



# Implantation and Introduction Teaching of the Course on the Principles and Applications of Single-Chip Microcomputers Based on Knowledge Graphs

Haidi Rao\*, Wenming Wang, Xiaofeng Ye, Juanjuan Zhu, Wu Feng

Anqing Normal University, Anqing, Anhui, China

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**Abstract:** This study addresses the complex knowledge structure, strong interconnectivity, and high teaching difficulty of the Microcontroller Principles and Applications course by proposing a knowledge graph-based, embedded and guided teaching approach. By constructing a multidimensional knowledge graph centered on microcontrollers, it systematically organizes the logical relationships between course content and prerequisite/sequential courses while integrating career development pathways to enhance students' holistic understanding of the curriculum framework. Practical implementation demonstrates that this approach effectively boosts student engagement, cultivates their ability to independently construct knowledge frameworks, and propels the microcontroller course toward intelligent and personalized teaching. It provides valuable insights for curriculum reform in engineering disciplines.

**Keywords:** microcontroller, knowledge graph, artificial intelligence, practice-oriented education

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## 1. Introduction

Microcontroller Principles and Applications serves as the core hardware course for computer engineering majors and forms a crucial foundation for electronic information system design and development. Characterized by its tight integration of software and hardware, complex knowledge structure, and strong practical orientation, this course often poses challenges for beginners in constructing a systematic knowledge framework. The current development of intelligent education emphasizes learner-centered approaches, particularly focusing on breakthroughs in key technologies such as knowledge graph construction and evolutionary reasoning. This provides a clear direction for reforming microcontroller instruction: knowledge graph technology can effectively integrate fragmented knowledge points[1], reveal their intrinsic connections, and thereby address teaching challenges like complex knowledge structures and weak interrelationships. This approach drives the course toward structured, visual, and personalized learning.

## 2. Research Background and Significance

Knowledge graphs, as a large-scale knowledge representation method based on semantic networks[2], provide crucial technical support for teaching reform in the Microcontroller Principles and Applications course through intelligent functions such as visualization, semantic search, and personalized recommendations. The course features a complex knowledge system and abstract content, making it difficult for students to build systematic understanding. Knowledge graphs clearly reveal knowledge connections through their “node-edge” structure. They not only assist students in forming knowledge frameworks but also provide teachers with diagnostic insights into student learning progress and personalized learning path planning, thereby enhancing teaching efficiency.

Developing a knowledge graph for microcontroller courses not only aligns with educational informatization initiatives but also effectively organizes knowledge structures and visualizes connections[3], accelerating the intelligent transformation of curricula. This exploration holds practical significance for addressing current teaching challenges and advancing precision teaching, while offering valuable insights for intelligent instruction in similar engineering courses.

## 3. Research Objectives

The development of a microcontroller knowledge graph has profoundly impacted university teaching across six dimensions: knowledge, curriculum, majors, students, faculty, and administrators[4]. It achieves the goal of enhancing teaching quality, with particularly notable effects in four areas: visual teaching, fostering innovation capabilities, promoting pedagogical reform, and adapting to contemporary demands. Consequently, it elevates students' comprehension abilities and overall competence[5].

First, it enhances teaching effectiveness. By leveraging the visual nature of knowledge graphs, complex theoretical

knowledge is presented in an intuitive diagram format, aiding students in better understanding and mastering course content, thereby improving teaching outcomes.

Second, fostering students' innovative capabilities. Through knowledge point interconnections and expansions, coupled with interactive learning platforms, students' knowledge horizons are broadened, cultivating their innovative thinking and capabilities.

Third, advancing teaching reform. This novel approach to course development offers fresh perspectives and methodologies for teaching reform in automatic control theory courses, contributing to the broader reform and advancement of the entire discipline.

Fourth, adapting to the demands of the times. The development of new forms of automatic control theory courses based on knowledge graphs can help students better adapt to the demands of the times, enhancing their comprehensive qualities and competitiveness.

Overall, knowledge graph-based course development drives educational reform, providing students with a more comprehensive and in-depth learning experience, and helping to meet modern society's demand for technical talent.

