

Exploration of AI-Enhanced Teaching Models in Microcontroller Courses

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Abstract: This paper discusses the integration of artificial intelligence (AI) into microcontroller principles and applications courses to enhance students' comprehensive abilities in response to industry needs. The "AI+" approach is introduced to redesign course content, focusing on application-based curricula and implementation pathways. Course content is structured around automotive electronics supply chains, integrating multiple disciplines including automotive electronics, embedded systems, and artificial intelligence. It is divided into three layers: foundational, application, and expansion, aiming to comprehensively develop students' basic knowledge and advanced skills. In teaching practices, AI-enabled collaborative development workflows are employed, emphasizing "need release - AI toolchain application - team collaboration" processes, forming a tripartite cooperation model: teacher guidance, student practice, and AI empowerment. To enhance resource integration and utilization, three tiers of teaching resources: course knowledge repositories, industry demand databases, and competition research libraries have been established. By incorporating AI into microcontroller courses, students are better prepared to meet both current and future engineering challenges, equipped with practical skills and encouraged to develop innovative capabilities.

Keywords: Microcontroller; AI Integration; Personalized Learning Paths; Industry Alignment.

1. Introduction

In recent years, AI technology has made significant breakthroughs across various fields, particularly in areas like voice recognition, image processing, and natural language processing [1,2]. These advancements have not only enhanced work efficiency but also driven innovation and development across multiple sectors. For instance, intelligent driving technologies are gradually changing how people travel [3]; AI-driven learning platforms provide personalized study plans for students[4,5]. The Ministry of Education has explicitly called for the promotion of "AI + education" initiatives, encouraging universities to integrate AI technology into course curricula and teaching practices to cultivate high-quality engineering talent with interdisciplinary perspectives and innovative capabilities.

However, the traditional Microcontroller Principles and Applications course primarily focuses on fundamental knowledge of hardware structures, instruction sets, and interface techniques. The experimental content is predominantly based on verification exercises, lacking integration with AI[6]. This curriculum is insufficient to meet industry demands for composite talent[7]. Students need not only to master the basics of microcontrollers but also possess the ability to design complex systems using AI algorithms. For example, in electric vehicles, a microcontroller system combined with AI can implement adaptive cruise control and intelligent obstacle avoidance features; in smart homes, AI technology enhances the intelligence level and user experience of the entire system.

To address these challenges, this paper discusses the implementation of an "AI+" approach in the Microcontroller Principles and Applications course. The reconstruction based on real-world applications, particularly within the context of smart driving technology has been proposed. The goal is to enhance student engagement by incorporating AI concepts

into existing curricula, thereby fostering a deeper understanding of both fundamental principles and advanced techniques in microcontroller programming. Through the creation of a collaborative learning model involving "teacher-guided, student-practiced, AI-empowered," combining intelligent car competitions and engineering contests, we have developed a curriculum that integrates demand-driven design, knowledge restructuring, and skill enhancement. Students engage in practical exercises using simulation software and hardware equipment, leveraging domestic large models for optimization of development processes. It helps students develop advanced application skills, enhance their problem-solving abilities, and cultivate professional talent with both theoretical and practical competencies.

2. The Proposed Method

2.1. Reconstructed Curriculum Structure

The course content is structured around the longitudinal axis of the new energy vehicle electronics supply chain, integrating multidisciplinary projects from automotive electronics, embedded systems, and artificial intelligence. This modular curriculum framework is divided into three progressive layers: Foundation Layer, Application Layer and Expansion Layer, providing a comprehensive knowledge pathway to help students master both foundational concepts and advanced skills. In the foundation Layer, it covers fundamental concepts and technologies such as microcontroller architecture, C programming, GPIO, timers, and interrupts. It focuses on practical applications including SPI/I2C communication, ADC/DAC, motor control, and sensor interfaces in the application layer. In the expansion layer, advanced topics like Battery Management System (BMS), intelligent driving assistance systems, and lightweight AI algorithm deployment have been involved.

By leveraging a case study database of leading enterprises,

real-world projects such as intelligent car competitions, smart homes, and industrial controls are introduced to integrate the knowledge of "automotive electronics + embedded systems + AI." For example, students must complete a project involving an autonomous tracing robot using a microcontroller. This project includes tasks such as sensor data acquisition, motor control, PID algorithm implementation, and optional image recognition. This teaching framework is demand-driven,

facilitating knowledge reorganization and skill enhancement, creating a "Demand, Knowledge Reconstruction, Ability Enhancement" cycle. As illustrated in Figure 1, this curriculum helps students progressively deepen their understanding from foundational knowledge to advanced application skills, thereby enhancing their problem-solving capabilities. It supports the development of professional talent required by industries.

