+student feedback" and limiting the scope of AI's knowledge base, the accuracy and reliability of teaching content can be ensured. In response to differences in teachers' acceptance of technology, tiered technical training can be provided, and an "AI Teaching Innovation Team" can be established to promote the overall iteration of teachers' abilities.

6 Conclusion

Using Activity Theory as an analytical framework, this paper constructs a "Three AI Agents" human–computer collaborative teaching model for the Electrical and Electronic Technology course. At the theoretical level, the research extends the concept of "division of labor" from Activity Theory from the interpersonal level to within the tool itself, proposing the new concept of "intra-tool division of labor." It reveals the specialized synergy mechanism of the three AI agents: Guidance, Experiment, and Evaluation. At the practical level, it completes the design of the Guidance Agent's "Five-Dimensional Profile" and differentiated paths, the Experiment Agent's "Layered Hints" mechanism, and the Evaluation Agent's "Three-Dimensional Nine-Item" evaluation model. Through a shared profile repository, it forms a "diagnosis-guidance-evaluation" teaching closed loop, offering a transferable reference framework for the intelligent reform of similar courses.

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