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KNOWLEDGE GRAPH EMPOWERS THE TEACHING REFORM OF PROGRAMMING COURSES

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Abstract

Against the limitations of traditional C language programming teaching—such as fragmented learning (failing to connect old and new knowledge), restricted teaching depth/breadth (insufficient in-depth analysis of knowledge points due to class time limits), and students' over-reliance on textbook examples—and MOOCs' inability to meet personalized needs (lacking tutor guidance), this study aims to improve teaching quality and students' abilities (independent learning, problem-solving, innovation) by *integrating knowledge graph and AI. First, a C language course knowledge graph was constructed via six steps: knowledge modeling (sorting core elements like data types and pointers), data preparation (collecting materials including 295 videos and 842 PPTs), information extraction (identifying relationships like inclusion and sequence), knowledge integration (hierarchical structure), storage (in graph database), and graphical display. Then, the knowledge graph was applied to teaching: enabling AI-assisted intelligent teaching (pre-class task design, in-class knowledge visualization, hierarchical after-class exercises), building a comprehensive evaluation system (learning trajectory analysis, knowledge mastery evaluation, resource recommendation), and planning personalized learning paths. Two semesters of practice showed the knowledge graph significantly boosted students' learning interest and key abilities. Futurely, with tech innovation and expanded scenarios, knowledge graph will have broader prospects in education to advance programming course teaching reform.*

Keywords:

Knowledge Graph, Artificial Intelligence, Intelligent Teaching, Personalized Learning

1. Introduction

As the cornerstone of learning data structures and algorithms, the importance of the C language course is self-evident. It not only has a complex system structure, but also the knowledge points are closely connected, forming a huge knowledge network. In the process of learning C language, students not only need to master basic syntax rules, such as data types, operators, loop condition statements, etc., but also have an in-depth understanding of basic algorithm principles, basic data structures and other knowledge. This knowledge requires not only theoretical mastery, but also consolidation and improvement through practice. As a course with strong theoretical depth, high practical requirements and wide comprehensive application, how to stimulate students' learning interest, help them break through learning difficulties and improve their practical ability are important issues faced by teachers.

In the C language programming course, the gradually deepened teaching method helps students master knowledge step by step. However, this method also has limitations: when new knowledge continues to pour in, without reviewing and integrating existing knowledge, the previous understanding may become vague or even forgotten. This "fragmented" learning method makes it difficult to form stable connections between old and new knowledge, increasing the difficulty of learning new knowledge. In addition, in the C language programming course, the limitations of teaching depth and breadth are obvious. Although four theoretical lectures and two practical operations are arranged every week, with the help of modern teaching media such as PPT, teachers are difficult to analyze each knowledge point comprehensively and in-depth due to the limitation of class time. Although the emerging online teaching and flipped classroom models have increased the classroom capacity, students often only have a preliminary understanding of knowledge points and are difficult to understand and use them flexibly. This leads to the fact that in the experimental stage, students can only mechanically apply the examples in the textbook, lacking independent thinking and innovation ability. The author has been engaged in C language teaching for a long time and is well aware that the above problems have seriously affected students' learning effect and enthusiasm.

In recent years, Massive Open Online Courses (MOOC) , as an innovative educational model, has been deeply integrated into the teaching practice of colleges and universities. It has successfully crossed the limitations of geography and time, allowing learners to easily access high-quality educational resources. However, on the other hand, MOOC course design is often oriented to universality and may not meet the personalized needs of all learners. In this model, learners need to formulate their own learning paths and solve problems encountered in the learning process independently. This undoubtedly increases the challenges for learners, because they lack direct guidance from tutors or field experts and personalized learning strategy suggestions. Therefore, although MOOC provides learners with broad learning opportunities, how to effectively meet their personalized needs is still a problem worthy of in-depth research and discussion.

