Exploration on the Continuous Improvement Mechanism of the Course Principles and Applications of MCU Based on Outcome-Based Education Concept

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Abstract: Against the background of New Engineering Construction and Engineering Education Certification, the traditional teaching system of the course Principles and Applications of Microcontrollers has problems such as lagging content update, disconnection from industrial demand, and lack of continuous improvement mechanism. This study constructs a closed-loop rapid iterative optimization mechanism of Collection-Evaluation-Update-Feedback-Optimization, and reversely designs the course structure based on the Outcome-Based Education (OBE) concept, optimizes the ratio of theoretical and practical teaching, implements a diversified assessment system, promotes the deep participation of enterprises in teaching through deepening the integration of industry and education, and explores the layered integration path of Artificial Intelligence (AI) technology and course teaching. The practical results show that this mechanism has effectively improved the teaching quality of the course, and both academic competitions and employment quality have been significantly improved. This study can provide practical reference for the teaching reform of similar engineering courses in application-oriented universities.

Keywords: MCU; Course Reform; Outcome-Based Education; Artificial Intelligence Integration; Engineering Education Certification

1. Introduction

Principles and Applications of Microcontrollers is a core compulsory course for majors such as Electronic Information Engineering, Communication Engineering, and Automation, which occupies an important position in the engineering education system. This course acts as a bridge to guide students from theoretical learning to engineering practice, and is a key link in cultivating students embedded system development capabilities [1-2]. With the rapid development of industries such as the Internet of Things and intelligent manufacturing, microcontroller technology is constantly updating and iterating. New types of microcontrollers such as STC series, ESP32, and Reduced Instruction Set Computer-V (RISC-V) have been widely used in industrial control, smart home, wearable devices and other fields [3]. However, the update of teaching content of traditional microcontroller courses is slow, which is difficult to keep up with the pace of industrial technology development, leading to a large gap between the knowledge learned by students and the employment needs of enterprises [4].

Under the dual background of New Engineering Construction and Engineering Education Certification, the Ministry of Education implemented the New Engineering strategic action in 2017, requiring engineering courses to actively adapt to the development needs of new technologies, new industries, and new economy, and take cross-integration and industry-university collaboration as the core to cultivate innovative engineering talents. At the same time, Engineering Education Certification, based on the Outcome-Based Education (OBE)/Accreditation Board for Engineering and Technology (ABET) standards, emphasizes the school-running philosophy of student-centered, outcome-oriented, continuous improvement, requiring the curriculum system to support the achievement of graduation requirement indicators and establish a continuous improvement mechanism for course quality. However, traditional microcontroller courses generally have prominent problems such as long update cycle (textbooks are updated once every 2-3 years), insufficient docking with certification standards, and lack of continuous improvement mechanism [5-7]. It is urgent to establish a rapid course content iteration mechanism that can respond to industrial demand and certification requirements. For this reason, this course has actively carried out the reform of rapid iteration and optimization mechanism of teaching content, explored the deep integration of Artificial Intelligence (AI) technology and course teaching, and strived to cultivate compound talents with solid microcontroller application capabilities and engineering innovation literacy, providing practical reference for application-oriented engineering education under the background of New Engineering [8-9].

2. Problems Existing in the Original Teaching System

Through nearly three years of teaching practice and student feedback research, it is found that the original curriculum system has the following prominent problems

2.1 Student Dimension

Most students of this course are junior college students, who have the foundation of prerequisite courses such as C Language Programming and Digital Circuits. However, there are large individual differences among students (uneven practical ability, uneven programming foundation), and some students have insufficient understanding of the practical value of the microcontroller course, so their learning internal drive needs to be stimulated.

2.2 Platform Dimension

The existing experimental platform is mainly based on the traditional 51 single-chip microcomputer development board, failing to keep up with the wide application of domestic single-chip microcomputers (such as STC series, ESP32, etc.) in industrial control, smart home, Internet of Things and other fields in recent years, which is disconnected from the actual needs of the industry.

2.3 Teacher Dimension

The teachers have strong theoretical background, but they are not closely connected with the front-line engineering practice of enterprises, lack of a continuous follow-up mechanism for new industrial technologies (such as Edge AI [10], RISC-V architecture, etc.), and there is a lag in capacity building of teachers updating before textbooks.

