Reform and Practice of a "Three-Link, Three-Drive, Three-Community" Blended Teaching Model for the Microcontroller Course under the Background of Emerging Engineering Education

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Abstract. The construction of Emerging Engineering Education (EEE) places stricter demands on engineering graduates' practical ability, innovative thinking, and capacity for self-directed learning, and it consequently challenges the way hardware-related courses such as the microcontroller course are taught. Several difficulties had long been observed in this course: students' individual learning needs were hard to satisfy, engineering and innovative thinking were insufficiently cultivated, and learning motivation was difficult to sustain. To tackle these problems, this paper presents a "Three-Link, Three-Drive, Three-Community" blended teaching model. The three links—theory, simulation, and practice—run through the entire teaching process and form a closed learning loop; the three drivers—project, case, and problem—activate learning through tasks at multiple levels; and the three communities—teacher–teacher research, teacher–student teaching, and student–student learning—build a diversified and interactive learning ecosystem. The model is underpinned by a three-level progressive task system, four-dimensional teaching resources, and a multi-dimensional assessment scheme, with ideological and political education integrated throughout. After two academic years of practice, grade analysis, questionnaire surveys, competition achievements, and multi-dimensional teaching evaluations all indicate that the model has effectively promoted students' knowledge construction, competence enhancement, and character development, and has significantly improved the teaching quality of the course and students' engineering innovation ability. The experience may serve as a reference for the teaching reform of similar hardware courses.

Keywords: emerging engineering education, microcontroller course, blended teaching, three-link, three-drive, three-community, teaching reform.

1 Introduction

Emerging Engineering Education (EEE) is a major strategic deployment of China's higher education in response to the new round of scientific and technological revolution

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and industrial transformation, and it is intended to accelerate the cultivation of engineering talents [1]–[2]. At its core, EEE emphasizes students' practical engineering ability, innovative thinking, and autonomous learning ability, which in turn raises the bar for the teaching of computer-related courses. Principles and Interface Technology of Single-Chip Microcomputers is a core professional foundation course for majors such as Computer Science and Technology, Internet of Things Engineering, Automation, and Artificial Intelligence. It serves as a bridge from circuit fundamentals and C language programming to embedded system development and directly supports follow-up courses such as embedded technology, wireless sensor networks, and intelligent terminal development. Because the course integrates software with hardware and is highly practical, it has become an important vehicle for cultivating students' practical engineering ability [3]–[4].

In practice, however, students vary considerably in their mastery of prerequisite knowledge, and the conventional "lockstep" mode of teaching can hardly accommodate such differences. The course content also contains a good deal of abstract internal structure and timing logic, which easily intimidates students and weakens the cultivation of engineering thinking and innovation ability. Moreover, theory teaching is often disconnected from real applications, students' learning motivation is difficult to sustain, and the conversion of knowledge into competence remains inefficient. As a result, the traditional teacher-centered, lecture-dominated mode falls short of the outcome-based requirements of engineering education accreditation and is clearly out of step with the goal of cultivating application-oriented talents with strong practical ability and innovative literacy under the EEE background [5].

In recent years, blended teaching has become an important direction of higher education reform under the EEE background, yet it remains an open question how a systematic blended teaching model can be constructed for advanced engineering courses. With this in mind, the present study takes the course Principles and Interface Technology of Single-Chip Microcomputers as its subject and develops a "Three-Link, Three-Drive, Three-Community" blended teaching model: the three links of theory, simulation, and practice run through the whole teaching process, the three drivers of projects, cases, and problems jointly stimulate learning motivation, and the three communities of teacher–teacher, teacher–student, and student–student collaboration reshape the relationships among teaching subjects. The model integrates online autonomous learning with offline practical guidance and has been implemented for two years, with the aim of providing a blended teaching solution that is replicable and transferable to other engineering courses.

2 Analysis of the Current Situation

The course is a four-credit compulsory course totaling 64 class hours, of which 16 are online and 48 are classroom hours, and it is offered to second-year undergraduates. It takes the 51-series microcontroller as the carrier and C language as the programming language, and covers the core architecture, internal interface technology, peripheral cir-

cuit design, and typical applications in intelligent detection and control. Proteus simulation software is employed to verify design schemes, and teaching management is carried out on a mainstream online learning platform (Chaoxing Xuexitong) that provides videos, quizzes, discussions, and dynamic learning statistics. Despite these conditions, the traditional teaching mode still gives rise to a series of problems in the implementation of this course, which are manifested in the following aspects:

(1) Students' foundations differ greatly, making individualized learning difficult to satisfy. The course requires both hardware fundamentals and programming ability, yet students' foundations are uneven: some are weak in circuit fundamentals and struggle with concepts such as registers, interrupts, and timing, while others lack programming experience and debug programs inefficiently. The traditional organization of “uniform progress and uniform content” can hardly accommodate such individual differences, and students with weak foundations are prone to frustration.

