International Educational Research; Vol. 8, No. 6; 2025
ISSN 2576-3059 E-ISSN 2576-3067
https://doi.org/10.30560/ier.v8n6p73

Construction and Practical Exploration of a Generative AI-Driven "Human-Computer Collaboration" Teaching Model in Higher Education —— Taking the Course "Electrical and Electronic Technology and Applications" as an Example

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Received: November 28, 2025; Accepted: December 17, 2025; Published: December 18, 2025

Abstract

Addressing the core challenges commonly faced by students majoring in Mechanical Design, Manufacturing, and Automation when learning the course "Electrical and Electronic Technology and Applications," such as "emphasizing machinery over electricity, having a weak foundation in high-power systems, and a disconnection between theory and practice," this paper employs Activity Theory as an analytical framework. It views the teaching activity as a dynamic system composed of "Subject (teachers and students) - Tool (AI) - Object (student competency) - Community - Rules - Division of Labor." Based on this framework, this study systematically constructs a generative AI-driven "Human-Computer Collaboration" teaching model (HCMAS). This model redefines the roles and division of labor for teachers, students, and AI across three stages: "pre-class exploration, in-class internalization, and post-class transfer." In the teaching practice of the "Electrical and Electronic Technology and Applications" course, using typical mechanical system control problems (such as motor control and PLC applications) as carriers, the model guides students to transform abstract theoretical knowledge of electrical and electronic technology into the ability to solve mechanical engineering problems through collaboration with and critical evaluation of AI. Practice has shown that this model effectively enhances students' learning engagement, engineering thinking skills, and human-computer collaboration literacy. This research provides a valuable paradigm reference for the intelligent transformation and teaching innovation practices of other fundamental engineering courses within the context of New Engineering Education construction.

Keywords: Generative AI, Human-Computer Collaboration, Teaching Model, Engineering Thinking

1. Problem Statement: Teaching Dilemmas in the Course "Electrical and Electronic Technology and Applications" for Mechanical Design, Manufacturing, and Automation Majors

"Electrical and Electronic Technology and Applications" is an important foundational specialized course for majors in Mechanical Design, Manufacturing, and Automation. Its teaching objective is not to train electrical experts, but to enable students to master essential electrical and electronic technology knowledge and develop the ability to design and analyze mechatronic systems. However, in actual teaching, we face the following severe challenges:

(1) High Cognitive Load: Compared to the intuitive analysis of mechanics and structures, concepts in electrical and electronic technology (such as phase, electromagnetic induction) cannot be directly perceived. Students must construct abstract mental models, which imposes a high intrinsic cognitive load, leading to learning difficulties.

(2) Difficulty Connecting Theory with Practice: Students struggle to effectively link course content like relays, PLCs, and motors with familiar mechanical systems such as machine tools, robotic arms, and automated production lines. This results in vague learning objectives and insufficient motivation.

(3) Practical Risks and Limitations: High-power experiments involve safety risks, and fixed-wiring experiment kits constrain students' design thinking, making it difficult to support innovative system design.

(4) Contradiction Between Compressed Class Hours and Abundant Content: Within limited class hours, it is challenging for traditional teaching models to cover necessary theoretical foundations while also cultivating students' practical abilities.

The emergence of generative AI provides a new path to address the aforementioned dilemmas[1]. It can serve not only as a tireless Q&A assistant but also as a "virtual mechanical-electrical assistant," allowing students to design, debug, and iterate in a safe digital environment. This shifts the teaching focus from "memorizing principles" to "applying principles to solve mechanical problems."[2]

2. Theoretical Construction of the HCMAS Teaching Model and Its Adaptability to Mechanical Design, Manufacturing, and Automation Majors

The core of this research is to construct a generative AI-driven human-computer collaborative teaching model, abbreviated as HCMAS (Human-Computer Model of AI-Synergized Teaching)[3]. Guided by Activity Theory, this model views teaching as a dynamic activity system composed of "Teacher (leader) - Student (subject) - AI (tool) - Mechanical Control Problem (object) - Course Community - New Rules (human-computer collaboration norms) - New Division of Labor."[4]

Adaptability Adjustments for Mechanical Majors:

Objective Reconstruction: The core "object" of teaching shifts from "mastering theoretical knowledge of electrical and electronics" to "acquiring the ability to solve electrical control problems in mechanical systems."

Deepening the Tool's Role: AI is not only a knowledge interpreter but also a "control scheme generator," "virtual debugging engineer," and "fault simulator."[5]

Context Creation: All teaching cases and projects are derived from typical mechanical systems (e.g., conveyor belts, elevators, robotic arms), ensuring that the learning context is highly relevant to professional goals.

