



Construction and Practice of the "Three-Stage Progressive" Teaching Model for MCU Courses under the OBE Concept

Hongmei Qin*

Chongqing Metropolitan College of Science and Technology, Chongqing, 401320, China

*75858081@qq.com

Abstract. The construction of emerging engineering disciplines has raised new requirements for engineering education to align with industrial needs and cultivate innovative interdisciplinary talents. In response to the problems existing in traditional MCU courses, such as emphasizing knowledge over competence, theory over practice, and a single evaluation system, this paper constructs a three-stage progressive teaching mode—basic competence → comprehensive application → innovative practice—based on the concept of Outcome-Based Education (OBE). By reversely designing course objectives, hierarchically implementing teaching contents, and establishing a diversified evaluation system, a trinity practice platform integrating virtual simulation + physical development + enterprise projects is developed. A dual quality assurance mechanism is formed: an internal closed loop of course objective attainment analysis → continuous improvement and an external closed loop of enterprise feedback → curriculum iteration. Practice shows that this mode effectively solves key problems including the disconnection between teaching contents and industrial demands, the lack of systematicness in practical links, and the weak correlation between teaching evaluation and learning outcomes. Students' engineering practice ability and innovative literacy have been significantly improved, providing a replicable paradigm for curriculum reform under the background of engineering education accreditation.

Keywords: OBE concept; MCU course; three-stage progression; teaching reform; engineering education

1 Introduction

With the advancement of China's Education Modernization 2035, the state has explicitly proposed increasing the proportion of training applied, interdisciplinary, and technical-skilled talents [1]. Against the background of the construction of emerging engineering disciplines, enterprises' demand for talents has shifted from knowledge reserve to comprehensive literacy such as problem-solving, innovation, and collaboration, which forces the reform of educational models [2].

© The Author(s) 2026

C. F. Peng et al. (eds.), *Proceedings of the 2026 5th International Conference on Humanities, Wisdom Education and Service Management (HWESM 2026)*, Advances in Social Science, Education and Humanities Research 1024,

https://doi.org/10.2991/978-2-38476-593-5_21

As a core cornerstone in embedded systems, the Internet of Things and other fields, the teaching quality of microcontroller technology directly affects the development of students' engineering practice ability. However, traditional microcontroller courses mostly follow a knowledge-imparting structure, with teaching contents centered on classic models such as the 8051, focusing on one-way instillation of theoretical details. Experimental links are limited to verification cases using fixed experiment boxes and prefabricated code templates, leaving students trapped in “process-oriented operation without systematic thinking” [3].

Outcome-Based Education (OBE) emphasizes taking students' learning outcomes as the fundamental orientation and reconstructing the teaching system through reverse design, which has become the core concept of international engineering education accreditation [4]. Scholars at home and abroad have made remarkable progress in integrating the OBE concept with engineering education.

Wang Xiaohong (2018) proposed applying the OBE concept to the reform of microcontroller courses and establishing a three-level teaching framework of “basic experiment–project development–comprehensive innovation” [5]; Zhang Qiang et al. (2020) found through empirical research that the three-stage progressive model of “theoretical cognition–skill enhancement–engineering application” can improve students' project completion rate by 37.5% [6]; Zhou Ming et al. (Hangzhou Dianzi University, 2023) adopted a “course group” model and developed a three-stage connected project case base of “basic experiment–subject competition–enterprise project”, raising students' engineering accreditation attainment to 88.5% [7].

Internationally, Spady (1994) systematically elaborated the implementation path of OBE: “defining outcomes–designing pathways–evaluating improvement” [8]; Prince (2004) verified the enhancing effect of PBL (Project-Based Learning) on engineering problem-solving ability [9]; Stanford University divided microcontroller teaching into three stages: “circuit foundation–embedded programming–intelligent system design” (Johnson, 2021) [10].

In summary, domestic and foreign studies have provided rich references for teaching reform, but deficiencies still exist: few studies focus on the systematic design of three-stage connection, insufficient integration of industrial standards, and lack of a long-term tracking and evaluation mechanism.

On this basis, this paper takes the OBE concept as the core, constructs a “three-stage progressive” teaching mode for microcontroller courses, and explores a systematic teaching reform path through reverse design, hierarchical implementation, diversified evaluation, and dual closed-loop quality assurance.

