Journal of Innovation and Development
ISSN: 2958-4752 | Vol. 13, No. 2, 2025

Exploring AI-Enabled Pathways and Innovations for Cultivating Application-Oriented Talents

-- Taking MCU Teaching as an Example

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Abstract: Against the backdrop of the rapid development of artificial intelligence technology and the increasing prevalence of microcontroller unit (MCU) technology, traditional teaching models are struggling to meet the current societal demands for the cultivation of application-oriented talents. This paper takes MCU teaching as an example to delve into the challenges in the current cultivation of application-oriented talents and the new opportunities brought about by AI empowerment. It elaborates on the innovative application pathways of AI technology in key aspects of MCU education, such as teaching, practical training, and capability evaluation. By constructing an AI-empowered MCU talent cultivation model, it achieves personalized teaching, intelligent practical guidance, and precise capability assessment, effectively enhancing students' comprehensive quality and innovative abilities in MCU system design and application development. The research results indicate that the AI-empowered educational model can significantly improve the efficiency and quality of MCU talent cultivation, providing new ideas and methods for the principles of MCU and the cultivation of application-oriented talents. It holds significant theoretical value and practical significance for promoting educational modernization and aiding industrial upgrading.

Keywords: MCU Teaching; Application-Oriented Talent; AI Empowerment; Personalized Instruction.

1. Introduction

With the rapid development of artificial intelligence technology, its powerful data processing capabilities, intelligent analysis abilities, and automated decision-making have brought unprecedented opportunities for the cultivation of application-oriented talents[1]. By precisely analyzing students' behaviors and abilities during the learning process through AI technology, personalized teaching content can be provided; by simulating real practical learning scenarios with AI technology, students are offered abundant opportunities for practice; and by comprehensively evaluating students' capabilities and interests through AI technology, scientific feedback for talent cultivation can be supplied. However, the potential of AI technology in the cultivation of application-oriented talents has not yet been fully explored, and related research and practices are still in their infancy[2].. Therefore, this paper takes MCU teaching as an example to delve into the pathways and innovative models of AI-empowered application-oriented talent cultivation, which holds significant theoretical and practical importance for improving the quality of talent cultivation and advancing the modernization of education.

2. Dilemmas and Opportunities in Application-Oriented Talent Training

2.1. Dilemmas

Against the backdrop of the deep integration of the digital economy with the real economy and the accelerating digital transformation of industries, the traditional model of cultivating application-oriented talents, which is centered on classroom lectures and confirmatory experiments, can no longer meet the industry's demand for high-quality engineers who are "quick to get started, strong in innovation, and capable of interdisciplinary work." Firstly, the criteria for evaluating talent capabilities in enterprises are shifting from "knowledge acquisition" to "complex problem-solving and system-level innovation," requiring graduates not only to have a solid professional foundation but also to be able to quickly perform requirement analysis, design solutions, iterate algorithms, and deliver products in real-world scenarios[3]. Secondly, traditional laboratories are constrained by the high cost of equipment, significant maintenance expenses, and safety hazards, leading to a triple contradiction of "few hands-on opportunities for students, heavy guidance workload for teachers, and slow updates to experimental content," which seriously hinders the quality of practical teaching.

2.2. AI-Enabled Opportunities

AI's generative and reinforcement learning technologies can effectively address the aforementioned challenges. Generative AI can automatically produce differentiated project examples, fault scenarios, and evaluation metrics within minutes, achieving personalized training tailored to each individual. The intelligent debugging engine of reinforcement learning can diagnose student operational errors in real-time and provide optimal troubleshooting paths, significantly reducing the cost of repetitive teacher guidance. VR/AR and digital twin technologies offer a zero-risk, infinitely reusable immersive experimental environment, allowing students to conduct "board-burning" trials and system-level verification on virtual hardware, accumulating valuable engineering experience.

It is evident that AI empowerment is not only a

technological choice for the digital transformation of education but also a core driving force in the reconstruction of the application-oriented talent cultivation model. Integrating AI deeply into the entire process of curriculum, experiments, and evaluation enables the mass cultivation of high-level embedded engineers who meet the needs of strategic emerging industries such as intelligent manufacturing, industrial internet, and new energy. This achieves seamless alignment between university talent supply and enterprise demand, providing continuous human resource support for the security of the national industrial chain and innovation-driven development.

