Journal of Education and Educational Research
ISSN: 2957-9465 | Vol. 21, No. 2, 2026

Research on AI-Assisted Practical Teaching in Embedded Systems

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Abstract: To address issues in traditional embedded systems laboratory instruction—such as students' insufficient preparation for experiments, weak problem-analysis skills, and limited ability to apply knowledge comprehensively—we conducted research on AI-assisted practical training in embedded systems laboratory instruction. Taking into account the characteristics of embedded systems laboratory instruction, we applied AI tools to stages such as experiment preparation, problem analysis, and comprehensive application. This approach guides students to use AI to supplement their knowledge, troubleshoot problems, and expand experimental designs, while verifying the analysis results through hands-on experiments. In teaching practice, we adhere to a student-centered approach with AI as a supplement, establishing a laboratory teaching process comprising "knowledge preparation—problem analysis—practical verification—integrated application." Practice has shown that AI-assisted learning provides students with more flexible learning support, helping to cultivate their abilities in self-directed learning, problem analysis, and the integrated application of knowledge, thereby offering valuable insights for reforming embedded systems laboratory instruction.

Keywords: Embedded Systems; Laboratory Instruction; Artificial Intelligence; AI-assisted Learning; Self-directed Learning; Hands-on Instruction.

1. Introduction

Embedded systems are highly practical and comprehensive, requiring students not only to master fundamental knowledge of microcontrollers, interface technologies, and programming, but also to understand the process of hardware-software co-design through experiments. Traditional experimental teaching of embedded systems mainly adopts a teaching model in which instructors explain the relevant content and students complete experiments according to laboratory manuals. Although this approach plays an important role in developing students' basic experimental skills, there remains room for further improvement in fostering students' independent learning and practical abilities. Previous studies have explored reforms in embedded systems experimental teaching from the perspectives of experimental content, teaching methods, and practical ability development [1].

With the development of artificial intelligence (AI), AI tools have gradually been introduced into education and teaching, providing students with assistance in knowledge explanation, learning feedback, and problem analysis. Relevant studies have shown that artificial intelligence has been applied to multiple aspects of higher education, including teaching, learning, and assessment, providing new technological conditions for improving traditional teaching methods [2].

Meanwhile, China has continued to promote the digitalization of education and proposed exploring the deep integration of artificial intelligence with education and teaching, gradually incorporating AI technologies throughout the educational process[3]. In embedded systems experimental teaching, AI is more appropriately used as an auxiliary tool during students' learning and experimental debugging processes rather than as a substitute for programming and experimental operations. Therefore, based on the practical requirements of embedded systems experimental teaching, this study conducts AI-assisted practice in three aspects: experimental preparation, problem analysis, and comprehensive application, aiming to explore approaches to using AI to promote students' independent learning and practical abilities.

2. Analysis of the Current Status of Embedded Systems Experimental Teaching

Embedded systems experiments generally include GPIO, USART, timers, ADCs, sensor interfaces, and other experimental topics. Different experiments involve multiple aspects, such as hardware connections, program design, peripheral configuration, and debugging, placing relatively high demands on students' comprehensive practical abilities. Previous studies on reforms in embedded systems experimental teaching have proposed that experimental content should be organized appropriately and that the connection between fundamental knowledge and engineering practice should be strengthened [4].

At present, experimental teaching is generally based on instructors explaining experimental principles, demonstrating experimental procedures, and students completing experiments according to laboratory manuals. This approach enables students to complete experimental tasks according to predefined procedures. However, some students lack adequate preparation before experiments and therefore spend considerable time consulting reference materials during the experimental process. In particular, when program errors occur, some students tend to seek direct assistance from instructors rather than analyzing experimental phenomena and troubleshooting problems step by step.

In addition, traditional experimental content is usually organized around individual knowledge points. After completing basic experiments on GPIO, serial communication, timers, and other topics, students may be able to complete individual experimental tasks but still need

further development in applying multiple knowledge points comprehensively to practical systems. Relevant studies have also pointed out that reforming experimental content and teaching methods can further strengthen students' practical and comprehensive application abilities [1].

