

Exploration and Practice of Blended Teaching Reform of the Analog Electronic Technology Course Driven by an Artificial Intelligence (AI) Smart Knowledge Graph

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Abstract

The Analog Electronic Technology course is concept-intensive, and its circuit analysis methods are flexible. A relatively common difficulty among students is that “single-point knowledge can still be mastered, but the overall context is difficult to connect.” In teaching, problems such as linear content organization, unified learning support, a long feedback cycle, and mismatch between resources and needs have existed for a long time. In response, this study takes Outcome-Based Education (OBE) as the basic guidance, connects the structured organization ability of the smart knowledge graph with the dialogue interaction ability of the artificial intelligence (AI) agent, and constructs a blended teaching model driven by an AI smart knowledge graph. Starting from graduation requirements and course objectives, knowledge points are reversely decomposed, four types of associations, namely prerequisite, parallel, causal, and application associations, are sorted out, and a three-layer smart knowledge graph organized in five levels of “course-module-chapter-knowledge point-sub-knowledge point” is formed. On this basis, an AI teaching agent is developed to undertake preview guidance, in-class question answering, homework correction, learning situation analysis, and other work. The teaching process is then rearranged according to the three stages of before class, in class, and after class. A one-semester comparative practice shows that the final average score of the experimental class is 8.7 points higher than that of the control class, the score difference in comprehensive questions is especially obvious, the proportion of students independently completing design experiments has increased, and the dispersion of scores has also narrowed. The relevant practices have certain reference value for the intelligent transformation of basic courses in electronic information majors, but the scope of application of the conclusions is still limited by the sample size and implementation rounds.

Keywords

smart knowledge graph, AI agent, analog electronic technology, blended teaching, teaching reform, OBE concept

1. Introduction

In the Education Informatization 2.0 Action Plan [1], the Ministry of Education proposed promoting the deep integration of new technologies such as AI and big data with education and teaching, and building a networked, digital, intelligent, and personalized education system. In 2024, the Ministry of Education launched

the AI-empowered education action, taking smart course construction as an important starting point for advancing the digital transformation of education. In terms of course construction, policy promotion and technological evolution have changed both the available means and the expected objectives. Smart knowledge graphs are good at organizing scattered knowledge into computable structures, while AI agents can undertake dialogue-based support that responds at any time. The two correspond exactly to two interdependent basic problems in smart course construction: by what structure course knowledge is organized, and in what way the learning process obtains support.

Analog Electronic Technology is a core basic course for electronic information, automation, electrical engineering, and related majors. It is highly theoretical, its concepts are abstract, and the same type of circuit often has several analysis methods, so the learning difficulty has long been relatively high. Classroom observation and student feedback show that the problems most often reported by students focus on three aspects: difficulty in understanding circuit principles, difficulty in establishing analysis ideas, and not knowing where to start when faults appear in experiments. These difficulties not only affect classroom teaching effectiveness but also, to a certain extent, hinder the formation of engineering thinking. From the teaching process itself, textbook content is arranged linearly by chapter. The prerequisite dependencies and horizontal connections among knowledge points are mostly hidden behind sections and are not explicitly expressed. Teachers have difficulty grasping each student's learning position at any time, and students, when facing a considerable number of learning resources, also lack a basis for judging which one to read first.

Domestic peers have already carried out much work on the intelligent transformation of this course. Xing et al. [2] used smart classroom tools to connect the three links of before class, in class, and after class, and promoted reform from teaching concepts, teaching methods, and assessment methods. Li et al. [3] relied on a smart teaching platform and worked simultaneously on five aspects: revision of teaching objectives, reconstruction of teaching content, innovation of teaching methods, improvement of the assessment system, and integration of course ideology and politics. Wu et al. [4] combined the OBE concept with AI technology and explored a smart teaching model for this course. These studies have accumulated experience that can be used for reference, but on the whole, they still mostly stay at the level of "introducing" smart tools into teaching. The logical structure of the knowledge system itself has not been explicitly portrayed, and AI also mainly appears in the form of scattered tools and has not truly entered the main line of course construction. Therefore, the overall effectiveness of smart course construction is constrained.