2.4 Industry Docking Dimension

The course lacks a systematic docking mechanism with regional key industries (digital intelligence of petrochemical industry, electronic information industry in Guangdong-Hong Kong-Macao Greater Bay Area), and there is a structural dislocation between talent training specifications and job skill requirements. The above root problems are intertwined, indicating that partial adjustment alone is difficult to achieve a fundamental improvement in course quality, and a systematic rapid iterative optimization mechanism must be established to deal with it.

3. Teaching Content Iterative Optimization Measures

3.1 Establishment of Content Iteration Mechanism

To ensure the continuous improvement of teaching content and synchronization with industrial development, this study establishes an iteration mechanism of Collection-Evaluation-Update-Feedback-Optimization, the core of which is to regularly collect various feedback information, conduct systematic evaluation and targeted update, and feed back the improvement results to students and enterprise partners, forming a virtuous cycle of continuous optimization. In specific implementation, at the end of each semester, we collect students opinions on teaching content through questionnaire surveys, connect with 3-5 cooperative enterprises every year to sort out talent needs and technical update points, update the cutting-edge content of 2-3 teaching modules every year with reference to the latest papers and technical reports of international academic organizations such as Institute of Electrical and Electronics Engineers (IEEE) and Association for Computing Machinery (ACM), organize teachers to prepare lessons collectively in winter and summer vacations to complete content revision, and establish course content update files, recording update information in detail to realize traceable and reusable teaching resources.

At the same time, to ensure the effective implementation of this iteration mechanism, the study combined teaching practice and industrial demand to formulate standardized quantitative standards and implementation rules: iteration is carried out with semester as the basic cycle for routine update, and multi-dimensional immediate trigger conditions are set, such as student course satisfaction lower than 75%, enterprise feedback content and job skill matching degree less than 70%, and major version iteration of core technology; a comprehensive evaluation system composed of content timeliness (30%), student achievement (35%), enterprise recognition (20%) and competition performance (15%) is constructed, and if the comprehensive score is lower than 75 points, mandatory update will be initiated; the implementation process is carried out in an orderly manner according to proposal collection, demonstration and evaluation, content writing, audit and trial lecture, release and implementation, and effect tracking, and the whole process is controlled within one semester, realizing efficient and rapid iteration of course content.

3.2 Establishment of Content Iteration Mechanism

According to the OBE concept, the course structure is reversely designed, and the original knowledge-driven model is transformed into an ability-driven model [11]. The traditional knowledge-driven model emphasizes the integrity of knowledge points, while the OBE concept requires starting from the abilities that students should have and reversely designing the course content. Under the guidance of this concept, we divide the course into six teaching modules, each of which corresponds to a specific ability goal. For example, the ability goal of the Interrupt System and Timer module is mastering control system programming. Students need to learn interrupt processing mechanism and timer application, and finally be able to independently write programs with real-time control functions. This structural adjustment enables students to gradually accumulate engineering practice ability while mastering theoretical knowledge, laying a foundation for the follow-up comprehensive project design.

Table 1 shows the comparison of course structure before and after optimization.

Table 1. Comparison of Course Structure Before and After Optimization

Teaching Module	Theoretical Hours	Practical Hours	Ability Goal
Microcontroller Foundation and Development Environment	6	2	Master Development Tool Chain
Instruction System and Programming	6	2	Have Programming Implementation Ability
Interrupt System and Timer	8	4	Master Control System Programming
Keyboard and Display Devices	6	4	Master Peripheral Driver Development
Serial Communication and Interface Expansion	8	4	Have System Integration Ability
Comprehensive Project Design and Practice	16	20 (Extracurricular Practice)	Cultivate Engineering Innovative Thinking

3.3 Adjustment of Theory and Practice Ratio

In terms of adjusting the ratio of theory and practice, we have carried out in-depth teaching design. The original ratio of theory to practice of the course was 2:1. Although this configuration ensured the systematicness of theoretical knowledge, it was insufficient for cultivating students practical ability. In the new course design, we introduced the Course Design Week (Weeks 15-16), allowing students to complete a complete comprehensive project in groups of 2-3 people. This project not only requires students to apply all the knowledge points learned in the first 14 weeks, but also requires them to complete the complete engineering process such as demand analysis, scheme design, device selection, Printed Circuit Board (PCB) design, program writing, debugging and verification. Through this learning by doing method [12], students not only consolidate theoretical knowledge, but also cultivate engineering thinking and team collaboration ability in practical operation. At the same time, the form of group cooperation also provides students with a real working environment experience.