(2) Knowledge is disconnected from application, and engineering and innovative thinking are insufficiently cultivated. Traditional teaching follows the chapter line of the textbook; knowledge points are scattered and lack the traction of real engineering contexts, so students often “know the knowledge points but cannot apply them well.” Experiments are dominated by verification-oriented items with insufficient openness and comprehensiveness, which further restricts the development of engineering and innovative thinking.

(3) Learning motivation is insufficient, and sustained engagement is hard to maintain. The course is content-heavy and strongly practical. As teaching progresses, some students gradually lose interest because of gaps accumulated in earlier stages; their classroom participation and after-class engagement decline noticeably, forming a vicious circle in which “the harder the content, the less they learn.”

3 Design of the “Three-Link, Three-Drive, Three-Community” Blended Teaching Model

3.1 Overall Framework

In response to the above problems, the course has adopted a reform route of “resource construction as the foundation, teaching model as the core, and assessment as the safeguard,” and the overall framework is shown in Fig. 1. Within this framework, the “Three Links” run through the teaching process, the “Three Drivers” stimulate learning motivation, and the “Three Communities” reconstruct teaching relationships. Supported by two phases of online resources and a three-level progressive task system, the model is organized and implemented through a three-stage blended teaching process, forms an “evaluation–feedback–improvement” closed loop through multi-dimensional assessment, and incorporates ideological and political education throughout the whole teaching process.

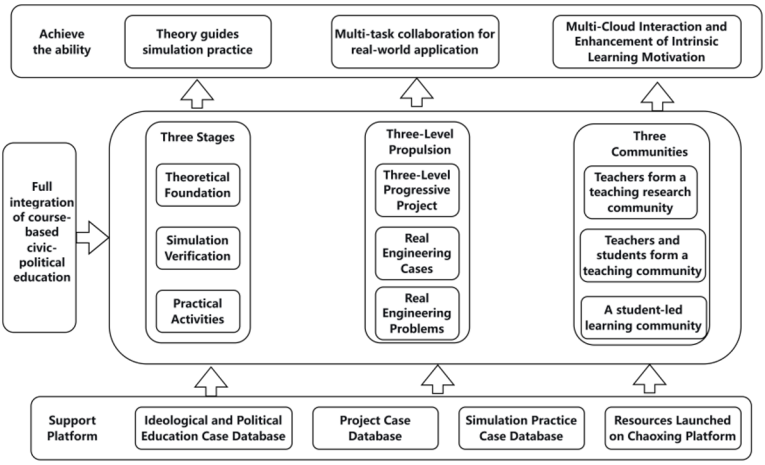


Fig. 1. Overall framework of the "Three-Link, Three-Drive, Three-Community" blended teaching model

3.2 Running Through the "Three Links": Building a "Theory–Simulation–Practice" Learning Closed Loop

The "Three Links" refer to theory, simulation, and practice running through the entire teaching process. In the theory link, core concepts, working principles, and interface methods are taught intensively so that students acquire a solid knowledge foundation. In the simulation link, Proteus is used to verify design schemes rapidly, which lowers the threshold of hardware operation and encourages students to try boldly and iterate quickly. In the practice link, physical construction and debugging are carried out on the basis of simulation verification, turning knowledge into engineering competence. The three links are closely interlocked and advance in a spiral: theory guides simulation and practice, simulation results deepen theoretical understanding in return, and practice consolidates the mastery of knowledge. Together they form a complete "theory–simulation–practice" learning closed loop that conforms to the experiential learning cycle of "concrete experience, reflective observation, abstract conceptualization, and active experimentation."

3.3 Coordinating the "Three Drivers": Multi-Dimensional Driving by Projects, Cases, and Problems

The "Three Drivers" refer to project-driven, case-driven, and problem-driven approaches working in concert to stimulate students' initiative through multi-level tasks. In project-driven learning, the course content is decomposed into 12 task-driven projects at three progressive levels—foundation, application, and innovation—so that students can apply what they have learned over complete project cycles [5]. In case-driven learning, large projects are broken into small cases close to engineering practice and

interspersed into each teaching link, closely combining knowledge learning with engineering contexts. In problem-driven learning, real engineering problems serve as the entry point and guide students to develop engineering thinking in the course of solving them. The three approaches complement one another and jointly strengthen students' engineering debugging and innovation abilities.