This study takes the Analog Electronic Technology course as the research object, attempts to use the structured representation ability of the smart knowledge graph together with the interaction ability of the AI agent, constructs a blended teaching model driven by an AI smart knowledge graph, and implements it in five links: course objectives, content organization, resource development, teaching implementation, and learning evaluation, in order to provide referable ideas and practical evidence for the intelligent transformation of basic courses in electronic information majors.

2. Related Concepts and Theoretical Basis

2.1 Smart Education and Blended Teaching

Smart education can be regarded as a form after education informatization develops to a certain stage. Its characteristic lies in the deep participation of data and intelligent technology in teaching. For a course, it involves at least three meanings: course content is organized into a computable and presentable structure rather than scattered across textbook pages; learning support varies from person to person and can adjust pushed content and learning paths according to student profiles; teaching evaluation runs through the whole learning process and does not depend only on a final examination. The three levels of content, support, and evaluation also constitute the starting point for the subsequent design of this study.

Blended teaching combines online learning with offline face-to-face teaching [5], with the purpose of allowing the two environments to give play to their respective strengths. The online link is more suitable for students to complete knowledge acquisition at their own pace, while the offline link is more suitable for promoting knowledge internalization through discussion, collaboration, and hands-on practice. The division of labor between the two makes teaching present different forms at different stages. A complete blended

teaching cycle usually covers the three stages of before class, in class, and after class, and this division is also the direct basis for organizing the teaching process in this study.

2.2 Smart Knowledge Graph and AI Agent

A smart knowledge graph uses nodes and edges to describe knowledge and its interrelations, and is essentially a semantic network. When used in a course scenario, the questions it needs to answer include how knowledge points are modeled, how associations among knowledge points are extracted, how learning paths are recommended, and how multimodal resources are mounted to nodes. For learners, the significance of the smart knowledge graph lies in making explicit the structure originally hidden in the textbook, enabling them to judge “what relationship this section has with that section,” and also providing a structured basis for personalized path planning [6-7].

An AI agent is built on “large language model + retrieval-augmented generation” and is an intelligent agent system with specific teaching functions. In course teaching scenarios, it can undertake roles such as teaching assistant, learning companion, and evaluation feedback, and can be used for instant question answering, learning guidance, resource recommendation, homework correction, and learning situation analysis. Compared with early question-answering systems relying on rules or keyword matching, AI agents perform obviously better in semantic understanding, contextual connection, and reasoning, and their replies are closer to natural dialogue. Therefore, they have the possibility of taking over some repetitive tutoring work.

Putting the two together, the smart knowledge graph provides an accurate and traceable knowledge framework, which can constrain the scope and sources of AI answers. The AI agent provides the ability to understand context and generate expression, and can present the content in the framework to students in a natural way. A single technology has shortcomings, and only coordinated use can possibly meet the two requirements of “knowledge structuring” and “interactive intelligence” at the same time.

2.3 OBE Concept

OBE, namely Outcome-Based Education, advocates that teaching design and teaching implementation should both take the learning outcomes finally obtained by students as the starting point. Its core can be summarized as student-centeredness, outcome orientation, and continuous improvement. According to this logic, a course first needs to answer “what abilities students should have when they graduate,” and then reversely determine the curriculum system, teaching content, and teaching methods, so that every teaching activity can correspond to the expected learning outcomes.

The main intention of introducing the OBE concept into the reform practice of this study is to avoid the separation of technology application from training objectives. Specifically, the construction of the smart knowledge graph starts from graduation requirements and course objectives, and is decomposed layer by layer into three types of objectives: knowledge, ability, and literacy. The functional design of the AI agent is carried out around the evaluation and intervention of learning outcome achievement. The evaluation system pays attention to multidimensional measurement of learning outcomes and an improvement closed loop. Through this treatment, the basis of technology selection returns to the training objectives themselves rather than the novelty of the technology.