3.4 Diversified Reform of Assessment Methods

Diversified assessment system is an important guarantee to realize the OBE concept. We have established a trinity evaluation system of Process Assessment + Ability Assessment + Innovation Assessment [13].

Among them, usual homework and experiments (20%) focus on examining students learning attitude and basic mastery; mid-term project defense (25%) examines students deep understanding of knowledge and expression ability through students on-site explanation and expert questions; final comprehensive examination (35%) adopts open-book written examination, focusing on examining students problem analysis and system design ability, rather than simple knowledge memory; course design works (20%) evaluate students comprehensive ability from multiple dimensions such as innovation, practicality and team collaboration. This multi-dimensional evaluation method can more comprehensively reflect students learning outcomes, and also encourage students to improve in different aspects.

Table 2. Diversified Assessment System

Assessment Link	Proportion	Evaluation Standard
Usual Homework and Experiments	20%	Complete on Time, Standard Code
Mid-term Project Defense	25%	Function Implementation, Defense Performance
Final Comprehensive Examination	35%	Knowledge Mastery, Problem Analysis
Course Design Works	20%	Innovation, Practicality, Team Collaboration

Table 2 shows the details of the diversified assessment system.

3.5 Improvement of Enterprise Participation

The integration of industry and education is the core requirement of New Engineering construction [14]. This semester, we have established in-depth cooperative relations with two leading enterprises in the field of embedded systems, Shenzhen Huaqingyuanjian and Guangzhou Yueqian Technology. This cooperation is not only reflected in the update of course content, but more importantly, the full participation of enterprise engineers. Specifically, enterprise engineers participate in the topic selection review of mid-term projects to ensure that the project topics not only meet the teaching objectives, but also close to the actual industrial application; they provide real industrial control cases as project materials, allowing students to learn while solving real problems; after the project is completed, enterprise engineers conduct professional comments on students works from the industry perspective, pointing out the deficiencies in code standards, system design and other aspects; in addition, we also invited the technical director of the enterprise to carry out a special lecture on The Application of Microcontrollers in the Internet of Things Industry, allowing students to understand the latest technology trends and industry needs. This in-depth integration of industry and education enables students to contact industry practice earlier and fully prepare for employment.

3.6 Deep Integration of AI and Teaching Content

The rapid development of AI technology has brought new opportunities and challenges to higher education. Integrating AI technology into the microcontroller course can not only improve teaching efficiency, but more importantly, cultivate students AI thinking and application ability, which is crucial for adapting to future industrial development [15,16]. Our AI integration strategy is divided into three levels, forming a progressive learning path from general education to professional education.

In the introduction part of the course, we introduced the concept of AI-assisted microcontroller development, allowing students to understand the application of AI tools such as GitHub, Copilot, Aily blockly, Openclaw in code writing, debugging and optimization. Among them, GitHub provides students with a large number of open source microcontroller projects and AI-assisted development cases, which is convenient for reference and builds a bridge between theory and practice; Copilot is integrated into the development Integrated Development Environment (IDE), through code completion and function generation functions, helping students quickly write microcontroller initialization and peripheral driver code, reduce repeated coding, and lower the entry threshold. Ailyblockly can realize Arduino library conversion and development board configuration generation, support natural language to generate project code, and adapt to students with different foundations. Openclaw assists code debugging and optimization, quickly identifies errors and provides modification suggestions, improving debugging efficiency. The introduction of these tools in the introduction can let students intuitively feel the innovation of AI on microcontroller development, break the dilemma of focusing on the bottom layer and neglecting innovation, stimulate learning interest, establish the concept of AI empowerment, lay a foundation for the follow-up practical teaching and the cultivation of students engineering ability and innovative thinking.

3.7 Typical AI Integration Teaching Cases

To further verify the feasibility and effectiveness of the AI-integrated teaching mode in practical teaching, and solve the pain points and difficulties of traditional embedded AI teaching, this section selects two typical teaching cases, elaborates the integration path, implementation process and application effect of AI technology and practical teaching in detail, providing reference for the development of similar teaching activities.