3.4 Collaborating the "Three Communities": Reconstructing the Subject Relationships of Teaching

The "Three Communities" consist of the teacher–teacher research community, the teacher–student teaching community, and the student–student learning community. The teacher–teacher research community shares teaching resources and teaching experience through regular teaching and research activities and jointly improves teaching design, thereby promoting teachers' professional development. The teacher–student teaching community emphasizes in-depth interaction between teachers and students in pre-class guidance, in-class discussion, and after-class tutoring, with teachers shifting from knowledge transmitters to learning guides and facilitators. The student–student learning community cultivates students' teamwork and communication skills through group projects, cooperative experiments, and mutual evaluation. Together, the three communities reconstruct the subject relationships of teaching, build a diversified and interactive ecosystem, and effectively strengthen students' intrinsic motivation.

3.5 Three-Level Progressive Task System and Four-Dimensional Teaching Resources

Table 1. Representative task-driven projects and knowledge points

Project	Type	Knowledge Points	Level
LED on/blinking	Basic introduction	Output I/O	Foundation
Running lights	Basic introduction	Output I/O	Foundation
Button control	Basic introduction	Input I/O	Foundation
Seven-seg. display	Consolidation	Timer, interrupt, I/O exp.	Foundation
Serial comm. display	Consolidation	Serial port, I/O	Foundation
LCD display	Consolidation	Display interface	Foundation
Smart home display (I)	Practical app.	Timer, interrupt, I/O	Application
Smart home display (II)	Practical app.	Timer, interrupt, display	Application
Smart home button ctrl	Practical app.	Timer, interrupt, button	Application
Smart home environ. mon.	Practical app.	Timer, interrupt, sensor	Application
Smart home curtain ctrl	Practical app.	Timer/interrupt, PWM, motor	Innovation
Smart home mon. system	Practical app.	Comprehensive design	Innovation

To implement the "Three Drivers" mechanism, the course has constructed a three-level progressive task system that decomposes the teaching content into 12 task-driven projects covering the three levels of foundation, application, and innovation; representative projects are listed in Table 1. Each project consists of three parts—hardware structure, software design, and application exploration—so that theory, simulation, and practice are all exercised in every task.

To support the progressive tasks, the course has built a four-dimensional teaching resource system composed of an ideological and political case library, a project case library, a simulation practice library, and a platform resource library. The system provides students with different foundations with personalized learning path navigation, supports integrated "resource–path–diagnosis" intelligent learning management, and lays a structural foundation for teaching students in accordance with their aptitude.

3.6 Three-Stage Blended Teaching Process

Relying on the online learning platform, the course implements a three-stage blended teaching process of "pre-class guided learning, in-class deep learning, and post-class extension." Before class, preview videos and unit tests are released through the platform; students complete the preview tasks and take part in themed discussions, while teachers identify common weak points from the platform data. In class, teachers give focused lectures on the problems that surfaced during preview, and interactive activities such as online voting, in-class quizzes, in-class tests, and discussions are used to enhance participation; key and difficult points are tackled through group cooperation and group presentations. After class, exercises are released and graded promptly, online and offline question-answering is provided, questionnaires on important knowledge points are distributed to track learning status, and group projects combining online and offline elements are organized on the basis of the extension project library to cultivate collaboration and innovation abilities.

The course also explores ideological and political elements from the perspectives of the discipline's development history, domestic chips and technological self-reliance, and the craftsman spirit, and integrates them into the whole teaching process in a subtle and imperceptible way, so that knowledge transmission and value guidance resonate with each other. In this way, students are guided to establish the ideal of serving the country through science and technology and a rigorous, truth-seeking engineering style, thus implementing the requirements of curriculum-based ideological and political education.

4 Teaching Implementation and Course Assessment

Chaoxing Xuexitong serves as the core teaching management platform, integrating course videos, courseware, question banks, discussion forums, and statistical functions. The practical link adopts a virtual–real combined path of "Proteus simulation verification first, followed by implementation on physical development boards." The course has built 135 teaching videos totaling 1,102 minutes; project cases are stratified into

four difficulty levels—foundation, consolidation, application, and innovation—and Proteus simulation circuits and source codes for the core cases, together with an ideological and political case library, are provided so that students with different foundations can choose according to their needs. The two phases of online resource construction are compared in Fig. 2.