In the era of surging digital education, big data and artificial intelligence technologies are widely adopted in the education field to improve education quality and realize personalized teaching. In the tide of this transformation, knowledge graph, as a structured semantic framework that can efficiently organize and process knowledge resources, is playing an increasingly important role. It injects new vitality into modern education by intelligently recommending teaching content, designing personalized learning paths, systematically integrating educational resources and enriching teaching interaction modes. In order to adapt to this trend, the teaching team of the author has actively innovated and constructed a course knowledge graph for C language programming. With core knowledge points as the center, this graph presents a three-dimensional and rich knowledge network through a well-designed module hierarchy, an association network of knowledge points at the same level, and a clever progressive relationship of cross-level knowledge points. It not only facilitates students to systematically construct their own knowledge framework, but also helps students quickly locate and obtain key information. The visualization feature of the knowledge graph is its unique advantage. Through an intuitive graphical interface, students can easily identify the internal connections between knowledge points, thereby deepening understanding and organizing and summarizing knowledge points. This not only helps students fill in knowledge gaps efficiently and accelerate the learning process, but also enables them to be more targeted and competent when facing challenges in teaching practice. After three semesters of teaching practice verification, this knowledge graph has shown a significant positive effect in practical teaching. It not only improves students' learning interest, but also achieves good teaching results in cultivating their independent learning ability, problem-solving ability and innovative spirit.

2. Construction of the Knowledge Graph for C Language Programming Course

A knowledge graph is a huge semantic network system. It not only describes the complex connections between entities such as individuals, geographical locations and events, but also stores and displays this information skillfully with the help of graph data structures. It goes beyond the scope of traditional databases or information libraries, integrates multiple components such as entities, attributes and relationships, and constructs a complex network structure, trying to simulate the way the human brain deeply understands and organizes knowledge. Combining the characteristics of the C language programming course and the actual learning ability of the student group, the teaching team carefully constructed the knowledge graph of the course.

The steps to construct the course knowledge graph are as follows.

2.1 Knowledge Modeling

In order to construct the knowledge graph of the C language programming course, it is first necessary to sort out and summarize the course content comprehensively and systematically. In this process, core elements such as basic concepts of data types, variables, operators, control structures, functions, arrays, pointers, structures and files, as well as their mutual connections and influences, become particularly important. By clarifying these key elements, the construction of the knowledge graph will be more targeted and in-depth, thus better helping students master the core knowledge of C language.

2.2 Data Preparation

In order to construct the knowledge graph of the C language programming course, the teachers of the teaching team systematically collected diversified teaching materials, including textbooks, teaching courseware, online open course videos and exercise questions. By extracting the key knowledge points and example demonstrations from them, they were carefully classified according to the logical structure, difficulty level and material type of the knowledge points, and labeled. This sorting process realizes the efficient integration and optimal allocation of educational resources, providing a solid basic material for the subsequent construction of the knowledge graph.

2.3 Information Extraction

With the help of advanced technologies of natural language processing and information extraction, the team teachers extracted various knowledge point entities (such as data types, function names) from massive data resources, and deeply explored their characteristics (such as the memory occupied by data types and the input parameter format of functions) . In the knowledge graph of the C language programming course, the types of associations between various knowledge points are rich and diverse, including but not limited to parent-child relationships, same-level associations and cross-level progressive relationships. This multi-dimensional association makes the knowledge graph more three-dimensional and comprehensive, providing strong support for students' learning. Within this course knowledge graph, the types of associations between various knowledge points include the following situations.

(1) Inclusion Relationship

That is, the relationship between the whole and the part. For example: Data Type → Integer Data.

(2) Sequential Relationship

①Dependence Relationship

The establishment of previous knowledge takes subsequent knowledge as a prerequisite, and the latter constitutes a necessary condition for mastering the former. For example: Input and Output of Character Arrays → Character Arrays and Strings.

②Progressive Relationship

Compared with the previous knowledge, the degree or scope of the latter knowledge is further advanced. For example: Definition of Pointer Variables → Access of Pointer Variables.

(3)Correlative Relationship (Parallel)

The two kinds of knowledge introduce different aspects of the same topic. For example: Control Statements ↔ Function Call Statements.

2.4 Knowledge Integration

Following the principle of proceeding from the easy to the difficult, the team teachers constructed each knowledge point in a hierarchical and systematic manner, forming a clear knowledge structure. The mutual association between various knowledge points helps learners gain an in-depth insight into their internal logic and interaction, thus improving the learning effect.

2.5 Knowledge Storage

The carefully integrated and processed knowledge is safely stored in the graph database. During the storage process, the well-constructed data structure model and efficient indexing strategy play a key role, which greatly improves the response speed of queries and ensures the consistency and accuracy of data.