Therefore, introducing AI-assisted tools into traditional experimental teaching can provide students with more flexible approaches to learning and problem analysis. AI can support students in reviewing relevant knowledge before experiments, analyzing problems during experiments, and further extending experimental content after completing basic tasks.

3. Approach to AI-Assisted Embedded Systems Experimental Teaching

AI-assisted embedded systems experimental teaching does not simply mean adding an AI tool to the existing teaching process. Instead, AI should be introduced into appropriate teaching stages according to the actual problems encountered by students during experimental learning.

First, AI can be used to assist students in reviewing relevant knowledge before experiments. Students can actively learn the fundamental knowledge involved in an experiment and address deficiencies in their understanding before entering the experimental stage.

Second, AI can assist students in problem analysis during experiments. When experimental results differ from expectations, students should first analyze the observed phenomena and then use AI to obtain possible troubleshooting directions. They can subsequently verify these analyses through actual debugging, gradually developing the ability to solve problems independently.

Finally, after completing basic experiments, AI can be used to assist in extending experimental tasks. Instructors can propose comprehensive experimental projects, while students analyze system functions and implementation approaches according to the task requirements. They can use AI, textbooks, and microcontroller datasheets to assist in system design and ultimately complete verification through practical experiments.

Therefore, AI mainly serves as an auxiliary tool throughout the experimental teaching process, while students remain the primary participants in learning and practical operations. This process can form a learning cycle of "knowledge preparation—experimental analysis—practical verification—comprehensive application."

4. Requirements for the Application of AI in Experimental Teaching

4.1. Using AI to Assist Experimental Preparation and Knowledge Reinforcement

Embedded systems experiments involve a considerable amount of fundamental knowledge. If students have not mastered the relevant knowledge before entering the laboratory, they may encounter difficulties in understanding the experimental tasks. Traditional experimental teaching mainly relies on laboratory manuals and classroom instruction for experimental preparation. However, students differ in their prior knowledge and learning abilities, making it difficult for standardized preparation materials to fully meet individual learning needs.

Therefore, students can be guided to use AI for targeted preparation before experiments. Instructors can establish preparation requirements based on the experimental content, while students use AI to study according to their individual knowledge gaps and then verify the information using textbooks and relevant microcontroller documentation.

For example, in an STM32 GPIO experiment, students need to understand basic concepts such as GPIO input, output, push-pull output, open-drain output, and LED driving. Students can use AI to obtain explanations of concepts they do not understand and then consult relevant reference materials for further verification. Instructors can focus on common problems identified during students' preparation and provide targeted explanations in class rather than repeating all basic concepts. Similar reforms in experimental teaching have emphasized strengthening the connection between fundamental knowledge and experimental practice [4].

This approach enables students to conduct learning according to their individual needs while also helping instructors identify areas of insufficient knowledge before experiments.

It should be noted that AI-generated explanations cannot replace textbooks or microcontroller documentation. For specific information such as pin functions, register configurations, and peripheral parameters, students should still refer to the relevant datasheets and verify the information through actual experiments.

4.2. Using AI to Assist Problem Analysis and Promote Independent Experimentation

Problems encountered during experiments constitute an important part of practical teaching in embedded systems. Issues such as program execution failures, incorrect hardware connections, and improper peripheral configurations require students to analyze and debug systematically. Therefore, instructors should avoid directly solving all problems for students and instead gradually develop their ability to analyze problems independently.

During experiments, students can be guided to follow a process of "phenomenon description—cause analysis—assisted inquiry—experimental verification." For example, in an STM32 serial communication experiment, if data transmission functions normally but data reception is abnormal, students should first check the serial communication parameters, GPIO alternate-function configuration, peripheral clock settings, and receiving program.