3. Analysis of the Teaching Difficulties of the Traditional Analog Electronic Technology Course

The content of Analog Electronic Technology covers modules such as semiconductor devices, basic amplifier circuits, integrated operational amplifiers, feedback amplifier circuits, signal processing and generation circuits, and direct-current power supplies. It has a large capacity and many concepts, and the requirements for both theory and practice are not low [8]. Combining classroom observation, student interviews, and learning situation data recorded by the teaching platform, the relatively concentrated problems in traditional teaching can be summarized into five aspects. It should be noted that these five aspects are not independent of one another, but often serve as cause and effect for each other.

The most direct type of difficulty comes from content organization. Textbooks and daily teaching mostly proceed linearly in chapter order. Prerequisite dependencies, horizontal analogies, and hierarchical attribution

among knowledge points are seldom clearly pointed out, and what students remember is often isolated fragments. Transistor amplifier circuits and field-effect transistor amplifier circuits have strong analogy in analysis methods, but students often regard them as two unrelated chapters. After learning them, students find it difficult to transfer knowledge, and this phenomenon repeatedly appears in exercise correction.

Related to content organization is the singleness of the learning path. The practice of unified progress, unified content, and unified exercises implies the assumption that “students have similar foundations and the same cognitive methods,” but the actual situation is not so. Students with weak foundations become increasingly strained as they learn, while students with spare learning capacity feel that they are “not fed enough,” and differentiation within the class then increases. The number of resources on the platform is not small, but when students face their specific problems, they lack a basis for judgment and do not know which resource to open. Therefore, the actual use efficiency is not high.

The third type of difficulty is reflected in the feedback link. Teachers mainly rely on homework correction and unit tests to understand learning situations. The cycle is usually counted by weeks, and the granularity is also relatively coarse. By the time problems are reflected in scores, students have often accumulated many knowledge debts, and the cost of remediation is obviously higher. More difficult is that it is hard to judge from one assignment whether an error is a common problem of the whole class or an individual problem of a particular student, so layered intervention lacks a basis.

The mismatch between resource supply and learning needs is the fourth type of difficulty. Existing resources are mostly packaged and stored by chapter. Their form tends to be static. They neither establish fine-grained correspondence with specific knowledge points nor mark difficulty levels. When students encounter difficulties, they cannot find materials that “are exactly explaining this knowledge point.” When teachers prepare lessons and want to reorganize resources according to learning situations, they also lack usable retrieval dimensions.

The weak practical link and insufficient cultivation of engineering ability constitute the fifth type of difficulty. This course is highly practical, but traditional experiments are mainly verification-based. Students connect wires, read data, and write reports according to steps, and the space for independent judgment and design is limited. Fault troubleshooting usually depends on on-site guidance from teachers. Students lack opportunities for independent analysis and are likely to have no place to start when facing real engineering problems later.