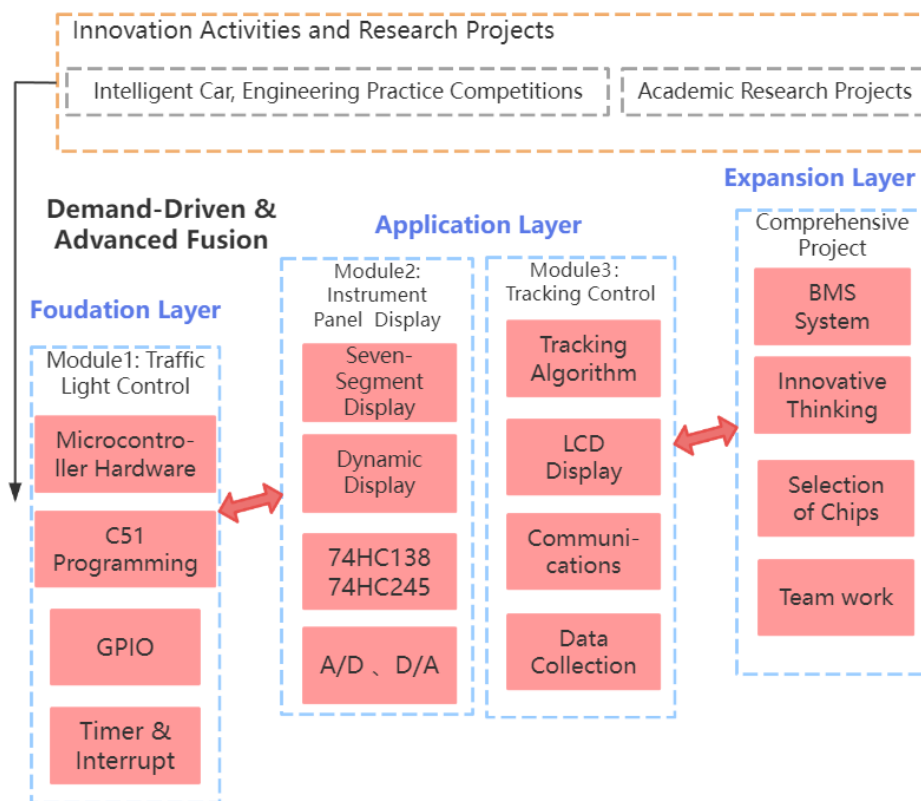


Fig 1. Reconstruction of Curriculum Structure

2.2. AI Collaborative Development Process

Based on large models, we construct an industry technology knowledge graph to capture the latest developments in the field, such as new automotive-grade chip standards or optimized intelligent driving algorithms. This allows us to dynamically generate personalized learning paths for students based on their abilities and interests. For example, a student interested in embedded systems will follow a pathway from GPIO configuration through mastering SPI/I2C peripheral driver development, multi-task scheduling, and finally designing a smart home controller. Alongside this learning path, we provide real-time support with Keil debugging tips and practical Modbus protocol examples. We adopt an AI-powered collaborative development process structured around the workflow of "Demand Release, AI Toolchain Application, Group Collaboration Development." This approach fosters a "Teacher-Guided, Student-Practiced, AI-Assisted" three-dimensional collaboration model. Teachers design project frameworks, set development requirements, and define security boundaries. Students then utilize simulation software like Proteus or hardware kits such as development boards to implement their designs and perform practical operations. Large models such as Deepseek and Tongyi Qianwen, deployed locally via LM Studio, assist in the development process, providing robust support through code review tools that continuously optimize algorithm

implementations. By leveraging this dual-engine system, we enhance development efficiency, ensuring students are equipped with the necessary skills and knowledge to meet the demands of evolving industries. This integrated approach not only improves practical skills but also fosters innovation capabilities, contributing to the development of highly qualified engineering professionals. As illustrated in Figure 2, this curriculum helps students progressively master foundational concepts through practical applications, enhancing their ability to solve complex problems and innovate.

