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Digital Circuit Course Development Based On AI

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Abstract: Artificial Intelligence (AI) is presenting unprecedented opportunities and challenges to higher education, making AI-driven curriculum reform imperative. By constructing a knowledge graph for the digital circuit course, this approach enables students to engage in goal-oriented learning processes through understanding the framework of key concepts, while utilizing assessment questions linked to specific knowledge points for self-evaluation. This AI-powered transformation can significantly enhance students' mastery of the course content.

Keywords: Artificial Intelligence; Digital Circuits; Knowledge Graph.

1. Introduction

In recent years, AI has undergone rapid development and has been widely adopted in university classroom instruction. As self-directed learning plays a pivotal role in knowledge acquisition among college students, AI-driven curricular reforms in higher education have become imperative. AI-enhanced teaching methodologies will break away from traditional pedagogical models, substantially improving teaching effectiveness while significantly reducing faculty workloads. Additionally, these approaches will provide students with more autonomous learning opportunities, creating greater intellectual space for exploration and critical thinking. This transformation will not only enhance students' scientific literacy to a greater extent but also play a vital role in cultivating their comprehensive competencies.

The Fundamentals of Digital Electronics serves as a cornerstone course for electronics and information-related disciplines. Its core objective lies in systematically establishing the theoretical framework for digital circuit design and analysis, with a strong emphasis on the practical applications of integrated circuits. The knowledge system in this field centers on digital signal processing, encompassing a full spectrum of content ranging from basic logic gates to complex system design.

2. Course Objective Setting

The teaching objectives of the Digital Electronics course are to enable students to:

✷Master the fundamental concepts, operational principles of basic circuits, and essential analysis and design methodologies in digital electronics through systematic learning;

✷Acquire foundational knowledge, theories, and practical skills in digital electronics through the introduction of typical digital logic devices and hands-on instructional modules;

✷Cultivate the ability to properly select and apply digital logic components using acquired knowledge, laying a solid foundation for addressing future digital system challenges;

✷Apply digital circuit expertise integrated with artificial intelligence (AI) technologies to solve real-world practical problems.

Aligned with the requirements of the academic program, these course objectives support three graduation competencies: engineering, design, and research. The detailed instructional objectives are presented in Table 1.

Table 1. Course Objectives and Graduation Competencies

Course Objectives	Graduation Competencies
Objective 1: Enable students to master fundamental knowledge of digital electronics through classroom instruction, understand analytical methods for combinational and sequential logic circuits, and demonstrate the ability to model and solve complex engineering problems in communication fields while meeting correctness and usability requirements. Equip students to leverage AI technologies for modeling and solving complex engineering problems in computer communication networks.	**Engineering Knowledge**: Possess mathematical, natural science, and communication-specific theoretical expertise to address complex engineering challenges in communication engineering.
Objective 2: Cultivate students' ability to apply scientific methodologies for digital circuit analysis, integrate disciplinary theories and principles, and develop AI-enhanced research solutions for targeted communication engineering problems. Foster competence in resolving complex communication engineering challenges through modular design approaches.	**Design**: Capable of devising solutions for complex communication engineering problems, designing systems/functional modules or processes that meet specific requirements, while demonstrating innovation and considering societal, health, safety, legal, cultural, and environmental factors.
Objective 3: Develop proficiency in constructing experimental systems using AI-driven scientific methods, skillfully operate electronic instrumentation for digital circuit analysis, master simulation tools for information system evaluation, and effectively communicate communication-related design solutions through technical diagrams and mathematical formulations.	**Research**: Able to investigate complex communication engineering problems through scientific principles and methods, including experimental design/execution, data analysis/interpretation, and deriving valid conclusions through information synthesis.

3. Course Knowledge Graph Construction

The knowledge graph, as a structured knowledge representation framework, effectively reveals intrinsic connections and logical relationships within complex content, enhancing the clarity of course delivery. In digital electronics courses, this approach significantly improves students' understanding of interconnections between key concepts such as digital circuit classification, combinational logic circuits, and sequential logic circuits, thereby mitigating comprehension difficulties caused by fragmented knowledge. Aligned with the course objectives and graduation competencies outlined in Table 1, the curriculum features an 8-tier knowledge hierarchy comprising over 50 knowledge points.

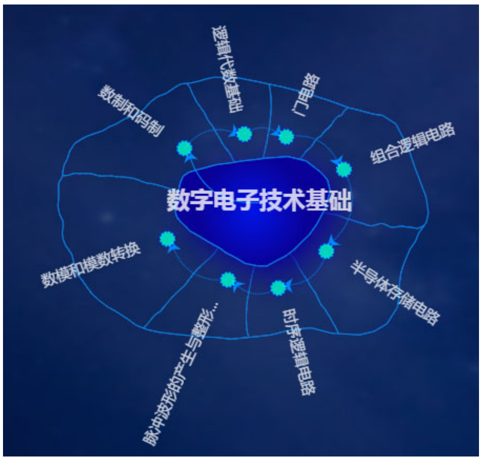

Figure 1. Tier-1 Knowledge Graph

The knowledge graph delineates prerequisite, postrequisite, and correlative relationships between concepts, integrating diverse instructional resources (videos, courseware, images, exercises) with corresponding knowledge points. This creates a cohesive structure where digital resources are systematically mapped to knowledge elements. As illustrated in Figure 2:,Combinational Logic Circuits Knowledge Graph, node geometries and shading intensities represent distinct hierarchical levels of knowledge points.