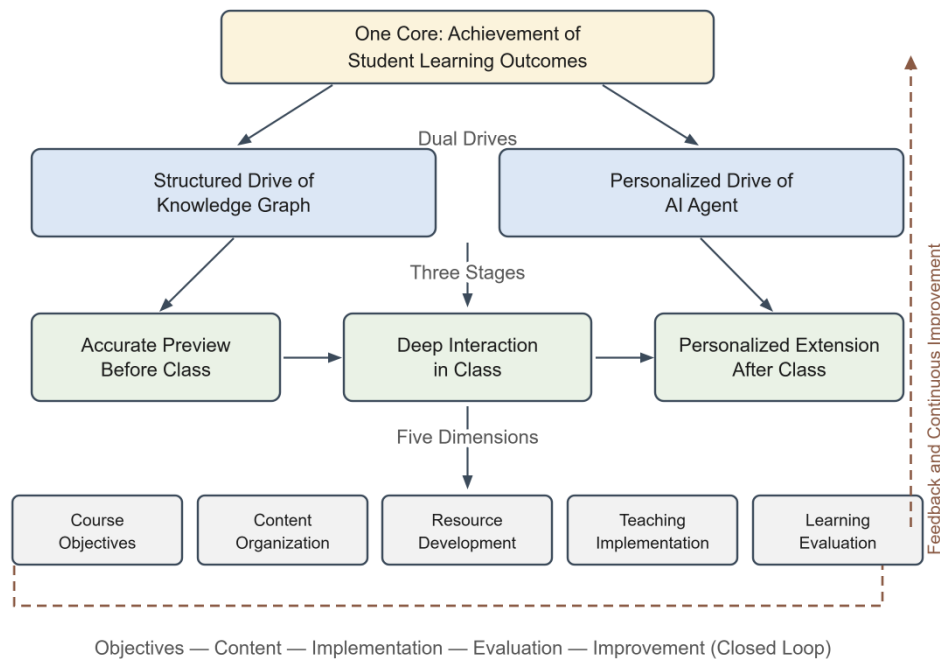
4. Construction of the Blended Teaching Model Driven by an AI Smart Knowledge Graph

4.1 Overall Design Framework

Taking the OBE concept as the foundation, this study builds an overall framework of “one core, dual drives, three stages, and five dimensions” (as shown in Figure 1). Among them, “one core” means taking the achievement of students’ learning outcomes as the core. “Dual drives” refer to the two parallel technical main lines of the structural drive of the smart knowledge graph and the personalized drive of the AI agent. “Three stages” refer to the three teaching stages of before class, in class, and after class. “Five dimensions” refer to the five links that need to be transformed simultaneously: course objectives, content organization, resource development, teaching implementation, and learning evaluation. The design intention of the framework is to make technical means serve clear teaching links and avoid function stacking.

The operation of the framework can be understood along one main line. The starting point is course objectives. On this basis, a multi-level course smart knowledge graph is constructed, and teaching resources are mounted one by one to corresponding knowledge points. Then, an AI teaching agent is developed, and it provides teaching services with the smart knowledge graph as the retrieval base. In the implementation stage, blended teaching is organized according to “accurate preview before class-deep interaction in class-personalized extension after class.” Finally, effects are monitored through process data collection and multidimensional evaluation, and the problems found are fed back to the previous links. In the whole chain, “objectives-content-implementation-evaluation-improvement” are connected from beginning to end, so the reform always points to learning outcomes.

Figure 1: Overall framework of the “one core, dual drives, three stages, and five dimensions” blended teaching model



4.2 Construction of the Course Smart Knowledge Graph

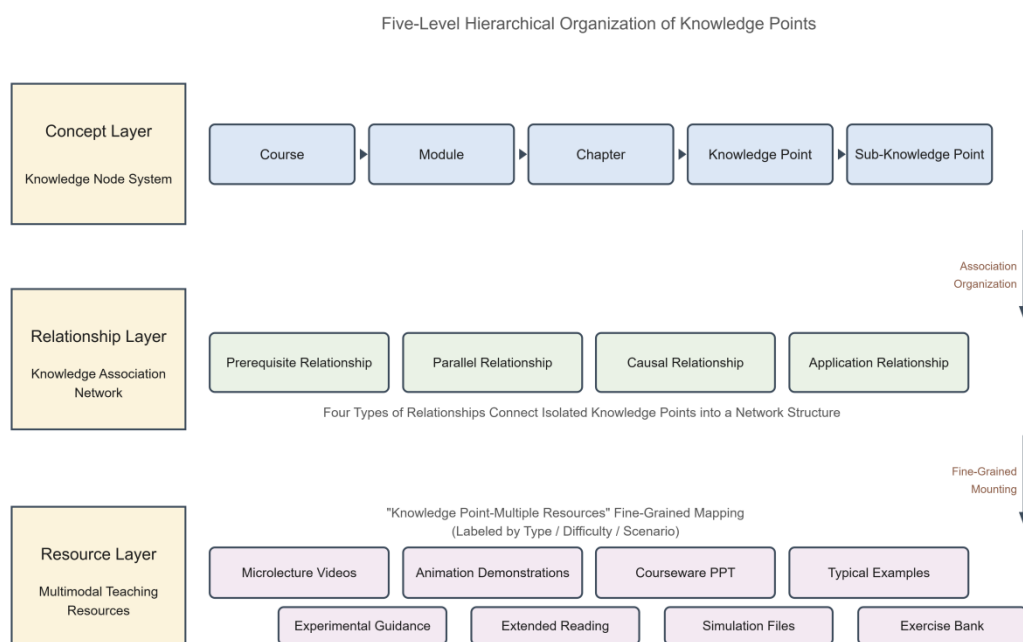
The smart knowledge graph of the Analog Electronic Technology course is constructed with a three-layer architecture of “concept layer-relationship layer-resource layer” [9] (as shown in Figure 2). The problems to be solved by the three layers are different.