In classroom instruction, we emphasize the social value and wide-reaching impact of engineering technology, encouraging students to apply their learned skills to solve real-world problems in society and daily life. By integrating discussions on social responsibility and ethical considerations into case studies, we guide students to deeply reflect on the interaction between technology and society. In practical teaching sessions, we stay current with societal hot topics, incorporating them into project topics to inspire students to think from an engineering perspective. This fosters their innovative thinking and practical skills. During project practice, students work in groups to strengthen the importance of teamwork. We also guide them to review the latest academic literature during development, helping them understand the recent research trends and developments in China's relevant engineering technology fields. Through this

comprehensive teaching approach, we not only enhance students' practical operation abilities and innovation capabilities but also cultivate their awareness of social

responsibility and ethical thinking. This ensures that they can make positive contributions to society in their future careers.

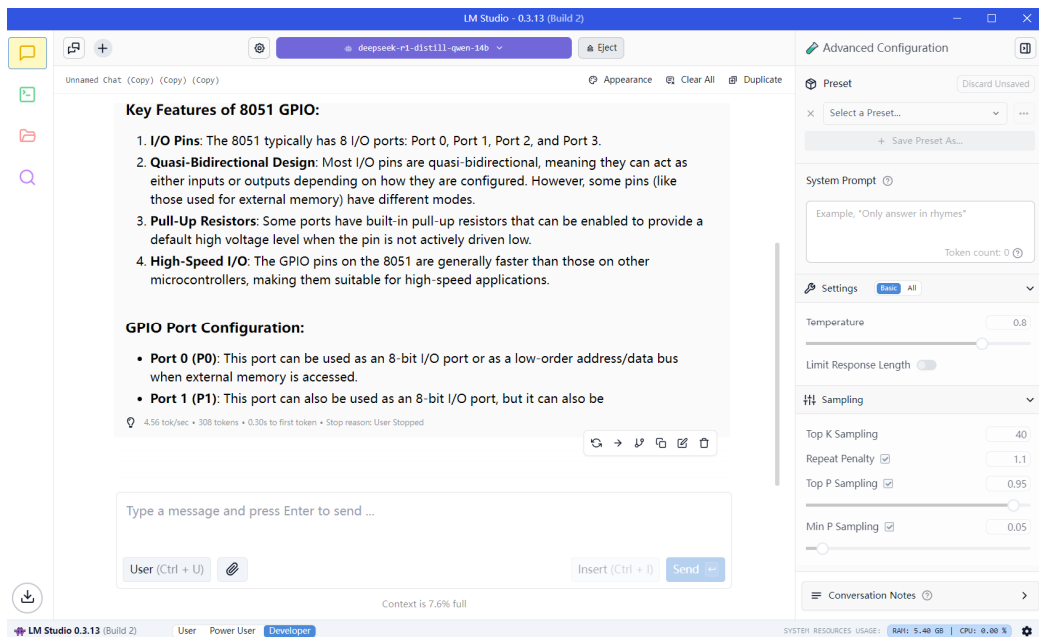


Fig 2. Locally Deployed AI Large Models for Microcontroller Development Assistance

3. The Implementation Path for Teaching

In the era of AI, introducing a variety of innovative strategies to enhance teaching effectiveness is crucial. Personalized learning path recommendations have been conducted. By constructing an "industry technical knowledge graph," we can dynamically capture the latest industry trends based on students' interests and abilities, thereby not only stimulating their proactive engagement but also ensuring they receive the most relevant and cutting-edge resources. For example, courses can tailor learning paths according to new automotive-grade microcontroller standards or optimization algorithms, providing more precise guidance for interested students.

Another important aspect is the development process automation through AI tools. Traditionally, students spend significant time on coding and debugging, but by integrating AI into this workflow, we can greatly increase efficiency and quality. Specifically, teachers set up project frameworks and safety boundaries to ensure that student activities stay focused on primary goals; students then use tools like Proteus, Keil, STM32Cube for hardware design and software programming. During this process, AI models such as Qwen or DeepSeek can assist in code writing, debugging optimization, and generating documentation. These tools not only automatically identify potential issues but also provide high-quality suggestions and resource links, thereby saving time and effort.

To further enhance teaching effectiveness, we adopt a tripartite collaborative teaching model: "teacher guidance - student practice - AI empowerment." In this framework, teachers act as designers, guides, and evaluators; they design learning plans and monitor students' progress to ensure that every step receives the right guidance and support. Students are practitioners, collaborators, and innovators; in team projects, they learn how to apply theoretical knowledge to solve real-world problems and reinforce their practical skills through actual projects. AI plays a vital role: it serves as an

assistant by providing technical support, helping resolve complex coding issues; at the same time, it acts as a consultant offering strategic advice, even generating parts of code or documents directly in some cases, thus relieving students' burden. The greatest advantage of this tripartite collaborative model is its flexibility and adaptability. Through this approach, teachers can provide personalized guidance based on different levels of student abilities; students gain practical experience by working together and receive timely feedback from AI; and AI enhances efficiency by providing abundant resources and services.