Case 1: Offline voice-controlled smart light. In teaching, we use ESP32 development board with LED light and microphone module. Learners can directly describe the development requirements to the AI auxiliary module of Aliy Blockly in Chinese natural language. The system will automatically generate graphical blocks for offline voice recognition initialization, instruction judgment, and Pulse Width Modulation (PWM) light control. Learners can also manually drag the blocks to fine-tune the parameters. After burning to the microcontroller, the voice control light function in the network-free environment can be realized. This AI-integrated teaching mode encapsulates all the high-threshold content involved in traditional microcontroller AI development, such as voice model transplantation and underlying driver writing, and compresses the special study period that originally required 2-3 weeks to 1 class hour. It not only solves the pain points of fragmented knowledge points and too high entry threshold in traditional teaching, realizes layered teaching, students with zero foundation can quickly complete the project through AI generation, and students with better foundation can independently expand the instruction function, implementing the teaching goal of precise education, but also allows students to intuitively understand the core logic of edge AI voice interaction in practice, significantly stimulating the learning interest and practical confidence of non-computer major students [17,18].

Case 2: Embedded object recognition assistant. Using ESP32-S3 development board with OV2640 camera and OLED display, students load the built-in lightweight object recognition AI model blocks in Aliy Blockly, and can complete the development by dragging graphical modules of image acquisition, model reasoning, and result display. Without mastering cross-domain knowledge such as complex deep learning model conversion and embedded memory optimization, they can realize offline recognition of common small objects such as fruits and stationery. This mode breaks the double knowledge barrier of deep learning theory + embedded underlying development in traditional embedded AI teaching, effectively making up for the lack of innovation in traditional experiments. Even freshmen can independently complete a complete AI hardware project, which not only transforms the abstract edge AI concept into tangible practical results, helps students establish a concrete cognition of AI technology, but also guides students to shift from code writing to product innovation, effectively improving students engineering practice ability and AI integration innovative thinking.

Practical results show that AI-assisted development can shorten the average time of students driver code writing from 45 minutes to 18 minutes, effectively releasing classroom time for principle exploration and system scheme design [19,20].

4. Reform Practice Effectiveness

After two years of practice in 8 classes of electronic major and telecommunication major in the School of Electronic Information, this course reform has initially seen some gratifying results: (1) After the implementation of the reform, the excellent rate of final comprehensive scores (≥75 points) increased from 52.3% before the reform to 64.1%, an increase of 11.8 percentage points; the failure rate decreased from 12.5% to 5.4%; the average score of comprehensive course scores increased from 67.8 to 74.6. (2) In 2025, participating in the National College Students Electronic Design Competition, students of this course won 1 national first prize, 4 national second prizes, 11 provincial first prizes, 4 provincial second prizes, and 6 provincial third prizes. This is the first time that the school has won the national first prize of this competition, and it is also the best result that the schools students have achieved in recent years. (3) Improvement of learning experience: The questionnaire survey at the end of the semester shows that students recognition of close to industrial demand of course content increased from 41% before the reform to 89%; the satisfaction with AI tool-assisted learning reached 82%; the overall satisfaction with the course reached 95%, an increase of 23 percentage points compared with before the reform. (4) Improvement of employment quality: Among the graduates of 2025, the proportion of those who chose to work in embedded system related jobs increased from 24% to 35%, and the enterprise feedback showed that the average adaptation period of students on the job was shortened by about 1 month.

5. Conclusion

Aiming at the pain point that the traditional teaching mode of the course Principles and Applications of Microcontrollers is difficult to adapt to the rapid iteration of industrial technology and the requirements of engineering education certification, this study constructs and practices a rapid iterative optimization mechanism of course teaching content. Through establishing a closed-loop feedback system, reconstructing the OBE-oriented course structure, deepening the integration of industry and education and AI-enabled teaching, it effectively solves the root problems of the original teaching system, such as insufficient student adaptation, lagging platform, slow update of teachers ability, and disconnection of industry docking. After two years of teaching practice verification in two different majors, this mechanism has realized the efficient and dynamic update of course content, significantly improved students academic performance, engineering practice ability and learning satisfaction, and at the same time promoted the enhancement of students employment competitiveness, verifying the effectiveness and feasibility of this reform mode. This reform not only implements the core concept of continuous improvement in engineering education certification, but also provides a replicable practical path for the dynamic optimization of engineering courses in application-oriented universities under the background of New Engineering.

Acknowledgments

The authors would like to thank all the students and enterprise partners who participated in this teaching reform for their valuable support and feedback.

Fund Project: This work was supported by the Projects of PhDs Start-up Research of GDUPT; AI + Major Construction and Talent Training Reform Project of Guangdong University of Petrochemical Technology.

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