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Teaching Exploration of the "AI+ Signals and Linear Systems Analysis" Course

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Abstract: With the rapid advancement of artificial intelligence (AI) technology, particularly the maturity of large language models, higher education models are undergoing profound transformation. Based on the core course "Signals and Linear Systems Analysis" in biomedical engineering, this paper explores the empowering practices of AI technology throughout the entire teaching process. By deeply integrating AI tools into three key stages—classroom instruction, after-class review, and learning assessment—the approach aims to enhance teaching efficiency, stimulate students' learning interest, and cultivate critical thinking skills along with the ability to properly use intelligent tools, which are essential in the AI era. Teaching practice demonstrates that this "AI-empowered" model can not only effectively assist instructors but also guide students to shift from passive knowledge acquisition to active exploration and knowledge construction, offering new insights for the reform of fundamental engineering courses.

1. Introduction

The course "Signals and Linear Systems Analysis" is a core component of the biomedical engineering curriculum, characterized by its strong theoretical nature and abstract concepts. Its core content revolves around the "three major transforms" (Fourier, Laplace, and Z transforms) and system analysis [1]. Key topics such as convolution, Fourier transform, and system response have consistently posed learning challenges for students. In traditional teaching models, the approach of instructor-led explanation and passive student reception often fails to help all learners develop an intuitive and deep understanding. Additionally, as a theoretical course, it cannot dedicate excessive class hours to teaching programming, resulting in difficulties for students with varying programming backgrounds to independently conduct practical exercises and validate theoretical knowledge.

The emergence of generative artificial intelligence (AI) offers a powerful tool to address these challenges [2,3]. It can not only generate text and code but also engage in multi-turn dialogue, acting as a "never-tiring teaching assistant." However, overreliance on AI may lead to diminished critical thinking and potential misinformation due to AI "hallucinations." Therefore, the core objective of this study is not simply to replace teaching with AI, but to explore "human-AI collaboration"—positioning AI as an auxiliary tool to enhance the capabilities of both instructors and students. Throughout this process, emphasis is placed on cultivating students' critical thinking and problem-solving skills. The AI referred to in the following discussion takes DeepSeek provided by the university as an example.

2. AI-Assisted Classroom Teaching

In classroom instruction, AI can serve as a tool for demonstration and critical thinking, supporting a shift from knowledge delivery to thinking training. The following two practical approaches have been designed.

2.1. AI-Assisted Explanation of Key Concepts

During lesson preparation, AI can aid in instructional design and inspire instructors with new ideas. For abstract concepts, instructors can prompt AI to generate vivid analogies.

For example, when teaching "convolution," a instructor might ask: "*Explain the concept of convolution in signals and systems to university students using an engaging analogy, emphasizing the process of 'flipping, shifting, and superimposing.'*" AI may respond: "*The physical meaning of convolution can be intuitively understood as the total effect (all the sounds you hear) when a signal (like a short shout) passes through a system (such as an echo-producing valley).*" While this example vividly illustrates how an input signal generates a response through a system, it does not perfectly align with the precise concept of convolution. When the prompt is refined to emphasize that convolution decomposes any excitation signal into a linear combination of impulse responses, AI tends to provide a more theoretical explanation rather than a figurative one. This reflects how the design of the prompt influences AI output—instructors may need multiple rounds of dialogue with the AI, continuously refining prompts to obtain ideal explanations.

As another example in explaining "modulation," AI offered the following analogy: "*A modulating signal (band-limited) is like a written letter (important in content, but unable to travel far on its own). The carrier wave is like a high-speed airplane (with strong transport capability). The modulation process is like loading the letter onto the plane. The modulated signal (band-pass) is the plane carrying the letter, now airborne.*" This response is more effective than the previous example, demonstrating that AI's utility in assisting instructional design can vary, requiring instructors to critically evaluate its suggestions. Such analogies can spark students' interest and help build an initial intuitive understanding of abstract concepts. However, instructors must promptly follow up with professional scrutiny and elaboration, pointing out inaccuracies in the analogy (e.g., the fundamental difference between signal modulation and physically loading a letter onto a plane)—guiding students smoothly from figurative understanding to rigorous theory, thereby achieving a cognitive leap from perception to reasoning.