2.3. Key Technologies Needed

In the cultivation of application-oriented talents empowered by AI, technologies such as big data, virtual reality (VR), augmented reality (AR), machine learning, and natural language processing (NLP) are required[4]. Big data technology forms the foundation of AI-empowered talent cultivation; it collects and integrates a vast amount of data generated by students during their learning process, such as learning behavior data, performance data, and practical operation data, providing AI with abundant training and testing samples. Additionally, big data analytics uncovers students' learning patterns, ability characteristics, and potential needs, providing a basis for personalized teaching. VR and AR technologies are important methods in AI-empowered talent cultivation; VR offers an immersive learning experience, assisting students in conducting practical operations and explorations in virtual environments, while AR makes virtual environments more realistic by collecting real-world data[5]. Machine learning technology is at the core of AI-empowered talent cultivation; by training machine learning models, it predicts and recommends students' learning behaviors, providing personalized learning resources and educational paths. NLP plays a significant role in AI-empowered talent cultivation; it enables intelligent Q&A systems, offering students timely learning support and answering services.

3. AI-Enabled Innovations in MCU Education

3.1. Personalized Theoretical Teaching

The traditional teaching model of "standardized supply" struggles to address the heterogeneous challenges of different learners' cognitive development, fundamentally due to the structural contradiction between the static knowledge system and dynamic cognitive needs. Implementing personalized teaching plans and content that align with individual learning patterns has become the foundation of cultivating application-oriented talents.

Big data serves as the foundation for AI-empowered MCU teaching[6]. By collecting and organizing students' learning behavior data (such as video viewing pace, online quiz answer trajectories, forum posts and mutual assistance records, classroom instant feedback, and hotspots and duration of textbook/e-book reading), experimental operation data (including Keil and IAR compilation logs, simulation platform waveform screenshots and parameter configurations, hardware debugging data download counts, breakpoint settings, register value change sequences, and automatically uploaded voltage, current, PWM duty cycle, and interrupt jitter waveforms from oscilloscopes/logic analyzers), project development data, group collaboration and emotional data, and industry enterprise demands, a vast amount of data is provided to enrich the training and testing samples for AI technology. Utilizing big data analysis techniques to uncover patterns, ability levels, and interests of students in MCU learning, personalized teaching plans are offered (for instance, providing more challenging programming projects and extended resources for students with strong programming capabilities in MCUs; offering more tutoring and support for students who struggle with hardware circuit design). Learning content, pace, and difficulty are dynamically adjusted based on student feedback to optimize learning outcomes to the greatest extent, achieving a transition from universal education to personalized instruction.

3.2. Virtual–Real Blended Practice Environment

Traditional MCU practical teaching is limited by the quantity of hardware equipment, wear and tear of instruments, and the availability of instructors. Typically, experiments are conducted with 3-4 students per group. During these experiments, frequent plugging and unplugging can lead to poor contact on breadboards, bending of MCU pins, and loss of sensors. At the same time, instructors have to monitor 30-40 groups of experiments, turning practical guidance into a "firefighting" Q&A session (unable to focus on students' code standards and logical structures). Once students burn out a chip, they develop a fear and hesitate to try boldly again. Therefore, MCU practical teaching has long faced the "three highs and three lows" dilemma: high hardware burnout rate (12.7%), high debugging time (an average of 4.8 hours per experiment), high repetitive guidance workload for teachers (an average of 2.3 hours per experiment), low code standardization rate (less than 46% effective code), low innovation scores (an average of 5.2 out of 20), and low alignment of experimental projects with enterprise needs (3%).

By leveraging AI's virtual reality and augmented reality capabilities through a 1:1 simulation engine, all MCUs, peripherals, and signal sources are fully digitized, creating a practical training environment where hardware is always online and programs can be corrected immediately after errors[7]. In this environment, students can complete hardware wiring, software compilation, and program debugging on the cloud 24/7, addressing the issues of high hardware burnout rates and long debugging times in traditional MCU practical teaching. Through behavior training for common mistakes in MCU practice, if the AI system detects issues such as improper code writing, coding errors, register operation errors, and wiring mistakes during practice, it can provide real-time error reasons and repair suggestions, solving the problems of high repetitive guidance workload for teachers and low code standardization among students. Using the AI system to search for a large number of real enterprise needs, simulating real MCU development scenarios and project tasks, allows students to conduct MCU system design and application development training in a virtual environment (for example, in the field of intelligent control, using AI technology to simulate complex MCU control system design and debugging processes, helping students design control algorithms, simulate systems, and debug in a virtual environment), improving students' practical operation capabilities and engineering experience in MCU control system design and application development. At the

same time, AI technology can also monitor and evaluate students' performance in real-time during practice, providing timely feedback and guidance to help students continuously improve.