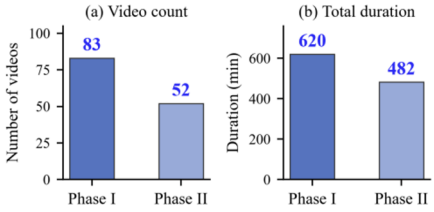


Fig. 2. Comparison of the two phases of online resource construction.

Through the backend data of Xuexitong (video viewing duration, test accuracy, and discussion participation), teachers can accurately grasp the learning status of the whole class and of individual students and dynamically adjust the focus and pace of offline classroom teaching, thereby realizing "teaching informed by learning." The overall composition of the course grade is illustrated in Fig. 3.

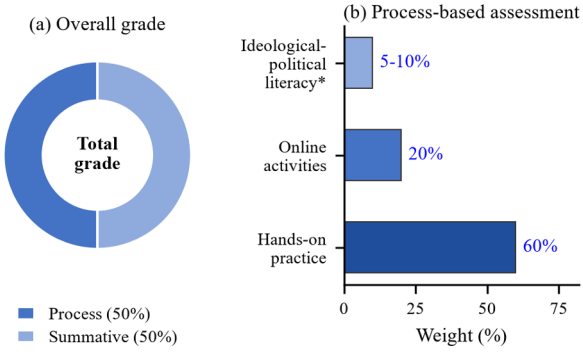


Fig. 3. Composition of the course grade: (a) overall grade; (b) components of the process-based assessment.

The reform was implemented in the spring semesters of 2025 and 2026, covering 273 students from three majors—Computer Science and Technology, Internet of Things Engineering, and Automation—with a teaching team composed of four lecturers and one practice teaching assistant, all of whom adopted the same teaching framework, teaching resources, and assessment scheme. During implementation, the team held regular teaching and research meetings, made horizontal comparisons of the statistical data of each class on the learning platform, and dynamically adjusted the pace of the three-stage teaching process; on the basis of the common problems exposed in simulation experiment reports and after-class exercises, the project task books and guidance points were also revised in a timely manner so that the reform took effect.

5 Implementation Outcomes

Course evaluations in the 2025–2026 academic year show that the evaluations by teaching supervisors, peers, and students were all rated "excellent," and the comprehensive evaluation ranked among the top 20% of the faculty in the college. Student feedback indicates that classroom participation increased markedly, and students spoke highly of the practical value of the simulation verification and project practice activities.

Over the past two years, drawing on what they learned in this course, students have won more than 100 awards in competitions such as the Lanqiao (Blue Bridge) Cup National Software and Information Technology Talent Competition, the National College Student Embedded Chip and System Design Competition, the National College Student Intelligent Car Competition, and the National Undergraduate Electronic Design Contest, and 12 graduation projects (theses) were rated university-level excellent. Teachers of subsequent courses have reported that students who completed this course show markedly greater enthusiasm and intrinsic motivation in professional learning, think clearly and adopt appropriate methods when learning other controller architectures, and exhibit good knowledge transfer ability.

During the reform period, the course completed the construction of an online open course, was approved as a university-level knowledge graph course and a university–enterprise cooperation course, and was rated as a university-level ideological and political demonstration course; the team won the second prize of the university-level teaching achievements and the title of university-level first-class course, and its ideological and political teaching case won an excellent case award. The teaching reform has thus gained relatively broad recognition.

At the end of each semester, the team reviews the teaching in light of the assessment results and platform data and feeds common problems back into the adjustment of resources and tasks; meanwhile, relying on university–enterprise cooperation, it advances industry–university–research collaboration and continuously introduces real enterprise cases and competition experience into the course. In the future, an intelligent learning center will be built to integrate the knowledge graph, virtual simulation, and competition question banks so as to generate dynamic learning reports for each student, and a four-level ability certification system and an enterprise dual-mentor mechanism will be explored to deepen the reform continuously.

6 Conclusion

To address the problems of individualized learning needs being difficult to satisfy, engineering and innovative thinking being insufficiently cultivated, and learning motivation being difficult to sustain in microcontroller course teaching, this paper has proposed a "Three-Link, Three-Drive, Three-Community" blended teaching model and presented a systematic design covering the task system, resource construction, teaching process, ideological and political education, and assessment, achieving favorable results in a two-year teaching practice involving 573 students. The model does not depend on any specific microcontroller platform and possesses strong transferability, thus

providing a reference for the teaching reform of similar hardware courses such as embedded technology and sensor networks. In future work, knowledge-graph-driven personalized learning support will be continuously improved, university–enterprise collaborative education will be further deepened, and new paths for cultivating engineering talents under the EEE background will be constantly explored.

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