

Reform Practices in C++ Object-Oriented Programming Courses: Integrating Knowledge Graphs and AI Tutors

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Abstract: Given the challenges in traditional C++ Object-Oriented Programming (OOP) courses, including abstract concepts, insufficient practical guidance, and the difficulty of meeting personalized learning needs, this paper proposes a blended teaching reform model integrating Knowledge Graphs (KG) and AI tutors. The approach first leverages Knowledge Graph technology to structurally reorganize core concepts into a visual knowledge network, facilitating a systematic cognitive framework for students. Concurrently, AI tutors are incorporated to provide intelligent support via Natural Language Processing (NLP) and machine learning, enabling real-time Q&A, personalized learning path recommendations, and automated assessment of programming assignments. Furthermore, a blended teaching workflow comprising "online previewing, offline discussion, and online consolidation" is implemented. Empirical teaching practices demonstrate that this model significantly enhances students' academic performance and programming skills while effectively stimulating learning interest, providing valuable insights for the digital transformation of computer science education.

Keywords: C++ Object-Oriented Programming (OOP); Knowledge Graphs; AI Tutors; Blended Teaching; Teaching Reform

1. Introduction

The traditional teaching model of C++ Object-Oriented Programming (OOP) courses is generally teacher-centred, and classroom exercises and laboratory sessions are only added on. Instructors present the rules of syntax, basic OOP concepts and programming methods in this model [1]. However, this one-way transmission

of knowledge has many problems in helping students grasp abstract ideas and learn by doing. First, as an OOP language, C++ has many abstract core concepts, such as dynamic binding in polymorphism and the use of virtual functions, which are not intuitive for beginners [2]. Second, traditional teaching focuses too much on theoretical instruction and gives insufficient attention to the development of practical skills; thus, students often feel lost when faced with real-world programming problems [3].

To address the above problems, some scholars have proposed integrating computational thinking into the curriculum and, by providing concrete application examples, helped students understand abstract concepts better and be more willing to learn them [4]. Although the above improvements have addressed some deficiencies in the old system to a certain extent, their actual impact is limited by teaching materials, teacher quality and available educational resources [5]. Therefore, at the foundation of the current educational reform is to improve the teaching model for C++ OOP courses.

The goal of the teaching reform is to improve the efficiency of teaching by introducing new pedagogical ideas and technological tools to motivate students to learn more eagerly and enhance their programming skills and innovative thinking [6]. In addition, the continuous development of Knowledge Graph (KG) technology has provided new ideas for reforming C++ OOP courses. Build a system of knowledge to help students better understand the connections among different concepts and thus improve their learning outcomes in this course [7]. In short, the new teaching model will help solve the problems of the old one and provide strong support for students' future life and work in the information age.

A knowledge graph is a kind of knowledge base that represents entities and their relationships in

the real world as a graph. At the core is to organise individual knowledge points into an organised knowledge network via semantic associations [8]. The three stages in the construction of a Knowledge Graph (KG) at the technical level are generally knowledge extraction, knowledge representation and knowledge fusion. KGs have been applied to education and show good prospects for development. For example, in C++ OOP courses, KGs can present abstract concepts and their logical connections more clearly to help students learn better [9]. In addition, KG-based learning navigation systems can dynamically recommend relevant knowledge points according to the students' learning paths to offer personalised learning support. Research shows that although KGs have achieved remarkable results in intelligent search and question-answering, their application in education and teaching is still in the exploration stage, and promoting and optimising them are thus highly beneficial for research [1-3].

An AI tutor is an intelligent teaching aid based on artificial intelligence technology, and its core technologies include Natural Language Processing (NLP), machine learning and deep learning [5]. NLP technology is used to perform lexical analysis, syntactic analysis and semantic analysis of the students' questions, and then an answer is provided by an AI tutor. Machine learning can be used to predict students' learning difficulties and provide personalised learning recommendations based on the analysis of large amounts of historical learning data [10]. AI tutors can perform several functions in C++ OOP courses. The above functions are organically integrated to form an AI tutor system; with the rapid development of technology today, such systems will be introduced into schools to improve teaching quality and student learning outcomes.

2. Teaching Reform Scheme for C++ OOP Courses Integrating Knowledge Graphs and AI Tutors

2.1 Knowledge Graph-Based Organization of Teaching Content

Knowledge Graphs (KGs) can be used in the teaching of C++ Object-Oriented Programming (OOP) courses to improve the organisation and logic of teaching materials. By organising and connecting individual knowledge points, KGs

build an organised knowledge system to help students better understand the context of the knowledge. Specifically, the core knowledge points of the C++ OOP course, such as classes and objects, encapsulation, inheritance, and polymorphism, need to be extracted and classified first to serve as entity nodes in the KG. Second, based on the semantic relationships among these knowledge points, such as "belongs to", "contains", or "is associated with", directed edges are built between nodes to form a multi-layered network structure. This way of knowledge representation can show the internal connections among the knowledge points more clearly and give students an all-over view of the knowledge, helping them build an all-encompassing knowledge system during their studies. KG-based visualisation technology can be employed to present the teaching content more effectively. For example, a graph can be used to show the hierarchy and dependency path of knowledge points, and students can quickly find the main and difficult parts. In this way, students can learn the basic knowledge more efficiently and be able to apply what they have learned flexibly in daily life [11].