Additionally, instructors can use AI to provide application examples relevant to biomedical engineering, such as the use of filters in ECG signal processing. By connecting abstract theory with specialized scenarios, students can more effectively grasp the practical relevance of course content.

2.2. AI-Generated MATLAB Examples and "Error-Spotting" Learning

When teaching theoretical concepts in the classroom, MATLAB (Mathworks) serves as a powerful tool for visually demonstrating signal transformation processes. Instead of directly providing correct sample code that is the traditional approach, this study attempts to adopt a more challenging "error-spotting" teaching method.

For example, when explaining finite Fourier series, the instructor first uses AI to generate a MATLAB code snippet that plots both a periodic rectangular pulse signal and a reconstructed signal formed by superimposing the fundamental wave and its harmonics. After entering the prompt, AI may produce code that appears correct but contains errors. When executed in MATLAB, the output might resemble Figure 1A. At this point, the instructor guides the students by asking: "*Does the reconstructed signal in this graph closely match the original signal? Based on the Fourier series theory we just covered, where did the AI go wrong?*" Through group discussions or individual reflection, students identify two issues in the figure: a height difference and a phase shift between the two signals. The instructor further explains that the height difference arises because the direct current component set by the AI (1) does not match the actual average value of the original signal (0.6). The phase shift stems from the AI's misunderstanding of the Fourier series—the original signal defined by the AI is not an even function symmetric about the vertical axis, whereas the theoretical derivation of the Fourier series assumes even symmetry. This discrepancy causes the AI's original signal and the reconstructed Fourier series signal to be offset by half the pulse width on the time axis. Once students grasp these theoretical issues, they can modify the code accordingly to produce the correct schematic (Figure 1B).

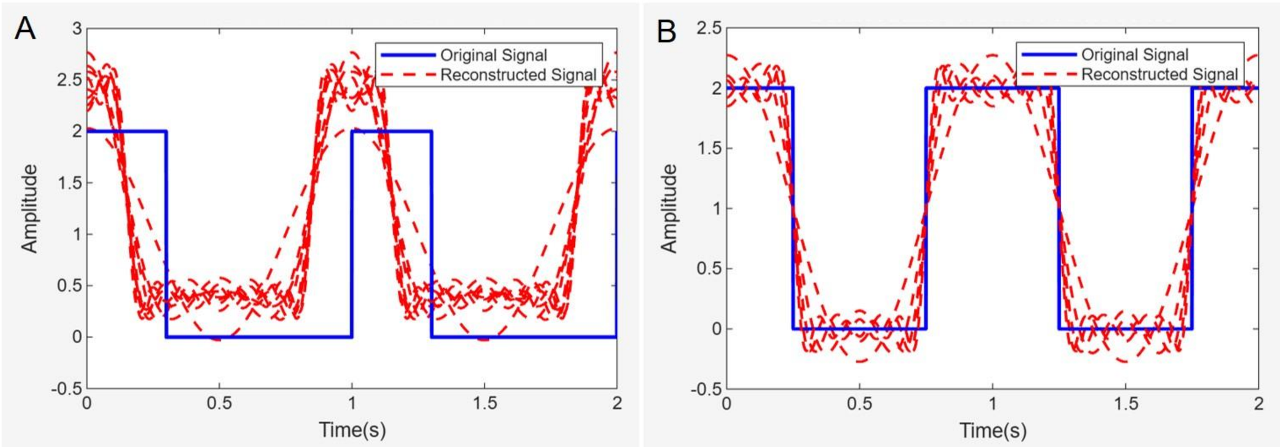

Figure 1. Graphs obtained in MATLAB using A) AI-generated code and B) revised code.