Therefore, AI-empowered practical teaching transforms experiments from "time-limited one-time" to "unlimited trial and error," the classroom from "waiting in line for kits" to "parallel innovation," and projects from "textbook-oriented" to "enterprise demand-oriented," providing a scalable, low-cost, and market-oriented new ecosystem for MCU practical teaching.

3.3. Precision Competency Assessment

Traditional microcontroller unit (MCU) teaching evaluations primarily rely on final projects and written exams, which suffer from a one-dimensional assessment, delayed feedback, strong subjectivity, difficulty in tracking learning trajectories, and an inability to quantify innovative abilities. These limitations make it hard to meet the current demands for cultivating application-oriented talents.

With the introduction of AI into teaching evaluations, each development board becomes an "assessment node." In theoretical teaching, pre-class contemplation and post-class exercises are used to gauge students' current learning outcomes. During lab sessions, AI analyzes the complexity, comment ratio, and module reuse rate of the code compiled in Keil in real-time, providing a "quality index" ranging from 0 to 100. In practical operations, cameras combined with gesture recognition models automatically record soldering techniques and chip insertion directions, scoring based on a standard posture database. If more than 30% of students perform poorly in a particular segment, the system immediately recommends relevant micro-lessons and prompts teachers to adjust the pace and content of their lessons.

The integration of AI means that grades are no longer determined by a single exam[8]. AI generates current evaluation scores by weighting scores from theoretical teaching, lab work, practical operations, project practice, and teamwork. Students can view their current performance throughout the process to understand their learning status. AI-empowered MCU teaching evaluations transform assessments from being a judge to a training partner, making every discussion, question, experiment, line of code, and soldering joint a step towards improving students' learning abilities.

4. Building an Application-Talent Training Platform

4.1. Industry–Enterprise–University Ecosystem

Undergraduate programs focused on applied studies position themselves on cultivating talents in applied technology, emphasizing the development of practical technical skills and fostering students' abilities to practice and innovate. However, within the closed ecosystem of traditional education, there is a disconnect between the imparting of theoretical knowledge and its practical application. Consequently, a key challenge in the cultivation of applied talents lies in the lack of practical application cases and scenarios in the practical teaching (which could be translated as "phase" or "component") that align with current enterprise needs.

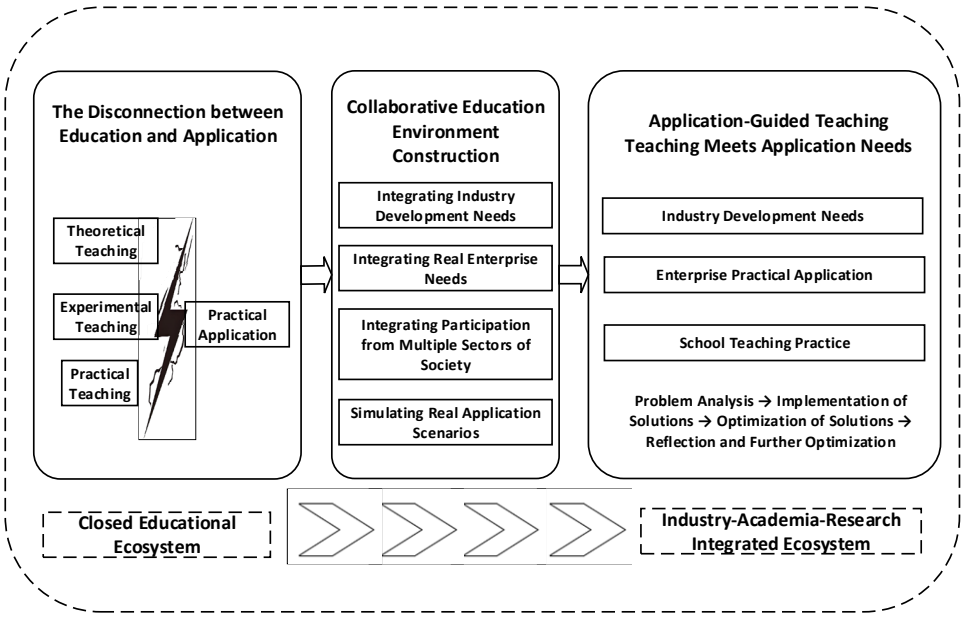


Figure 1. Industry-Academia-Research Integrated Ecosystem

To address the issue of the disconnect between theory and practice in the traditional education system, the teaching team uses AI technology to integrate real-world case resources from the industry and simulates real application scenarios based on the complex problems faced by enterprises, as shown in Figure 1. Teachers guide students through a complete application cycle starting with complex problems in real application scenarios, including "problem analysis—solution iteration—solution implementation - reflection and optimization."