The concept layer needs to determine what knowledge nodes exist in the course. The course team takes the teaching syllabus and the textbook used as the base, compares them with course standards and professional graduation requirements, and adopts the method of “machine automatic extraction + teaching team verification” to extract knowledge points. First, natural language processing technology is used to conduct named entity recognition and relation extraction on materials such as textbooks, courseware, and exercises, obtaining candidate core concepts, basic principles, analysis methods, and typical applications. Then, teachers check, merge, and revise them one by one. The placement of nodes follows the five-level hierarchy of “course-module-chapter-knowledge point-sub-knowledge point.” Taking semiconductor diodes as an example, sub nodes such as device structure, volt-ampere characteristics, main parameters, equivalent circuits, and typical applications can be decomposed under it. The manual verification link seems time-consuming, but it determines the usability of the graph. If errors in extraction results are not checked, they will be amplified layer by layer along the relationship layer and finally affect the reliability of resource recommendation and question answering.

The relationship layer is responsible for connecting the above nodes. The course team focused on sorting out four types of edges. A prerequisite relationship indicates the content that must be mastered before learning a certain knowledge point. For example, to understand a transistor amplifier circuit, the volt-ampere characteristics of the diode should first be clarified. A parallel relationship points to knowledge points at the same level that are related to one another, and common-emitter amplifier circuits and common-collector amplifier circuits belong to this type. A causal relationship reflects a derivation chain, such as deriving the amplification principle from the current distribution relationship of the transistor. An application relationship corresponds knowledge points to their engineering scenarios, and the virtual short and virtual open of the operational amplifier correspond to proportional operation circuits. After the four types of relationships are superimposed, the originally scattered knowledge points are connected into a network available for navigation, and the knowledge system can also be visually presented.

The task of the resource layer is to mount suitable teaching resources on nodes. Microlecture videos, animation demonstrations, courseware, typical examples, experimental guidance, extended readings, and other materials are classified by knowledge point, while resource type, difficulty level, and applicable scenario are marked. The same knowledge point usually corresponds to several resources, forming a “one-to-many” mapping, which provides a basis for subsequent personalized recommendation. Taking the differential amplifier circuit as an example, under this node are mounted a principal explanation microlecture, an animation demonstration, basic examples, advanced examples, and Multisim simulation files, which students can use according to their own mastery level.

Figure 2: Three-layer architecture of the course smart knowledge graph: “concept layer-relationship layer-resource layer”



4.3 AI Agent Teaching Support System

The agent part relies on the smart knowledge graph to carry out Retrieval-Augmented Generation (RAG). Four types of functional agents are developed, corresponding to different links of teaching.

The preview-guidance agent is used before class. It reads students' knowledge mastery profiles, combines the prerequisite relationships in the graph to plan a preview path for each person, and pushes corresponding preview materials and remedial suggestions for prerequisite knowledge. Questions raised by students during preview are answered by the agent according to the graph, while high-frequency questions are recorded for teachers' lesson preparation. The agent also automatically generates a group of preview test questions, and the answer results reflect the preview effect.