## 4. Methods

### 4.1 Research Content

The Microcontroller Principles and Applications course covers core knowledge modules including microcontroller architecture, instruction sets and assembly programming, interrupt control mechanisms, timer/counter applications, serial communication protocols, parallel I/O interface design, and A/D and D/A conversion modules[6]. This course relies heavily on the foundational knowledge of discrete mathematics' logical operations, algorithmic thinking from programming fundamentals, low-level programming skills in assembly language, and hardware design capabilities in circuitry and analog electronics, digital circuits, and digital logic. It also requires students to possess a high school physics background in circuit theory and semiconductor knowledge. As a pivotal course bridging hardware and software, its knowledge framework connects upward to subsequent courses like Microcomputer Interface Technology, Embedded System Development, Operating System Resource Scheduling, and Database Hardware Interaction. Downward, it forms a tight vertical knowledge chain with prerequisite courses such as Computer Organization Principles and Digital System Design.

The microcontroller course exerts multidimensional influence across computer science disciplines[7]. For instance, teaching the microcontroller interrupt system requires integrating logic control principles from digital circuits with event-driven models from programming. Mastery of this module directly impacts the depth of learning in subsequent courses like real-time task scheduling for embedded systems and operating system interrupt response mechanisms. Similarly, teaching microcontroller A/D conversion interfaces requires integrating signal conditioning circuit knowledge from analog electronics, which in turn provides technical support for advanced applications like IoT sensor data acquisition and hardware implementation in industrial control systems. Furthermore, designing memory expansion for microcontrollers requires applying data structure concepts for memory management. Such practical skills directly transfer to advanced domains like storage optimization in compiler theory and caching strategies in database systems[8]. Constructing a knowledge graph centered on microcontrollers holds significant value for students learning specialized courses, particularly foundational required courses. This approach to knowledge graph construction can also serve as a reference for other foundational required courses across disciplines.

### 4.2 Research Methodology

First, the key to guiding students in constructing knowledge maps lies in the first class; second, the process of building knowledge maps should be integrated into every theoretical lecture. Through continuous training in knowledge map construction thinking, students will develop the ability to learn independently and construct knowledge maps.

#### (1) Delivering an Effective First Lecture.

The inaugural lecture plays a pivotal role in the teaching process. Utilizing case studies of visual knowledge maps, combined with diagrams illustrating the relationship between knowledge maps and career planning, significantly enhances students' systematic understanding of the curriculum framework. For instance, teaching microcontroller interrupt systems must build upon foundational knowledge of flip-flops and priority encoders within digital circuits and logic. Furthermore, the collaborative application of microcontroller memory expansion designs (e.g., EEPROM and Flash storage) with serial communication interfaces (e.g., I2C, SPI) exemplifies the "multi-level storage-peripheral interaction" architecture in embedded systems. This directly resonates with the bus hierarchy theory covered in computer architecture courses.

Evidently, the integration of knowledge graphs and their relationship diagrams with career planning not only facilitates

students' autonomous and selective review of prerequisite courses but also aids in selecting subsequent courses and planning career paths. Most importantly, it enhances students' appreciation for the course, fostering greater learning interest and enthusiasm.

#### (2) Integrating Embedded Teaching with Introductory Instruction.

Beyond the first class, the teaching reform for Microcontroller Principles and Applications should be implemented throughout the entire course. Specifically, each theoretical lecture should employ embedded teaching to integrate the detailed knowledge map for that section into the course content. At the start of each class, Traditional teaching methods like reviewing prior knowledge or problem-based introductions remain applicable. However, with the explicit integration of knowledge maps (displayed in lecture handouts), introductory segments should fully leverage these maps to articulate the relationship between the upcoming content and prerequisite/subsequent courses. This enhances students' focus and interest in the current lesson.

During the course delivery, traditional teaching methods like lecture-based instruction and student questioning remain viable. Concurrently, implicit knowledge map embedding (not displayed in handouts) can be employed. Teaching approaches such as student questioning can be used to stimulate reflection and deep recall regarding the embedded knowledge map, aiding student comprehension and mastery.