2 Problems Existing in Traditional MCU Teaching

2.1 Disconnection between Course Content and Industry Demand

The content of traditional single-chip microcomputer (MCU) courses usually stays at the theoretical level, taking classic models such as 8051 as the main body, focusing on the one-way instilling of theoretical details including chip architecture and assem-

bly instructions, while lacking connection with cutting-edge technologies such as intelligent hardware and the Internet of Things[11].

The teaching content fails to be updated in a timely manner and cannot keep pace with the rapid development of MCU technology, resulting in students learning knowledge that may be outdated or inapplicable.

When the industry is in urgent need of interdisciplinary talents who are proficient in PCB design, embedded development and system optimization, the backwardness of traditional teaching content has become a key bottleneck restricting the cultivation of application-oriented talents.

2.2 Lack of Systematic Ability Cultivation Path in Practical Links

The practical links of traditional MCU courses are mostly dominated by confirmatory experiments, using fixed experiment boxes and prefabricated code templates. Students only operate according to procedures, lacking the cultivation of systematic design ability.

The experimental content is relatively simple or repetitive, which cannot fully exercise students' practical ability. The components purchased for course design are usually fixed types, which can hardly meet the requirements of students' innovative ability cultivation[12].

The practical path is unclear, making it difficult to achieve progressive training from basic skills to comprehensive abilities and then to innovative abilities.

2.3 Low Correlation between Teaching Evaluation and Learning Outcomes

Traditional teaching evaluation mostly relies on final examinations, which one-sidedly examine the memorization of fragmented knowledge points and lack comprehensive assessment of students' learning process, thus failing to reflect students' learning outcomes and ability improvement[13].

The single evaluation system dominated by written tests lacks dynamic evaluation of engineering specifications, debugging ability and innovative thinking, further intensifying the phenomenon of "high scores but low abilities".

With a single evaluation dimension, it ignores collaborative innovation and problem troubleshooting efficiency, and is disconnected from actual demand, making it difficult to conduct a comprehensive evaluation of students.

3 Design of the "Three-Stage Progressive" Teaching Model Based on OBE

3.1 Design Concept and Framework

Based on the OBE concept, this course adopts a teaching closed loop of "reverse design – hierarchical implementation – diversified evaluation" to build a systematic

cultivation path from theory to practice. In the reverse design stage, guided by industrial needs, the abilities students should possess after graduation are defined, and course objectives and teaching content are derived reversely. In the hierarchical implementation stage, three teaching modules (basic, comprehensive and innovative) are designed according to students’ learning abilities and interests. In the diversified evaluation stage, process evaluation and summative evaluation are combined to monitor learning progress in real time and optimize teaching strategies through feedback.

3.2 “Three-Stage Progressive” Curriculum System

The modular design of the curriculum system is divided into three levels (see Figure 1):

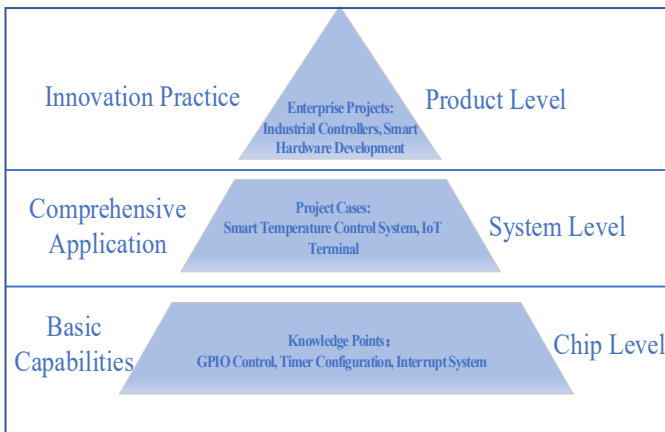


Fig. 1. The modular design of the curriculum system

Basic Ability Level.

It focuses on core knowledge such as MCU hardware architecture, C language programming and basic peripheral driver. Students’ basic skills are consolidated through Proteus virtual simulation and case-based teaching. Experiments include LED blinking, static/dynamic digital tubes, key input, timer timing, external interrupt and serial communication, helping students master basic MCU operation and debugging methods.

Comprehensive Application Level.

Driven by projects, typical industrial scenario experiments such as smart home control, industrial sensor data acquisition and smart agriculture are designed. Students are required to complete hardware construction, software debugging and system joint debugging to cultivate engineering thinking and problem-solving abilities. Through group cooperative learning and modular development kits, students practice systematic design and innovative thinking.

Innovative Practice Level.

