


Research Article

# Teaching Reform of “Telecommunication Electronic Circuits” Based on the Integration of Artificial Intelligence and Human Wisdom

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## Abstract

As an important compulsory course for the students who major in telecommunications engineering, the Telecommunication Electronic Circuits (High-Frequency Electronic Circuits) course confronts two major challenges: high knowledge complexity and limited resources for practical engineering training. In order to overcome the challenges and promote teaching effects, we utilize the scheme of integrating artificial intelligence (AI) technology with human wisdom in teaching the Telecommunication Electronic Circuits course. The scheme combines the advantages of both AI technology and human wisdom. AI technology can take the responsibilities in records of learning process, analyses of learning data, knowledge delivery of adaptive content based on personalized recommendations, automatic assessment and feedback. Teachers can pay more attention to critical thinking cultivation, engineering experience transmission, values shaping and professional ethics cultivation. In pre-class phase, with AI technology, some preparatory short videos and related questions are pushed to learners for personalized learning. Then, teachers preview the response data of learners and the AI-generated feedback to adjust lesson focus accordingly. In the phase of in-class teaching, teachers explain core principles and those misunderstanding according to the response data generated in the pre-class phase. Circuit simulations are also shown and discussed. During the class, discussions on theoretical analyses, circuit simulation results and actual circuits' performance are organized. In the process, teachers not only convey engineering thought and experience, but also cultivate innovation thinking and proper ethical values. In post-class phase, AI automatically grades homework of learners, offers real-time feedback, and creates individualized learning profiles. Then, teachers design research projects with different difficulties for learners' further practical study based on the individualized learning profiles generated by AI. Such a personalized learning process is beneficial to foster the learning interests of each learner and conduct them to achieve more. Besides, AI can help teachers find those who might need assistance in learning, so that teachers can implement early interventions to mitigate academic failure risks. By adopting the scheme, we have improved the test pass rate of lower-performing learners by about 18% in 2024 compared to 2023. The paper then describes the challenges of the scheme and give some comments on the teachers' role transformation, ethical boundaries, and hybrid assessment systems. The limitation of AI technology nowadays is also discussed.

## Keywords

Teaching Reform, Telecommunication Electronic Circuits, Artificial Intelligence, Human Wisdom

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## 1. Introduction

With the rapid development of information technology, Artificial Intelligence (AI) has been used in various ways, such as Personalized Learning, Enhancing Teaching Practices, Decision-Making and Policy Formulation, Student Support Services, Organizational Leadership and Strategic Planning [1], etc. It has become an important auxiliary tool for education [2]. AI technology has revolutionized education process by offering intelligent and data-driven solutions that have effectively improved teaching, learning, and administrative efficiency. It promotes institutional operations and ensures more accessibility and effectiveness in education [3-7]. During the teaching practices, AI can help teachers enhance instructional quality and improve teaching effects [8]. Besides, AI can serve learners as a personalized learning companion, because it can not only answer questions and resolve doubts, but also act as a study pal by prompting suitable contents for learners. The adoption of AI technology in teaching expands learning possibilities, diversifies educational approaches, and provides a more personalized learning experience [9-12].

As a core compulsory course for the learners who major in telecommunications engineering at universities [13], "Telecommunication Electronic Circuits" (High-Frequency Electronic Circuits) is featured by diversified concepts, wide knowledge scope, high practicality, and broad comprehensiveness [14]. Most learners find it very challenging. The course introduces the fundamental theories of how radio signals are transmitted and received [15]. Its main contents include: high-frequency small-signal resonant amplifier, high-frequency power amplifier, sine wave oscillator, amplitude modulation and demodulation along with mixing, angle modulation and demodulation, feedback control circuit, frequency synthesis technology, etc. The teaching process of the course has been long plagued by two fundamental contradictions: cognitive gap challenge and resource-practice mismatch.

The cognitive gap challenge can be seen where the inherent complexity of topics, such as nonlinear circuit analysis and spectrum shifting principles, conflicts with the weak mathematical foundations and underdeveloped engineering thinking of some learners.

The challenge of resource-practice mismatch is shown where the high cost of specialized equipment and the risks of circuit experiments restrict practice opportunities [16], in spite of their critical importance for the skill development of learners.