The learning-companion agent covers in-class and after-class stages and is equivalent to an online teaching assistant available at any time, providing instant question answering, idea guidance, and wrong-question explanation. Its feature lies in the ability to conduct multi-round dialogue by combining students' historical questions with their current knowledge points. The course team does not let it directly give answers, but adopts a questioning method to guide students to advance by themselves. For example, when a student asks how to calculate the gain of an amplifier circuit, it first asks the student to review the circuit configuration and analysis method, and then gradually completes the derivation process, so that analytical thinking is trained.

The experiment-assistance agent is used in the practical link. For common faults in the experiments of this course, the course team has organized a fault smart knowledge graph. After students describe experimental phenomena, the agent guides them layer by layer to locate causes according to the troubleshooting order, rather than directly reporting conclusions. It can also participate in the discussion of circuit design schemes and

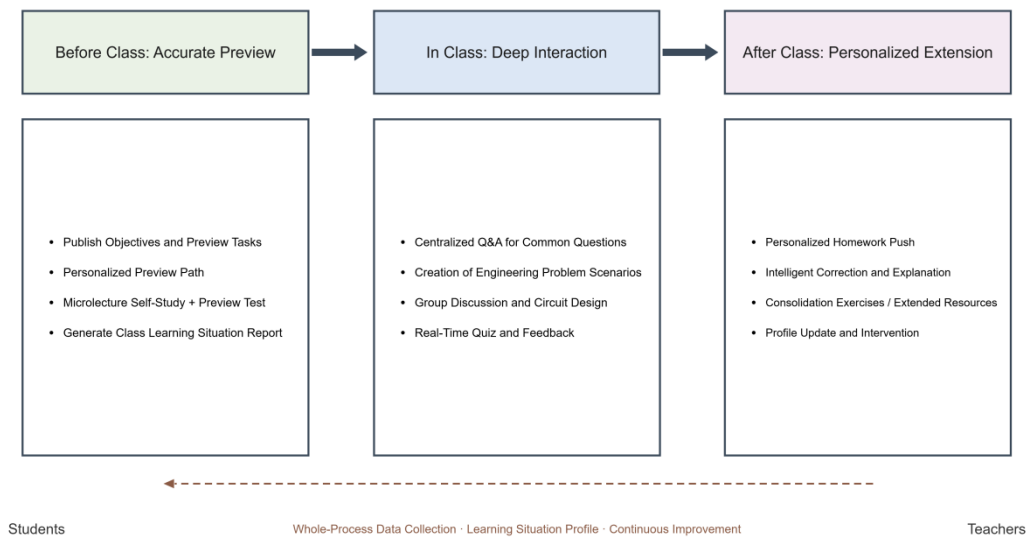
provide references in ideas and parameter calculation, so as to support the development of design-oriented and comprehensive experiments. For Multisim simulation experiments, it can also assist in interpreting simulation waveforms and results.

The evaluation-feedback agent is used in the evaluation link. In addition to automatic scoring of objective questions, it can also analyze the solving steps and ideas of subjective questions and give specific comments. More importantly, it summarizes whole-process learning data, generates individual student ability profiles and class learning situation reports, marks weak links and risk points, provides a basis for teachers to determine intervention objects, and at the same time generates personalized review and extension suggestions for each student.

4.4 Three-Stage Blended Teaching Process of “Before Class-In Class-After Class”

For the implementation of each class, teaching is divided into the three stages of before class, in class, and after class for organization. The overall design is shown in Figure 3.

Figure 3: Three-stage blended teaching process of “before class-in class-after class”



4.4.1 Before CLASS: Accurate Preview and Learning Situation Profile

Before class, two issues need to be solved: letting students enter the classroom with questions, and letting teachers grasp the basic situation before class. After teachers publish the learning objectives and preview tasks of the class on the platform, the AI agent generates personalized preview paths according to each student's knowledge mastery status and the prerequisite dependencies in the graph. Students with weak foundations receive review materials for prerequisite knowledge, while students with faster progress can access extended content in advance.