After completing an initial investigation, students can submit the experimental phenomena and the items they have already checked to an AI tool and ask it to provide possible troubleshooting directions. Students should not directly copy programs generated by AI. Instead, they should examine the program and hardware step by step based on the suggested analysis and verify the results by downloading the program again, modifying configurations, and conducting practical tests. Relevant studies have shown that generative artificial intelligence can provide support for teaching activities and learning processes, but its application still requires careful attention to learning quality and potential risks. [5].

This approach can reduce students' tendency to follow the pattern of "experimental error—ask the instructor directly—obtain the program." In this process, the instructor primarily guides students in analyzing problems, while AI serves as an auxiliary tool for providing possible troubleshooting ideas.

4.3. Using AI to Extend Experimental Content and Promote Comprehensive Knowledge Application

Practical embedded systems applications usually require multiple knowledge points to work together, whereas traditional basic experiments are often designed around individual knowledge points. Therefore, after students complete basic experiments, AI can be used to assist in extending experimental content, gradually guiding students from merely "completing experiments" toward "designing and implementing systems."

For example, after completing basic experiments involving GPIO, USART, timers, and ADCs, instructors can design a simple environmental parameter monitoring project that requires students to implement sensor data acquisition, data processing, display, and serial data transmission without providing a complete program.

Students first analyze the required system functions, determine the required hardware interfaces and software modules, and then use AI to analyze and compare different implementation approaches. After determining the implementation scheme, students independently complete the program design and hardware connections and verify the system functions through practical experiments.

During this process, AI can help students understand new knowledge, compare different implementation approaches, and analyze program structures, but it should not replace students in completing hardware connections and experimental verification. By combining multiple basic experiments, students can gain a deeper understanding of the relationships among different peripherals and improve their ability to apply knowledge comprehensively. Previous studies on embedded systems experimental teaching have also emphasized strengthening students' comprehensive practical abilities through reforms in experimental content [1].

5. Requirements for the Application of AI in Experimental Teaching

Although AI can provide convenience for embedded systems experiments, its use should be appropriately controlled during the teaching process.

First, students' primary role in experiments should be clearly maintained. AI can provide knowledge explanations and problem-analysis suggestions, but program development, hardware connections, and experimental verification should still be completed by students.

Second, students should be encouraged to develop the ability to evaluate AI-generated content. Embedded systems involve specific microcontroller models, peripheral configurations, and hardware conditions, and the implementation of the same function may differ across different hardware platforms. Therefore, students need to verify information provided by AI using textbooks, microcontroller datasheets, and actual experimental results.

Finally, excessive dependence on AI should be avoided. Instructors can require students to describe experimental phenomena and present their own preliminary analysis before using AI for assistance, rather than directly asking AI to generate complete experimental programs. In this way, AI can serve as an auxiliary tool in students' independent learning and practical activities rather than replacing their thinking and problem-solving processes. Policies concerning the digitalization of education have also proposed promoting the integration of artificial intelligence with education and teaching while emphasizing the development of students' abilities [3].

6. Conclusion

AI technology provides new approaches for assisting embedded systems experimental teaching. Based on the practical process of embedded systems experimental teaching, this study conducts AI-assisted practice in three aspects: experimental preparation, problem analysis, and comprehensive application, enabling AI to provide knowledge reinforcement, auxiliary problem analysis, and experimental task extension, respectively.

During the teaching process, students remain the primary participants in actual experimental operations, while AI is used as an auxiliary tool for learning and debugging. This enables students to experience a process of "knowledge preparation—problem analysis—practical verification—comprehensive application." Such an approach can provide students with more flexible learning support and contribute to the development of their independent learning, problem-analysis, and practical application abilities.

In future teaching practice, the AI-assisted teaching process can be further refined for different experimental projects, and its integration with experimental assessment can be explored to enable AI to play a more appropriate and effective supporting role in embedded systems experimental teaching.

Acknowledgments

Anhui Xinhua University University-Level Teaching Innovation Team (2025cxtdx04); Anhui Xinhua University University-Level Quality Engineering Project (2025jy017); Anhui Xinhua University University-Level School-Enterprise Cooperation (2024xqhz092); Anhui Xinhua University University-Level Serving Emerging Industries (2025cxtdx04)

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