At the conclusion of the lecture, summarizing key points and posing questions — common practices in traditional teaching — remain effective. Concurrently, explicitly integrating the knowledge map serves dual purposes: it reinforces and synthesizes the current lesson's content while seamlessly transitioning to subsequent topics and their connections to prerequisites and follow-up courses. This approach underscores the session's significance, boosts students' motivation for post-class review, and guides them toward self-directed learning for upcoming content.

### 4.3 Primary issues to be resolved

Compared to courses such as programming and data structures, Microcontroller Principles and Applications is characterized by its strong theoretical foundation, systematic approach, and modular knowledge structure. This course is commonly regarded as challenging to both teach and learn. Analysis of its current teaching practices reveals the following issues:

#### (1) Course content is abstract and difficult to grasp, with relatively monotonous teaching materials.

As a highly applied technology, microcontroller technology places particular emphasis on integrating theory with practice. Microcontroller experiments in some universities lack relevance to real-world engineering projects, failing to meet the needs for cultivating students' practical skills and innovative thinking. Current microcontroller courses predominantly feature verification experiments conducted according to established protocols. Students merely follow procedures to achieve predetermined outcomes, lacking opportunities for independent thinking and exploration. Experiment content is often confined to basic circuit connections and programming tasks, failing to sufficiently develop students' comprehensive abilities and innovative thinking. This approach hinders the cultivation of skills in microcontroller system design and development.

#### (2) Lack of Innovation in Teaching Methods.

In microcontroller instruction, some instructors primarily focus on traditional hardware interfaces and assembly language programming, neglecting the application of new electrical control components. This creates a significant gap between the knowledge students acquire and the demands of real-world engineering applications. Furthermore, the case studies selected by instructors are relatively limited and lack content relevant to engineering practice. Consequently, students struggle to integrate theoretical knowledge with practical applications during their learning process, resulting in a lack of deep understanding and grasp of engineering projects. Due to the course's dense information load, abstract concepts, and limited class hours, students commonly face the dilemma of “lofty ambitions but limited skills.” This manifests as weak theoretical foundations and poor practical operational abilities, making it difficult for them to quickly grasp the fundamentals or pursue in-depth learning.

(3) Students do not sufficiently value this course, resulting in an inadequate learning attitude and a lack of effective study methods.

They merely treat this course as an ordinary subject, failing to recognize its importance. The study methods they employ are unsuitable for the course content, focusing solely on exam scores rather than building a solid foundation in computer science. The course itself is highly systematic, with complex relationships among the five major functional components of computer systems. Each functional module is also closely intertwined with other courses. If students isolate these relationships and connections, adopting traditional single-module learning approaches, it hinders effective learning and mastery of the course.

#### (4) Insufficient practical project training.

Due to limited experimental equipment, group experiments are conducted, with assessment primarily based on lab reports. This creates opportunities for some students to “free-ride,” failing to spark genuine interest or enthusiasm for both the theoretical and experimental components of the course. Constrained by limited class hours for the Microcontroller Principles and Applications course design, only verification experiments can be scheduled. This prevents the full implementation of design innovation experiments, hindering the development of students' innovative thinking and systematic modular thinking.

In summary, this course plays a crucial role within the knowledge network constructed throughout the undergraduate teaching system. The aforementioned issues severely constrain and impact the teaching effectiveness and quality of this course. How to simplify and make this course more tangible, enhance students' interest and enthusiasm for learning, and better guide them in building their own knowledge networks are questions that teachers must contemplate and resolve.

## 5. Conclusion

Moving forward, we will explore deeper integration pathways for knowledge graphs in microcontroller experimentation, project-based training, and course evaluation, driving the formation of an intelligent teaching closed-loop integrating “theory-practice-assessment.” Simultaneously, we aim to extend this model to other engineering disciplines, fostering organic integration between educational technology and specialized instruction to continuously empower the cultivation of innovative engineering talent capable of meeting future technological demands.

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