Students' preview actions include watching microlectures, reading the textbook, and completing preview tests, and they can ask the agent questions at any time during the process. In addition to answering questions, the agent records data such as question points, error types, and dwell time. After preview ends, the system automatically generates a class learning situation report, summarizes high-frequency questions, test accuracy, and mastery of each knowledge point, and teachers determine the focus and depth of classroom explanation accordingly.

4.4.2 In Class: Deep Interaction and Knowledge Internalization

The classroom adopts a combination of problem orientation and interactive inquiry, concentrating time on difficult-point explanation and higher-order ability training. Teachers first conduct centralized question answering for common problems according to the pre-class learning situation report and remove basic

obstacles. Then they set engineering problem scenarios around core knowledge points and organize group discussion, case analysis, circuit design, and other activities.

The AI agent participates throughout the classroom, but its role is limited to assistance. Teachers can use it to quickly generate exercises, organize real-time quizzes, and count answer situations. Students can consult through terminals whenever they have questions. During group discussion, it can assist in retrieving materials or providing idea inspiration. Teachers' energy is thus released from repeated lecturing and used more for observing student status, organizing activities, and responding to deeper problems. The three types of interaction among teachers and students, students and students, and humans and machines are superimposed, so the process of digesting knowledge is more sufficient than simply listening to lectures.

4.4.3 After Class: Personalized Extension and Closed-Loop Improvement

After class, the focus is on personalized consolidation and extension. The agent generates layered homework according to classroom performance and knowledge mastery. Knowledge points that are not firmly mastered are matched with consolidation exercises and supplementary explanations, while students with spare learning capacity receive advanced questions, engineering cases, and frontier materials.

After students submit homework, the agent corrects it immediately. In addition to scores, it also gives prompts on solving ideas and recommends similar questions. Students correct and practice again accordingly, forming a cycle of "practice-feedback-correction-reinforcement." At the same time, the agent continuously updates students' knowledge profiles and provides a basis for the learning path in the next stage. Teachers use the learning situation dashboard to grasp the overall class situation and the students who need focused attention, and arrange targeted tutoring in time.

5. Teaching Practice and Effect Analysis

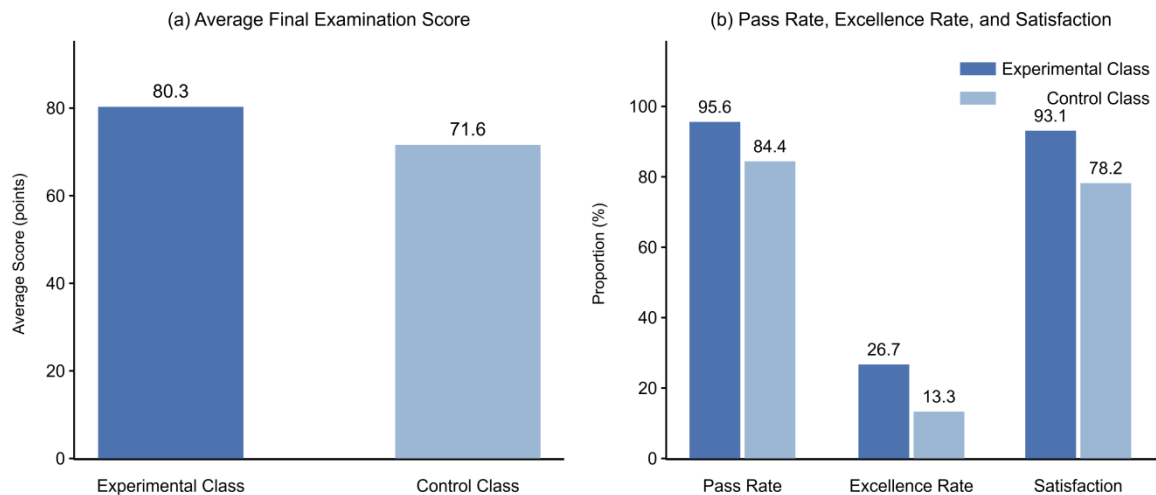
5.1 Practice Design

The practice objects are two parallel classes of the 2024 cohort in the electronic information engineering major at the university. The experimental class adopts the blended teaching model proposed in this study, and the control class follows the original teaching method. Each class has 45 students. After testing, there is no significant difference in entrance scores and prerequisite course scores between the two classes, so they are comparable. The course has a total of 64 class hours, including 48 theoretical hours and 16 experimental hours, and lasts for one semester.