Traditional teaching methods, which rely on blackboard derivations, Multisim simulations, and standard lab kits, have proven insufficient to overcome the above challenges.

The rapid growth of AI in education presents more opportunities and challenges. While AI-powered tools offer unprecedented opportunities in personalized learning and virtual experimentations, the over-reliance on AI technology is

gradually diminishing the human roles of education. In fact, human plays a crucial role on cultivating the engineering judgment and ethical values among learners. Both AI technology and human wisdom need to be emphasized in the teaching process.

Therefore, we integrate AI technology and human wisdom into our teaching process and learners' learning process to facilitate personalized learning and real-time feedback. So far, the teaching reform has proven very efficient in improving teaching effects and welcomed by learners. The test pass rate for lower-performing learners increased by about 18% in 2024 compared to 2023.

The rest parts of this paper are organized as follows: In Section 2, the integration of AI and human wisdom is presented. In Section 3, the AI empowerment in teaching is discussed in detail. In Section 4, the irreplaceability of human wisdom is described. In Section 5, some challenges of the proposed scheme are discussed and some comments are given. Finally, Section 6 concludes the paper.

## 2. The Integration of AI and Human Wisdom

### 2.1. The Responsibilities of AI and Human Wisdom

In the teaching process of the Telecommunication Electronic Circuit course, both AI technology and human wisdom have their own advantages. AI is superb at data processes and work efficiency, while human's emotional intelligence and judgement in ethical values are essential for education.

In our scheme, AI and teachers are mainly responsible for different parts, which are shown in Table 1.

### 2.2. How to Integrate AI and Human Wisdom

Here is our suggestion on how to integrate AI and human wisdom to fully develop the potentialities of both AI and human wisdom based on the current information technology.

#### 2.2.1. Pre-class Phase

In the pre-class phase, learners need to do some preparations for in-class learning. Usually, before the class, with AI technology, some preparatory short videos and related questions are chosen and pushed to learners for personalized learning. Then, teachers preview the generated response data of learners and adjust lesson focus accordingly. For example, before teaching "Class C power amplifiers," learners catch AI-pushed contents and answer some questions related to the topic, and then teachers review the response data to get to know the common misconceptions among learners. If the data shows that learners misunderstood the concept of con-

duction angle, then teachers would spend more time on class to explain the concept and its effects on circuits.

**Table 1.** Responsibilities of AI and teachers.

Responsibilities of AI	Responsibilities of Teachers
learning process recording and learning data analyses	innovation stimulation more related to real-world cases
knowledge delivery of adaptive content based on personalized recommendations	engineering experience transmission
automatic assessment and feedback	thought guidance, values shaping and professional ethics cultivation

### 2.2.2. In-class Phase

In the phase of in-class teaching, teachers explain core principles using rich analogy examples as clearly as possible, and those misunderstanding according to the response data generated in the pre-class phase. Then, some circuit simulations are shown to prove the explanations in theoretical situations. In order to make the circuit simulation closer to real engineering cases, AI generates more data existing in actual engineering situations to influence the circuit simulations. For example, by dynamically adding the noise data generated by AI onto the receiving side, teachers guide learners to observe the different responses of the circuit and to analyze the possible reason of the responses. Such a process is beneficial to fostering the engineering thinking of learners and improving their ability to tackle real problems in engineering fields.

During the class, teachers organize discussions and debates on theoretical analyses, simulation results and engineering practice. In the process, teachers may invoke innovation ideas, transmit their engineering experience, and gradually cultivate proper values, engineering thought and professional ethics of learners.

### 2.2.3. Post-class Phase

In this phase, AI automatically marks or grades homework of learners, offers real-time feedback, and creates individualized learning profiles. Then, teachers design research projects with different difficulties for students' further study in practical circuits based on the learning profiles generated by AI. For example, some advanced learners will explore the research project on "reconfigurable filters in software-defined radio", while several of others are still spending time on the reinforcement of fundamental circuits. Learners can obtain more achievements through the personalized learning process based on the learning profiles generated by AI. The personalized learning process is beneficial to foster the learning interests of each learner and conduct them to achieve more.

Unlike traditional one-fits-all teaching approaches, the scheme based on the integration of AI technology and human

wisdom can dynamically adjust content, methodology, and assessment based on the personalized learning profiles of each learner.