Real enterprise projects or electronic design competition topics are introduced. Innovative design is carried out combined with cutting-edge technologies such as AIoT and edge computing, integrated with ideological and political elements including craftsmanship spirit and social responsibility, to improve technical application and teamwork abilities. By participating in real enterprise projects and school-enterprise collaborative development, students deeply understand actual industrial needs and technical challenges, and enhance engineering innovation ability.

3.3 “Trinity” Practical Platform

A trinity practical platform of “virtual simulation + physical development + enterprise projects” is developed to form a complete practical path from virtual to physical and from basic to innovative:

Virtual Simulation Platform: Online experimental tools such as Proteus and Keil are used to simulate the MCU hardware environment, helping students complete basic experiments and complex circuit design in a virtual environment, reducing experimental cost and risk. Students can verify circuit functions and performance in advance, shortening debugging time on actual hardware.

Physical Development Platform: Real MCU development boards and sensor kits are provided to support hardware debugging and program optimization, strengthening hands-on ability. The basic level is equipped with 35 sets of industrial-grade multi-functional MCU experiment boxes (supporting 8051/STM32/PIC multi-architecture expansion); the development level deploys 15 sets of full-stack smart hardware development systems (integrated with ARM Cortex-M4 core and FPGA programmable logic units).

Enterprise Project Platform: Practical engineering projects are introduced through school-enterprise cooperation, enabling students to apply knowledge in real scenarios and cultivate abilities to solve practical problems. The IoT layer builds a 20-node industrial IoT sandbox system for scenario-based project training such as intelligent warehousing and digital twin; the computing layer is equipped with 45 high-performance engineering workstations to form a virtual-real integrated digital engineering development environment.

4 Teaching Implementation Path

4.1 Reverse Design Method: Reconstruction of Course Objectives Based on Post Competence Requirements

Centered on the post competence demand matrix, the abilities students should possess after graduation are clarified from the end point, and course objectives and content are reversely derived. Through in-depth industrial research, industry competence requirements for MCU-related positions are collected to form a post competence demand matrix. Based on these requirements, a three-dimensional course objective of “knowledge – ability – quality” is reconstructed, as shown in Figure 2.



Fig. 2. OBE Reverse Design Closed-Loop Flowchart

Knowledge Objective: Master MCU functional architecture, working principle, instruction set, assembly language programming, and MCU system expansion and interface technologies.

Ability Objective: Be proficient in programming with C51 or assembly language; master the writing and debugging of MCU I/O control programs; be able to write interrupt service routines and initialize and apply timers/counters; independently complete peripheral circuit construction, program downloading and debugging.

Quality Objective: Cultivate engineering practical ability, innovative thinking, teamwork spirit and autonomous learning awareness; establish craftsmanship spirit and social responsibility.

4.2 Hierarchical Teaching Method: Three-Stage Progressive Ability Cultivation

Hierarchical teaching is adopted, dividing teaching into three levels: basic, comprehensive and innovative(see Figure 3):

Level 1: Basic Level – Modular Experiments (Proteus Simulation + Basic Development Board)

Students systematically learn principles and programming of MCU resources including I/O ports, timers, interrupts and communication protocols. Virtual experiments are conducted via Proteus to gradually master operation and debugging skills. Teaching mainly uses lectures and demonstrations to lay a solid theoretical foundation. A special evaluation scale is provided at each stage to ensure mastery of basic knowledge.

Level 2: Comprehensive Level – Project-Driven Teaching (Typical Projects such as Smart Home Control System)

Teaching focuses on systematic design ability and integrated application of knowledge. Through project-driven learning with modular kits, students practice practical and innovative abilities. Group cooperative learning is adopted to enhance understanding of comprehensive MCU applications. Smart agriculture and smart home projects help students grasp interface technologies between sensors and MCUs.

Level 3: Innovative Level – School-Enterprise Collaborative Development (Aligning with Real Enterprise Needs)

Teaching aims to cultivate engineering innovation ability. By participating in real enterprise projects and collaborative development, students understand industrial needs and challenges and propose innovative solutions. Case analysis and apprenticeship teaching are used to help students master engineering application and innovation skills. Evaluation emphasizes innovation and practical achievements.