Data collection runs through the whole semester. The teaching platform records process data such as preview completion rate, video watching duration, homework accuracy, number of classroom interactions, and question frequency. At the end of the semester, the two classes use the same paper for the final examination, and subjective feedback is collected through questionnaires and student interviews. The analysis is carried out from three dimensions: knowledge mastery, ability development, and learning experience.

5.2 Analysis of Practice Effects

The final examination results show that the average score of the experimental class is 8.7 points higher than that of the control class, and both the pass rate and the excellent rate are improved (as shown in Figure 4). The difference is more obvious in comprehensive and applied questions, indicating that students' depth of understanding and ability to combine and apply knowledge have indeed changed. Another noteworthy phenomenon is that the standard deviation of scores in the experimental class is smaller than that of the control class. The previously worried situation of "grasping both ends and losing the middle" did not appear, and students with weak foundations benefited more obviously from this round of reform.

Figure 4: Comparison of teaching effects between the experimental class and the control class

In terms of ability development, in the experimental assessment, students in the experimental class are better than those in the control class in the speed and accuracy of circuit fault troubleshooting, and the proportion of students independently completing design experiments is also higher. This is related to the guided troubleshooting training and scheme demonstration support of the experiment-assistance agent. In addition, in the course assignment, students in the experimental class perform more completely in information retrieval and scheme design, and their awareness of autonomous learning is enhanced.

Questionnaire results show that the satisfaction of the experimental class with the course teaching model is obviously higher than that of the control class. Most students mention that the smart knowledge graph helps them clarify the course context, the agent can respond to questions in time, and personalized recommendation also saves the time of searching for resources. Some students also report that the arrangement of listening to the class with questions before class, participating in discussion in class, and targeted consolidation after class makes learning more active and “no longer just sitting and listening.” Classroom interaction data also show that the participation and question frequency of the experimental class are higher.

The practice also exposes some problems. A small number of students are not sufficiently familiar with the functions of the agent, and additional use guidance is needed in the early stage. For some complex circuit analysis problems, the answer accuracy of the agent still fluctuates, and it is necessary to continue supplementing graph content and adjusting prompts. A few students also show dependence tendencies. When encountering problems, their first reaction is to ask the agent rather than think first. This suggests that the link of independent thinking needs to be more clearly emphasized in teaching design.

6. Conclusion and Prospect

In view of the above difficulties in the teaching of the Analog Electronic Technology course, this study constructs and implements a set of blended teaching models driven by an AI smart knowledge graph. The course smart knowledge graph is used to present the structure of the knowledge system, the AI teaching agent is used to provide personalized support throughout the whole process, and the three-stage process is used to connect online and offline teaching. A one-semester practice shows that this model has produced observable changes in improving learning scores, training engineering ability, and improving learning experience.

It should be noted that the practice sample of this study comes from two parallel classes in one application-oriented undergraduate institution, and the scope of application of the conclusions still needs to be tested through more rounds and more schools. Follow-up work can continue from three aspects: extending the smart knowledge graph from a single course to a professional course group, so as to support connection among courses; improving the multimodal ability of the agent, so that it can handle more complex tasks such as circuit diagram recognition and simulation result interpretation; and introducing finer-grained learning analytics to portray students' cognitive status based on multi-source data, making teaching intervention more accurate. As

AI technology continues to evolve, its combination with course teaching will continue to change, and this is also a direction for continuous attention in follow-up work.

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