The above subsections present the practice of integrating AI and human wisdom in teaching process. The following two sections will discuss the importance of AI and human wisdom separately in further details.

## 3. AI Empowerment

With the development of information technology, AI is injecting more and more energetics into teaching through data-driven approaches and cognitive enhancement. Although the AI technology is not perfect now and there is room for its improvement, AI has already exerted great influential effects on at least the following three aspects.

### 3.1. Dynamic Learning Path Construction

With the aid of AI technology, knowledge graphs are easily generated to illustrate the structure of telecommunication electronic circuit knowledge systems. Using the knowledge graphs, learners can construct knowledge map in mind more specifically to facilitate their learning process. For example, correlating "LC parallel resonance" with all the related knowledge points shown in one knowledge map will guide learners to understand the "LC parallel resonance" knowledge point and its applications more quickly and thoroughly.

Personalized knowledge maps provide support for the student-centered, data-driven personalized learning. They can be efficiently obtained by the learning behavior data generated with AI technology.

During our teaching process in the last semester, 95% of the learners welcome the personalized learning process due to its effectiveness in learning process.

### 3.2. Intelligent Assessment Systems

Using the AI-based homework grading systems, topologi-

cal errors in circuit diagrams can be identified immediately. Besides, AI-generated "error type maps" help teachers quickly identify class-wide cognitive blind parts, for instance, common confusion between single-tuned and double-tuned circuit impedance characteristics.

According to the quantitative data provided by the AI-based grading system, teachers can get more accurate feedback on teaching effects and make suitable plans for further adjustment based on their teaching experiences and wisdom.

### 3.3. Intelligent Upgrade of Circuit Simulations and Experiments

The AI-based adaptive circuit simulation platform, constructed by Multisim and AI helper, can analyze learner operation paths in real-time, automatically generate fault scenarios, such as amplifier self-oscillation and mixer inter-modulation distortion, and provide some possible solutions. Such a platform shows great potential in improving the efficiency of circuit simulations and enlarging the knowledge horizons of learners, although some of the faults in circuit simulations might be too complicated to be solved without the help of teachers. In our future work, we will continue to update and improve the performance of the AI-powered adaptive circuit simulation platform to make it more implementable.

During the actual circuit experiments in laboratory, a computer vision-powered monitoring system tracks and analyzes student facial expression during laboratory experiments, providing real-time feedback to teachers. For example, when prolonged hesitation is detected by AI based on the analyses of students' facial expressions, some prompts are sent to teachers for just-in-time interventions. In the future, unsafe practices would be detectable in the system to avoid possible damage to equipment.

## 4. Human Wisdom — The Irreplaceable Human Element

Despite the indisputable power of AI technology, the deep involvement of human wisdom is still undoubtedly required in education. The essence of education remains in innovation inspiration and values transmission, which is unachievable nowadays without human wisdom.

Human educators play important roles at least in the following three critical areas.

### 4.1. Embodied Transmission of Experiential Knowledge

Teachers employ analogical teaching methods to explain and clarify abstract concepts based on cognitive psychology that AI may not yet perform autonomously. For example, by

comparing signal modulation/demodulation to "cargo loading/unloading" or "human on/off buses", teachers can make the concept of modulation/demodulation more understandable.

Teachers are also more welcomed than AI while telling their real engineering experiences. For example, when one of our teachers explained "Class C resonant power amplifier conduction angle optimization", he inserted his experience on specific transmitter models experiencing efficiency drops due to excessive conduction angles. Then, a discussion among learners and teachers is intrigued immediately and engineering thinking of learners is stimulated gradually.

### 4.2. Cultivation of Higher-Order Capabilities

Teachers play a unique role in guiding learners to question simulation results and circuit experiments based on cognitive psychology. For example, by comparing and contrasting the results of ideal models, circuit simulations, and actual circuits, teachers can organize discussions among students gradually from theoretical analyses to engineering practice.

Moreover, teachers can encourage debate exercises on technical tradeoffs among students. For example, while teaching the Class C amplifiers, teachers can organize some discussions on the advantages and weaknesses of Class B and Class C amplifiers. Then, by offering a certain situation of engineering applications, teachers can discuss the situation with learners and help learners identify which one is more suitable for the situation.