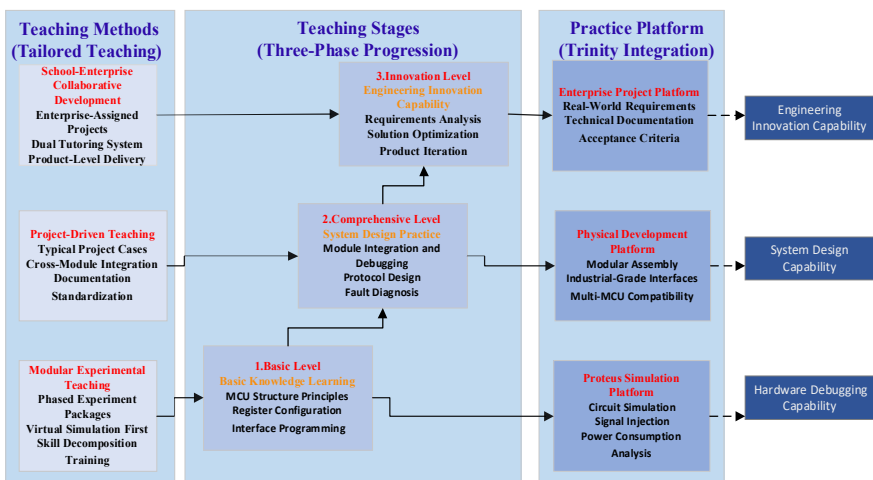


Fig. 3. Implementation Path of Layered Teaching

4.3 Diversified Evaluation Method: Assessment System Combining Process and Results

A diversified evaluation system is constructed: “process evaluation (10%) + basic theoretical examination (50%) + project practical assessment (40%) + innovation bonus points”.

Process Evaluation (10%): Covers attendance, homework completion, classroom performance and experiment completion, assessing basic knowledge mastery and learning attitude.

Basic Theoretical Examination (50%): Closed-book written test covering MCU principles, instruction set, architecture, peripheral interfaces and programming methods, including multiple-choice, fill-in-the-blank, short-answer and comprehensive questions.

Project Practical Assessment (40%): Requires students to apply theory to practice and deliver project outcomes. Project defense evaluates practical operation, design, problem-solving, expression and teamwork abilities.

Innovation Bonus Points: Awarded for innovative project proposals, excellent teamwork and problem-solving, encouraging exploration and innovation.

4.4 “Double Closed-Loop” Quality Assurance Mechanism(See Figure4)

A dual quality assurance mechanism is established: internal closed loop “course objective attainment analysis → continuous improvement” and external closed loop “enterprise feedback → curriculum iteration” :

Internal Closed Loop: Measures learning outcomes from theoretical mastery, practical skills and innovative thinking. The diversified evaluation system comprehensively assesses objective attainment. Weaknesses are analyzed, and teaching syllabus, methods, faculty and resources are adjusted accordingly. Student feedback is collected for continuous improvement.

External Closed Loop: Cooperation with enterprises is established; enterprise experts participate in curriculum design and evaluation. Students are arranged for internships and project cooperation. Enterprise feedback on graduates’ MCU skills is collected via questionnaires and interviews. Curriculum content is adjusted based on project acceptance, and enterprise cases are integrated to deepen industry-education integration.

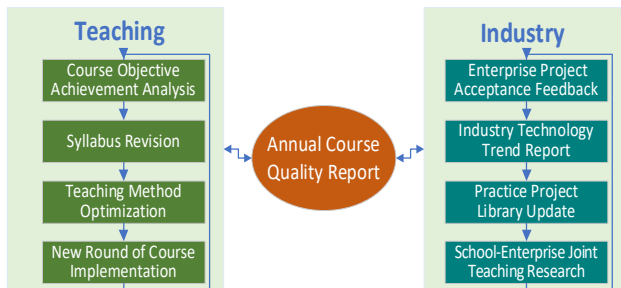


Fig. 4. Double closed-loop quality assurance mechanism diagram

5 Practical Effects and Case Analysis

5.1 Achievements in Teaching Resource Construction

Based on the “Three-Stage Progressive” model, a complete teaching resource package has been developed, including:

10 micro-lecture videos covering basic MCU theory, simulation operation and project development;

More than 20 project cases including basic experiments, comprehensive projects and real enterprise projects;

Supporting experiment guides and project task sheets clarifying learning objectives and evaluation standards.

5.2 Project Case: Smart Home Control System Design

Taking the smart home control system project at the comprehensive level as an example, students complete development in groups of 3–5. Based on STM32 MCU, the system integrates temperature/humidity, smoke, human infrared sensors, OLED display and WiFi module to realize environment monitoring, security alarm and remote control.