Such teaching process yields a range of positive outcomes. On one hand, it embraces the AI trend by showing students how to use AI to accelerate programming and deepen their understanding of theoretical knowledge. On the other hand, through a concrete case, it vividly demonstrates that AI is not infallible—it can make mistakes, and a solid theoretical foundation is the only reliable means to identify and correct these errors. This approach effectively prevents students from blindly relying on AI and strengthens their sense of agency and critical thinking. As a follow-up, students can be assigned tasks to practice this process independently. Since the errors generated by AI may vary each time, students can deepen their theoretical understanding by identifying and correcting different types of mistakes.

3. AI-Assisted After-Class Review

In the after-class review process, AI can provide uninterrupted support to students, aiding in the deeper internalization of knowledge.

3.1. Intelligent Learning Companion

Unlike instructors with limited office hours, students can pose questions to the AI at any time—such as "*Please explain the general method for solving system responses.*" or "*What are the* *connections and differences between the Laplace transform and the Fourier transform?*" The AI can offer immediate and detailed explanations from multiple perspectives, addressing the shortcomings of traditional teaching where timely instructor feedback and personalized guidance are often unavailable. Instructors can guide students in honing their questioning techniques, encouraging them to engage in follow-up inquiries and deepen the dialogue based on the AI's responses, thereby transforming after-class review into an in-depth conversational process. At the same time, students should be reminded to remain critical and identify potential inaccuracies in the AI’s answers. This course has also explored the development of a dedicated AI learning companion tailored to the curriculum, aiming to improve the accuracy and subject-specific relevance of AI-generated responses.

3.2. Generating Study Guides

After completing each chapter, instructors can task the AI with generating a study guide that includes a list of core concepts, key formulas, typical problem types, and solution strategies. These AI-generated guides serve as roadmaps for student review, helping them construct a knowledge framework and identify areas requiring further attention. While this approach enhances instructional preparation efficiency and provides students with additional learning resources, it is essential to review the AI-generated content to prevent potential misunderstandings. Students can also leverage the AI to create customized guides targeting their individual weak points, enabling a more personalized and adaptive review process.

4. AI-Assisted Learning Assessment

In the realm of learning assessment, AI provides substantial support to instructors. Instructors can utilize AI to rapidly generate a large volume of diverse exercises and test questions. For example, by inputting a prompt such as, "Please generate five practice problems on 'signal convolution computation,' with difficulty ranging from easy to hard, and include reference answers and step-by-step solutions," AI can accomplish this task within seconds. This significantly reduces the burden of question creation for instructors and makes updating and expanding the question bank highly efficient.

It is important to note that questions generated by current AI systems often contain issues, such as focusing on overly niche knowledge points, computational inaccuracies, or conceptual misunderstandings, which necessitate careful review by the instructor. The instructor’s core responsibility thus shifts from writing questions to selecting and refining questions, i.e., choosing from the AI-generated items those that are of the highest quality and most closely align with the teaching objectives, followed by polishing and correcting the provided solutions.

5. Practical Reflections and Challenges

Throughout the implementation process, several challenges have emerged, leading to the following reflections. Instructors must consistently emphasize the importance of theoretical foundations to prevent students from falling into a state of “knowing the how but not the why.” Clear guidelines should be established to prohibit the direct use of AI for completing assignments and exams that require independent work, while encouraging students to treat AI as an aid for learning and thinking rather than a substitute for their own effort. Additionally, the role of the instructor needs to evolve from that of an authoritative knowledge transmitter to a learning designer, facilitator, and co-supervisor of AI tools—a shift that places higher demands on teaching competency.

6. Conclusions

This paper has systematically implemented a new AI-empowered teaching model in the "Signals and Linear Systems Analysis" course. By creatively applying AI tools across three core aspects, from teaching to learning and assessment, the approach has not only improved instructional efficiency but, more importantly, cultivated two essential competencies for students in the age of artificial intelligence: the ability to leverage AI to enhance learning effectiveness, and the ability to maintain independent thinking and critically evaluate AI-generated content. Future work will continue to deepen the application of AI in areas such as project-based learning and comprehensive experiments, while establishing a more robust evaluation system to measure its long-term educational impact, thereby consistently promoting innovation and development in course construction.

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