During the problem analysis phase, teachers guide students to deeply understand the essence of the problem, identify key factors, and determine the goals for solving the problem. In the solution iteration phase, students engage in open discussions in groups, propose various possible solutions, and continuously iterate and improve until they finalize their

group's plan[9]. In the solution implementation phase, students, working in groups, put their chosen plans into practice and verify the effectiveness and feasibility of the plans through hands-on operations. In the final reflection and optimization phase, teachers guide students to evaluate the outcomes of the plan implementation, analyze the reasons for success and failure, and optimize the design plan accordingly.

Through the above teaching model, students are honed in multiple dimensions when facing challenges in real application fields. On one hand, students' innovative abilities are greatly enhanced when dealing with complex problems through creative thinking and plan design. On the other hand, students not only learn how to apply theoretical knowledge to solve practical problems but also learn how to innovate and adapt in a constantly changing environment[10]. Additionally, the hands-on operation in simulated real scenarios improves students' practical skills. The enhancement of these abilities is crucial for students' future career development, helping them better adapt to the rapidly changing work environment after graduation and play a leadership role within it.

4.2. MCU Faculty with AI Literacy

Teachers are the main participants and executors in teaching, and the teacher team is key to influencing the quality of teaching and talent cultivation. In the context of cultivating application-oriented talents, strengthening the construction of the teacher team, especially in developing a microcontroller (MCU) teacher team with artificial intelligence (AI) literacy, is crucial for improving the quality of education and meeting industry needs. As a key factor in AI-empowered application-oriented talent cultivation, teachers need not only to master the basic theories and application methods of AI technology but also to effectively integrate AI technology into all aspects of theoretical teaching, experimental teaching, practical teaching, and talent cultivation.

To enhance the AI literacy of the MCU teacher team, firstly, schools often organize teachers to participate in training and academic exchange activities related to AI technology[11]. In these activities, teachers can not only grasp the latest developments in the field of AI but also effectively improve the team's ability to apply AI technology. Secondly, schools encourage teachers to innovate teaching models and methods to adapt to the needs of cultivating application-oriented talents. In addition, schools introduce professionals with a background in AI technology into the teacher team to integrate AI knowledge with teaching theory and jointly develop MCU courses that incorporate AI technology, ensuring the cutting-edge and practical nature of the teaching content.

In summary, by strengthening the construction of the teacher team and cultivating MCU teachers with AI literacy, schools can better adapt to the needs of modern education and cultivate more application-oriented talents who can meet future challenges for society. This will not only improve the quality of education but also promote educational innovation, laying a solid foundation for the long-term development of the school.

5. Conclusion

AI has brought new opportunities and possibilities for the cultivation of application-oriented talents. By leveraging innovative approaches such as personalized teaching, intelligent practical training, and precise competency assessment, the quality and efficiency of talent development can be effectively enhanced. Taking MCU teaching as an example, constructing a new model for AI-empowered application-oriented talent cultivation achieves a deep integration of education with modern information technology, which is an important direction for promoting educational modernization and aiding industrial upgrading. However, the application of AI technology in the cultivation of application-oriented talents is still in the exploratory stage, necessitating further strengthening of related technical research and practical exploration to address issues such as data security, privacy protection, and technology popularization. In the future, with the continuous development and improvement of AI technology, its role in the cultivation of application-oriented talents will become more prominent, training more intelligent and innovative application-oriented MCU talents for society and promoting the sustained development and progress of the economy and society.

Acknowledgments

2025 LiaoNing Institute of Technology Education and Teaching Research Project "DeepSeek Empowering the Pathways and Innovations in Cultivating Application-Oriented Talents" (Project Number: LKJY202507);

The 2024 Course Ideological and Political Construction Project at Liaoning Institute of Technology for "Principles and Applications of Microcontrollers (Project Number: 6088A415);

2024 LiaoNing Institute of Technology Undergraduate Teaching Reform Research Project "Innovation and Practice of Artificial Intelligence Empowering the Education in the Provincial First-Class Major of Automation" (Project Number: xjglx202403).

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