3. Operational Framework of the HCMAS Teaching Model

This model runs through the entire teaching process, and its core operational framework is illustrated as follows:

(1) Pre-class Exploration Phase: AI as a "Personalized Theory Coach" and "Scheme Pre-simulator"

Teacher: Designs guiding questions based on mechanical system scenarios. For example, before the "Motor and Control" chapter, assign the task: "Conceive a relay control scheme for a conveyor belt requiring forward and reverse rotation, and consider how to prevent simultaneous engagement of forward and reverse."

Student: Engages in dialogue with AI to obtain preliminary explanations of concepts like self-locking and interlocking, and generates basic circuit diagrams. The key task is to record the highlights and potential flaws of the AI-generated scheme.[6]

AI: Provides personalized conceptual explanations, generates preliminary design schemes, and answers student questions.

(2) In-class Internalization Phase: AI as a "Devil's Advocate" and "Thinking Expander"

Teacher: Serves as organizer and guide. Designs in-depth discussion activities based on common problems exposed in pre-class student-AI interactions (e.g., widespread neglect of interlocking).

Student: Critiques and optimizes AI-generated schemes in groups under teacher guidance, focusing on "risk analysis" and "scheme optimization."[7]

AI:

As a "Devil's Advocate": The teacher instructs the AI to defend its flawed design (e.g., "Simplified design can reduce costs"), stimulating students to refute from the perspectives of safety and reliability, thereby deepening engineering awareness.

As a "Real-time Resource Repository": Quickly generates partial code or circuit fragments for student groups during project design, improving efficiency.

(3) Post-class Transfer Phase: AI as a "Project Collaboration Partner" and "Design Validator"

Teacher: Designs interdisciplinary comprehensive projects, such as "Design of a PLC-based Robotic Gripper and Rotation Control System."

Student: Collaborates with AI in groups to complete the entire process from scheme design and component selection to programming and documentation.

AI: Assists with tasks like generating PLC ladder diagram frameworks, drafting initial documents, and performing complex calculations. Students are responsible for reviewing, optimizing, integrating, and experimentally verifying the outputs.

The three-phase implementation process is illustrated in the following diagram:

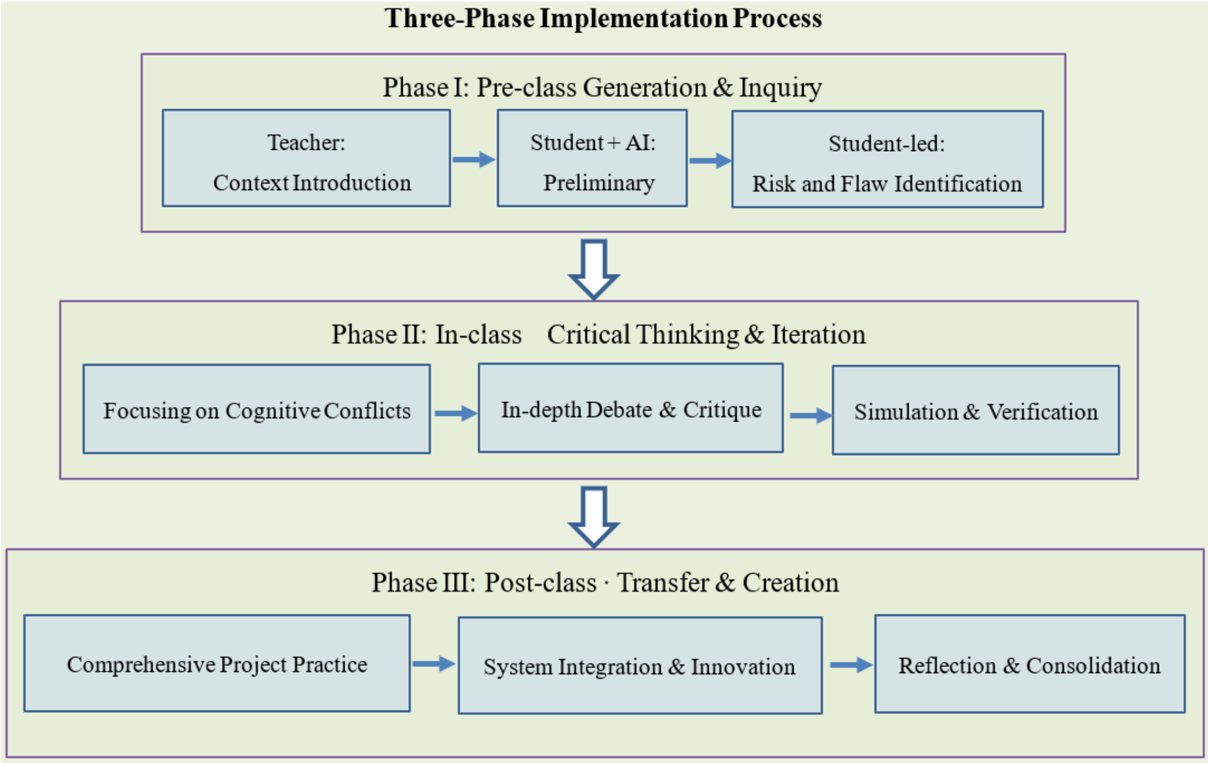

Figure 1. Three-Phase Implementation Process Flowchart

4. Teaching Practice Case: Taking the Unit "Relay-Contactor Control of Three-Phase Asynchronous Motors" as an Example

(1) Teaching Context

This unit is fundamental for students majoring in Mechanical Design, Manufacturing, and Automation to understand equipment power and control. The key and difficult point lies in understanding and applying the core safety logic of "self-locking" and "interlocking."

(2) Implementation Process

Pre-class:

Task Sheet: "Assume you need to design an electrical control cabinet for a small belt conveyor requiring the motor to achieve 'forward rotation - stop - reverse rotation.' Please consult an AI electrical assistant and have it generate a preliminary relay control circuit diagram. Your task is to evaluate the feasibility of the scheme and identify any potential safety hazards."

Student Feedback: Most students obtained functionally correct circuit diagrams lacking "interlocking." Some students, through further questioning, guided the AI to reveal the risk that "directly switching between forward and reverse rotation may cause a main circuit short circuit." All students entered the classroom with the question, "How to solve this risk?"

In-class:

Segment One: Focusing on the Problem. The teacher displays a typical AI-generated diagram (without interlocking) and guides students in analyzing its consequences. Combining their pre-class thoughts, students quickly understand the severity of a short circuit.

Segment Two: Principle Exploration and Critique. Instead of giving the answer directly, the teacher instructs the AI: "Please defend the design without interlocking just presented, explaining under what circumstances it might be acceptable?" The AI generates a statement such as "It can save costs under ideal operation and strict training." This instantly ignites a classroom debate. Students passionately refute the AI from perspectives like mechanical safety standards and human factors engineering, profoundly recognizing the engineering principle that "safety design must prevent misoperation."

Segment Three: Collaborative Design. After understanding the necessity of interlocking, the group task is: "Based on the AI-generated diagram, add necessary interlocking logic and consider incorporating overload protection." Each group uses AI to quickly generate modified schemes and verifies them in simulation software.

Post-class:

Project Task: "Design a motor control circuit for a workshop lifting platform. Requirements: (1)It can automatically stop at the upper and lower positions.(2) It has upper and lower limit protection. (3)It has an emergency stop function. Please submit the circuit diagram, component list, and write a report explaining how your design ensures safety and describing the assistance provided by AI."

Students deeply collaborate with AI. AI provides support in areas like component selection and symbol standardization, while students focus on integrating and optimizing the safety logic.

5. Practical Effects and Reflection

Through one semester of teaching practice, the following positive changes were observed:

(1)Increased Learning Interest: AI-assisted collaborative tasks centered on mechanical systems have significantly stimulated students' curiosity and sense of ownership.

(2) Deepened Engineering Thinking: The "debate" process with AI forces students into critical thinking, incorporating engineering factors such as safety, reliability, and cost into design considerations.

(3)Enhanced Knowledge Transfer Ability: Students gradually applied what they learned in the course to extracurricular projects like mechanical innovation design competitions, achieving effective knowledge transfer.

Simultaneously, we face and continue to explore solutions to the following challenges:

"Prompt Engineering" as a Competency: There is a need to cultivate students' ability to ask precise, professional questions, which is key for future engineers to collaborate efficiently with AI.

Innovation of the Evaluation System:How to fairly assess students' individual contributions in human-computer collaboration is an ongoing subject of exploration. We currently use a combined method of "design report + process log" for comprehensive assessment.

Successful Transformation of the Teacher's Role: Teachers have successfully transformed from knowledge transmitters into learning task designers, guides for human-computer dialogue, and cultivators of engineering thinking.

6. Conclusion

In the course "Electrical and Electronic Technology and Applications" for Mechanical Design, Manufacturing, and Automation majors, the generative AI-driven human-computer collaborative teaching model has successfully transformed a foundational specialized course that students often find intimidating into a challenging and enjoyable engineering exploration activity. By positioning AI as a "collaborative design partner" and a "thinking collision opponent," we have not only imparted theoretical knowledge of electrical and electronic technology but also cultivated students' crucial critical thinking, system design capabilities, and human-computer collaboration literacy. This model confirms that the rational application of AI technology is an effective strategy for addressing the teaching dilemmas of fundamental engineering courses and cultivating outstanding mechanical engineers who can adapt to the demands of the intelligent era.

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