2.2 Guidance and Assistance of AI Tutors in the Learning Process

AI tutors are smart teaching tools that can guide and help students learn C++ OOP more effectively during their studies in this course. First, based on the learning data of students, AI tutors can recommend personalised learning paths. They can find out what the students don't know and teach them. Second, the AI tutor will answer questions and help the student solve problems in real time. Natural Language Processing (NLP) technology will be used to understand the intent of the students' questions, retrieve corresponding answers from the pre-built knowledge base, or provide solutions to similar problems. AI tutors can also perform an initial assessment of the programming task in the programming exercise through code analysis and static detection technology. They can find the syntax error, logical fault or performance bottleneck and suggest changes. Promptly correct the errors that students have made and help them learn to think independently and solve problems. The above functions will help the AI tutor support students in their studies and improve the results of learning [12].

2.3 Design of the Blended Online-Offline Teaching Workflow

With the addition of Knowledge Graphs and AI tutors, the combined online-offline teaching process for C++ OOP courses has been further optimised to maximise the teaching effect. In the online preview stage, students can use the KG visualisation platform to get an overview of the entire knowledge structure and main contents of the course beforehand. At the same time, they can use the learning path recommendation function of the AI tutor to set learning goals and tasks. In the explanation and discussion stage of the offline class, KGs can be used to present the connections and logic among knowledge points to help students better understand the core concepts of OOP. In addition, the real-time Q&A function of the AI tutor can be used in class to address common student problems centrally and improve teaching efficiency. Students can submit programming homework for automatic grading by AI tutors in the online review and practice stage, and based on the learning reports provided by the system, revise their future study plans. This blended teaching model can fully utilize the flexibility of online resources and the interactivity of offline teaching, and at the same time, enhance students' learning experience and results through the synergistic effect of Knowledge Graphs and AI tutors.

3. Analysis of the Practical Effects of Teaching Reform

To fully understand how students feel about and are satisfied with the new teaching model for C++ Object-Oriented Programming (OOP) that combines Knowledge Graphs (KG) and AI tutors, the research team distributed questionnaires and conducted individual interviews with students. Based on the questionnaire results, more than 85 per cent of the students were willing to learn under the new teaching model and expected better learning outcomes. Among them, the learning navigation function of the Knowledge Graph has been receiving much attention. Students believe that this function can help them quickly find the knowledge points and understand how they are related logically to improve their study efficiency. In addition, the real-time Q&A function of the AI tutor was also very popular; students thought that they could ask questions during their study hours and thus made learning more interactive and enjoyable.

In the in-depth interviews, some students further pointed out that the personalized learning recommendation function of the AI tutor played an important guiding role in formulating their study plans. For example, for students with a weak foundation, the AI tutor will recommend more review materials for basic knowledge; for students who are already strong, it will give them more difficult extension exercises. In this way, the students will feel more independent and achieve some success in their studies, thus increasing their enthusiasm for learning. However, a small number of students have reported that the AI tutor's answers are sometimes too mechanical and lack humanised emotional expression, thus affecting their sense of use. In short, most students were willing to learn under the new combined teaching mode and hoped that it would be improved further in the future.

4. Conclusion and Future Research Prospects

This teaching reform plan builds a student-centred C++ OOP teaching model that integrates Knowledge Graphs and AI tutors. First, Knowledge Graphs can be used to address the problem of scattered knowledge points in traditional teaching that hinder the formation of systematic cognition, and clear learning paths and all-encompassing knowledge systems can be provided for students. Second, AI tutors have been introduced to enhance the personalisation of teaching. An intelligent learning recommendation and real-time feedback mechanism will help students solve their learning problems and improve the efficiency and quality of their studies. Finally, the Design of the blended online-offline teaching workflow fully utilizes the strengths of both teaching models. It can provide rich content and broad coverage for classroom teaching, as well as extend the space and time for students' self-study to optimise the teaching process.

In the future, we will continue to optimise the technical architecture of AI tutors to strengthen their Natural Language Processing (NLP) and logical reasoning abilities and better meet the learning needs of students. At the same time, efforts should be made to develop more cost-effective construction methods for Knowledge Graphs and thus promote their wider application and spread in teaching.

In short, the teaching reform practice for C++ OOP courses that integrates Knowledge Graphs

and AI tutors has improved students' academic performance and learning experience significantly, and also provided valuable references and ideas for teaching reform in higher education.

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