In addition, to optimize the aforementioned implementation paths, we use polynomial weighting models and exponential weighting models for performance evaluations. For instance, evaluating students' knowledge acquisition can be done through a combination of end-of-term project reports and obtaining database-related certifications; emotional and value cultivation can be assessed by collecting data on in-class performance and participation in ideological and political education activities, which informs adjustments to teaching strategies to foster students' all-round development. Utilizing AI technology for personalized learning suggestions and improvement plans not only provides immediate feedback but also boosts students' motivation and sense of personal efficacy.

4. Teaching Resource Construction and Integration

To enhance teaching effectiveness, we have established a tri-level teaching resource library that integrates course knowledge, enterprise demands, and competition research. Specifically, in the course knowledge resource library, we provide students with abundant micro-lectures on key points, experiment project libraries, experimental manuals, virtual simulation tools, AI-assisted tools like intelligent companion digital human beings, and semiconductor manuals. These resources not only help students understand theoretical

knowledge but also improve their practical skills through hands-on practice. In the enterprise project resource library, we have introduced actual engineering projects from local new energy vehicle electronics companies into our curriculum. This has established a specialized "Automotive Microcontroller Teaching Laboratory" tailored to the local industry. The experimental platform focuses on complex engineering issues such as battery health control systems and intelligent driving assistance systems. By participating in real business scenarios, students can solve practical technical challenges, accumulate hands-on experience, and enhance their ability to tackle actual technology problems. In addition, the competition research library is a crucial component that combines automotive electronics and embedded system knowledge using intelligent vehicles as carriers. It leads students to participate in relevant academic competitions and innovation projects. These activities not only stimulate students' proactive learning interest but also enhance their comprehensive abilities through the "innovation activities + research projects" driving teaching method.

We have leveraged the cooperation between Zhaoqing City and our local new energy vehicle enterprises under the project of deepening college-industry collaboration to establish an experimental platform based on the industry's advantages and the school's professional talent cultivation characteristics. By introducing excellent resources from enterprises and real engineering requirements, we established multi-level experiment projects such as basic microcontroller simulation and automotive microcontroller control, providing strong support for gradual innovative capability development in students. For example, the "basic microcontroller simulation" module starts with fundamental principles; the "automotive microcontroller control" focuses on deeper understanding at the application level. Cross-disciplinary crossover parts encourage students to apply their knowledge across multiple domains, while competition challenges offer opportunities for showcasing and exercising comprehensive abilities. This step-by-step teaching design aims to comprehensively improve students' practical levels, enabling them to address various problems they may encounter in future work. By integrating these resources and designing a progressive curriculum, we can effectively support the development of students' engineering skills and overall capabilities, preparing them for both current and future challenges in their careers.

5. Conclusion

We explore the teaching reform pathways for engineering courses in the context of "AI+" in this paper. By establishing a multidisciplinary curriculum that integrates AI-assisted development processes and leveraging three-tiered resource libraries, we effectively enhance students' engineering skills and innovative capabilities. Firstly, we construct a curriculum centered around microcontroller principles while incorporating emerging fields such as IoT and machine learning. By integrating AI into the development process, we ensure that students receive timely feedback and guidance. The use of AI to analyze student learning data helps identify weak areas and dynamically adjust course content and

teaching strategies. Secondly, in terms of instructional resources, we have developed a three-tier resource system and a four-level experimental curriculum framework. This includes virtual simulations, module development, real-world industrial experiences, and competition challenges. It spans from foundational simulations to practical applications, providing a comprehensive training model that connects classroom learning with industry needs. Our goal is to bridge the gap between academic studies and real-world engineering practices.

We plan to deepen our collaboration with industry partners to further integrate AI technologies in course evaluations and learning analytics in the future. We will continue to expand the enterprise project resources available to students, enhancing their practical skills through real-world applications. By utilizing AI tools for intelligent assessments, we aim to provide personalized study recommendations. Moreover, as the integration of AI into education continues to evolve, we are exploring new pathways that align with these technological advancements. This approach supports the development and nurturing of engineering talent capable of meeting the demands of the modern era. Our ongoing efforts contribute to the broader goal of advancing both technology and education in tandem.

Acknowledgments

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