During this process, critical thinking and engineering thought can be cultivated and fostered.

### 4.3. Emotional Connection in Education

Although the interactions with AI can definitely exert some effects on the emotions of learners, human still plays a more crucial role for emotional connection in education. For example, by telling the historical stories of telecommunication electronic circuits, such as the historical event on how superheterodyne receivers revolutionized radio development, teachers can evoke thinking and organize discussions among learners, transmitting scientific spirits step by step in the process.

Besides, by constructing the "AI Early Warning and Teacher Intervention for Struggling Learners" mechanism, which is designed for teachers to find the learners who might need assistance in academic, teachers can implement early interventions to assist learners in avoiding possible course failures. Such an effective measure can also relieve the possible mental burdens of struggling learners by helping them focus on their achievable objectives. Fortunately, with the aid of AI-human collaboration and "AI Early Warning and Teacher Intervention for Struggling Learners" mechanism, we reduced course failure rate of lower-performing learners by about 18% in 2024 compared with 2023.

It is noticeable that the wisdom of learners is also very important for the teaching effects. In teaching practice, we have been continuously exploring effective measures to stimulate learners' enthusiasm for learning and fully develop their potentials in learning. Both teachers' wisdom and learners' wisdom are important and essential for a successful teaching process.

## 5. Challenges and Comments

During the implementations of integrating AI and human wisdom, the role of teachers has been transformed from "knowledge transmitters" to "learning architects". In order to completely meet the requirements for such a transformation, some teachers need more systematic AI-teaching competency training. Each member in our teaching team has been systematically trained on how to use AI technology. Discussions on teaching feedback and experiences are usually held weekly to facilitate communications among teachers.

Besides, there are also some ethical boundaries to set for AI involvement limits. For example, any AI-generated content must be explicitly labeled; a direct experiment report totally generated by AI should be prohibited. In our teaching practice, we announce certain rules to set AI involvement limits during our first class. Each student is obliged to follow the rules and keep academic integrity in mind all the time.

Moreover, in order to evaluate the academic performance of learners more thoroughly, we have established a hybrid assessment model combining "AI quantitative metrics" and "teacher qualitative evaluations" to exert the advantages of both AI and human. For example, AI tracks the accuracy of calculations and the iterations of circuit optimization, while teachers assess the innovation ideas of learners.

It is important to realize the risks of AI in the creation of fake content and misinformation [17]. While generative AI has revolutionized knowledge requisition, its outputs are inherently fallible due to its weaknesses [18]. However, the legal liability for such faults remains unresolved [17]. We should pay attention to the fact that not all of the content generated by AI is trustworthy. People need to view the outputs of generative AI critically [19]. For example, ChatGPT has been shown to provide unreliable data and fabricated citations and it has been criticized for false information [20, 21]. We cannot depend too much on AI technology. The guidance of teachers in the teaching process on how to use AI properly is necessary and the role of teachers remains irreplaceable.

## 6. Conclusions

In this paper, we introduce our teaching reform approaches and practices in teaching the Telecommunication Electronic

Circuits course by integrating AI and human wisdom. As far as we are concerned, AI is not a "competitor" but an educational "promoter" for teachers. By effectively integrating AI technology with human wisdom, we are able to promote our teaching effects and improve students' abilities gradually. Hopefully, more and more outstanding engineers with excellent telecommunication circuit design and innovative abilities will emerge.

It is noticed that AI is not always trustworthy and it may generate false content. Teachers should guide students to use AI technology in a proper way. The role of teachers is still irreplaceable in the teaching process.

The utilization of the integration of AI and human wisdom make it possible for teachers and learners to gradually overcome the two challenges mentioned in Section 1. The educational transformation driven by the effective integration of AI and human wisdom makes it possible for college education to return to educational essence: enabling each student experience the excitement of academic achievements and the thrill of further intellectual exploration, while touching the great attractiveness of technology development through engineering practice.

## Abbreviations

AI Artificial Intelligence

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## Author Contributions

**Jinmei Liu:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing

**Hua Yuan:** Resources, Methodology, Supervision, Writing – review & editing

**Xue Lin:** Methodology, Investigation

**Nianqiang Li:** Supervision, Investigation

## Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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