Project Implementation Process: Requirement Analysis: Investigate the smart home market and define system functions and technical indicators;

Hardware Design:

Build STM32 minimum system, design sensor interface and power supply modules;

Software Design:

Program sensor data acquisition, LCD display and WiFi communication for cloud platform uploading;

System Integration and Testing: Conduct software-hardware joint debugging and test stability and reliability;

Project Defense:

Present achievements and answer questions from teachers and peers.

Project Effect:

Students master STM32 peripheral configuration, sensor driver programming and WiFi communication protocols, and enhance systematic design and engineering practice abilities. They report deeper understanding of MCU knowledge and significantly improved practical problem-solving abilities.

5.3 Reform Effect Evaluation

Comparison between two student cohorts before and after reform shows significant effects:

Student Ability Improvement:

Students systematically master MCU principles, development and application, with advanced capabilities from simple programming to complex system design. Practical operation is greatly enhanced, and project completion rate increases by more than 35%.

Course Objective Attainment:

Attainment rates in knowledge, practice and innovation all exceed 85%, an increase of 15 percentage points.

Student Feedback:

Course satisfaction reaches 92%. Students recognize the clear learning path, stimulated interest from project-driven teaching and improved employability via the enterprise project platform.

6 Conclusion

Based on the OBE concept, this paper constructs a “Three-Stage Progressive” teaching model for MCU courses. It reversely designs course objectives, implements hierarchical teaching, establishes a diversified evaluation system, develops a trinity practical platform and forms a double closed-loop quality assurance mechanism. Practice shows that this model effectively solves key problems in traditional teaching: disconnection between content and industry, unsystematic practice and low evaluation-outcome correlation, significantly improving students’ engineering practice and innovative literacy.

Featuring “teaching determined by industrial demand”, the model realizes progressive ability improvement from chip-level to system-level and product-level, enabling students to advance from basic skills to systematic design and engineering innovation, ultimately achieving the transformation from knowledge to practice. Further teaching reform will be carried out to explore more effective methods and improve the long-term tracking evaluation mechanism, contributing to the cultivation of high-quality talents for emerging engineering education.

References

1. The State Council. 2019. China Education Modernization 2035[Z].
2. Wei L, Yonghua X, Guangjun W. 2021. Research and Practice of Advanced Learning Teaching Mode for Engineering Courses under the Background of Emerging Engineering Education[J]. *Research in Higher Education of Engineering*, (3): 163-168.
3. Zhengzhong J, Caigui H, Xingguo L. 2025. Exploration on Teaching Reform of the Course “Principles and Applications of Single-Chip Microcomputer”[J]. *Southern Agricultural Machinery*, 56(7): 195-198.
4. Li C , et al. 2022. Construction of Evaluation System for Single-Chip Microcomputer Course under Engineering Accreditation[J]. *Journal of Electrical & Electronic Education*, (6): 33-37.
5. Xiaohong W. 2018. OBE-Oriented Reform of Single-Chip Microcomputer Course[J]. *Experimental Technology and Management*, (6): 45-48.
6. Qiang Z, et al. 2020. Research on Three-Stage Progressive Teaching Mode of Single-Chip Microcomputer[J]. *Journal of Electrical & Electronic Education*, (4): 12-15.
7. Zhou M, et al. 2023. Practice of Three-Stage Integrated Project-Driven Teaching[J]. *Research and Exploration in Laboratory*, (2): 112-116.
8. Spady W G. 1994. Outcome-Based Education: Critical Issues and Answers[M]. Arlington: American Association of School Administrators,
9. Prince M. 2004. Does Active Learning Work? A Review of the Research[J]. *Journal of Engineering Education*. 93(3): 223-231.
10. Johnson R. 2021. Three-Stage Microcontroller Teaching Model at Stanford University[J]. *IEEE Transactions on Education*, 64(2): 112-118.
11. Shao, D. G., Bi, Q, Yang, Q. H., et al..2025. Exploration on the curriculum reform of "Principles and Applications of Single-Chip Microcomputers" under the background of "New Engineering" [J]. *Industry and Information Technology Education*, (2), 46-50.

12. Liu, S., Li, Y. H., Zhao, R. T., et al. 2025. Research on the exploration of experimental teaching reform integrating classroom and practice [J]. Education and Teaching Forum. (12), 63-66.
13. Hu, Z. J.. 2025. Teaching reform and practice of "Principles and Applications of Single-Chip Microcomputers" based on OBE concept under the background of New Engineering [J]. Journal of Pingxiang University, 42(3), 95-100.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