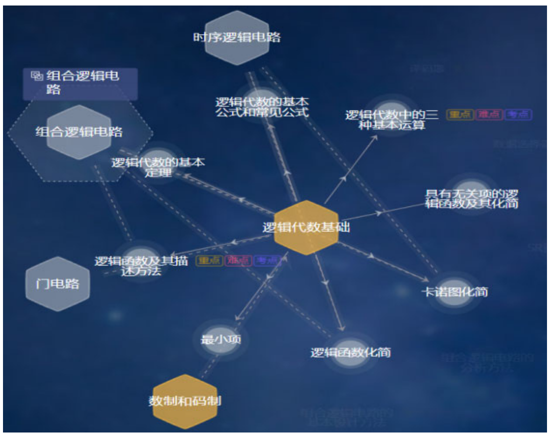

Figure 2. Combinational Logic Circuits Knowledge Graph

4. Intelligent Teaching System

The knowledge graph enables real-time monitoring of teaching outcomes, identification of cohort-level knowledge gaps, and data-driven instructional optimization.

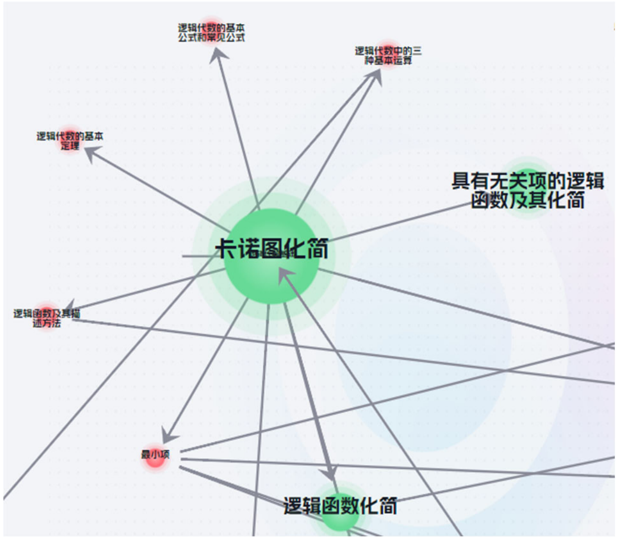

Figure 3. Karnaugh Map Simplification Mastery Analysis

4.1. Overall Course Analysis

By analyzing students' completion of learning tasks, homework, in-class exercises, and assessment results, teachers can evaluate the overall teaching effectiveness of each knowledge point and module. Based on this analysis, the following instructional recommendations are provided:

①Strengthen Chapter Quiz Management: Teachers should regularly remind students to complete chapter quizzes and urge those who fail to do so.

②Focus on Students with Low Completion Rates: Provide additional guidance and support to students with low task completion rates or incomplete assignments.

③Enhance Student Engagement: Boost learning motivation and participation by incorporating interactive activities and discussions.

4.2. Individual Student Analysis

Teachers can conduct targeted reviews of individual students' learning progress, particularly for those struggling academically, to analyze their performance and provide timely guidance or personalized tutoring. Additionally, by developing multimodal teaching resources at the knowledge-point level, teachers can systematically organize content and teaching materials, enabling the design of innovative digital textbooks. Figure 4 illustrates a student's mastery of specific knowledge points.

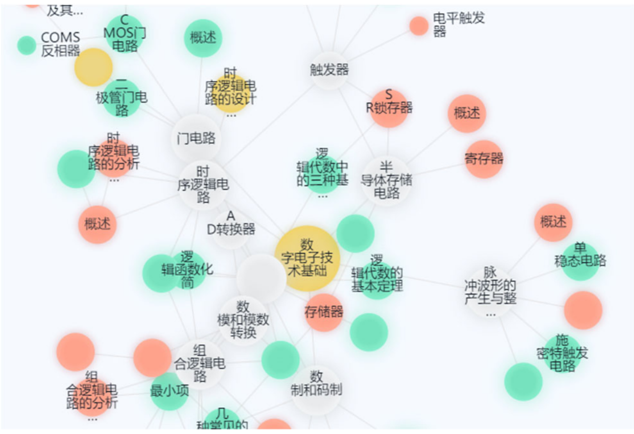

Figure 4. Individual Student's Mastery of Knowledge Points

Based on this analysis, the following learning recommendations are proposed:

①**Address Uncompleted Tasks and Assignments**: Teachers should remind and urge Chen Bocheng to complete pending tasks and assignments, identify reasons for incompletion, and offer necessary assistance.

②**Strengthen Instruction on Low-Mastery Knowledge Points**: For topics with low mastery rates, such as "Overview" and "Common Types of Encoding," teachers should increase targeted explanations and practice to improve understanding.

③**Encourage Self-Directed Learning**: Encourage Chen Bocheng to engage in self-study during free time, such as reviewing instructional videos or textbooks, to reinforce learning outcomes.

5. Summary

Through the instructional design of the digital circuits course, a course knowledge graph was constructed, accompanied by a detailed breakdown of knowledge points and the development of targeted teaching resources. This framework enables granular analysis of learning outcome achievement at the knowledge-point level for both teachers and students, guiding them to refine teaching and learning activities based on actionable insights. The outcome-oriented approach ensures precision in course delivery.

Building on the knowledge graph, intelligent services such as semantic search, automated Q&A, and personalized learning resource recommendations were provided to students. Feedback indicates that the course knowledge graph effectively reflects individual mastery of each knowledge point in real time, empowering students to focus on weaknesses, enhance learning efficiency, and achieve better outcomes.

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