2.6 Knowledge Display and Application

The knowledge graph is displayed by means of graphics, and the entire knowledge structure of the C language programming course is presented by using a graphical user interface. Figure 1 shows the partial knowledge graph (loop structure).

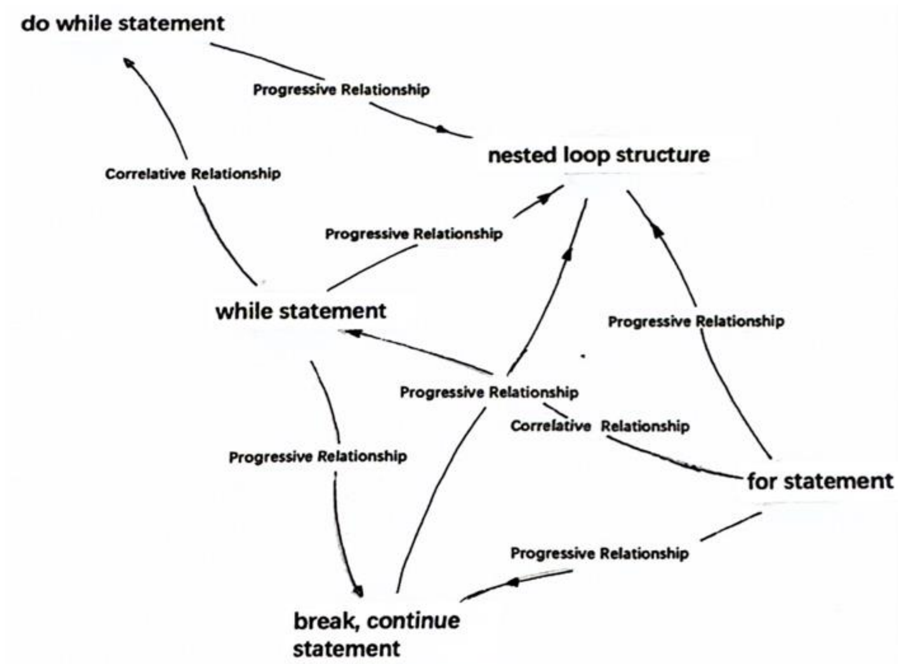

Figure 1: *Knowledge Graph of C Language Programming Course(partial)*

3. Teaching Implementation Based on the Course Knowledge Graph

Integrating knowledge graph and artificial intelligence technology with course content can highlight the great potential of digital technology on the basis of the current educational model. It breaks the limitations of traditional teaching models and realizes the harmonious unification of large-scale teaching and personalized teaching. Through differentiated teaching, personalized learning and accurate evaluation, the application scheme of the knowledge graph for the C language programming course is shown in Figure 2, demonstrating the unlimited possibilities of digital technology in the field of teaching.

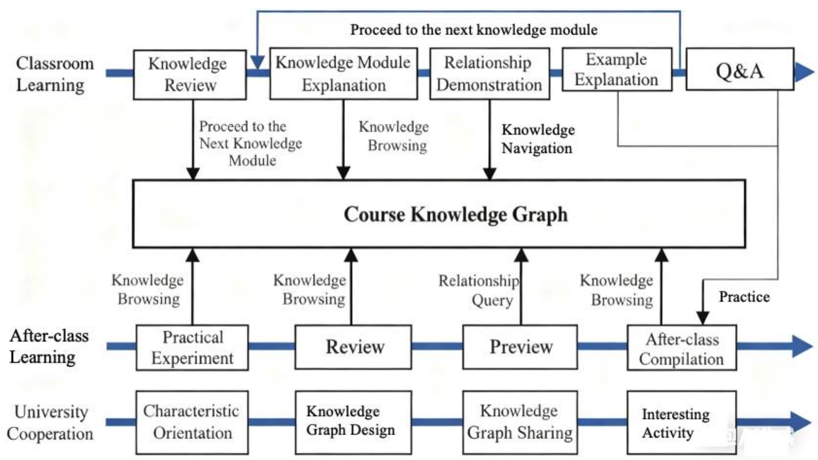

Figure 2: *Application Scheme of the Course Knowledge Graph*

3.1 Carrying out Intelligent Teaching with the Knowledge Graph

In the teaching process of the C language programming course, the author applied the knowledge graph as an auxiliary teaching tool in various links of teaching practice, as shown in Figure 3.

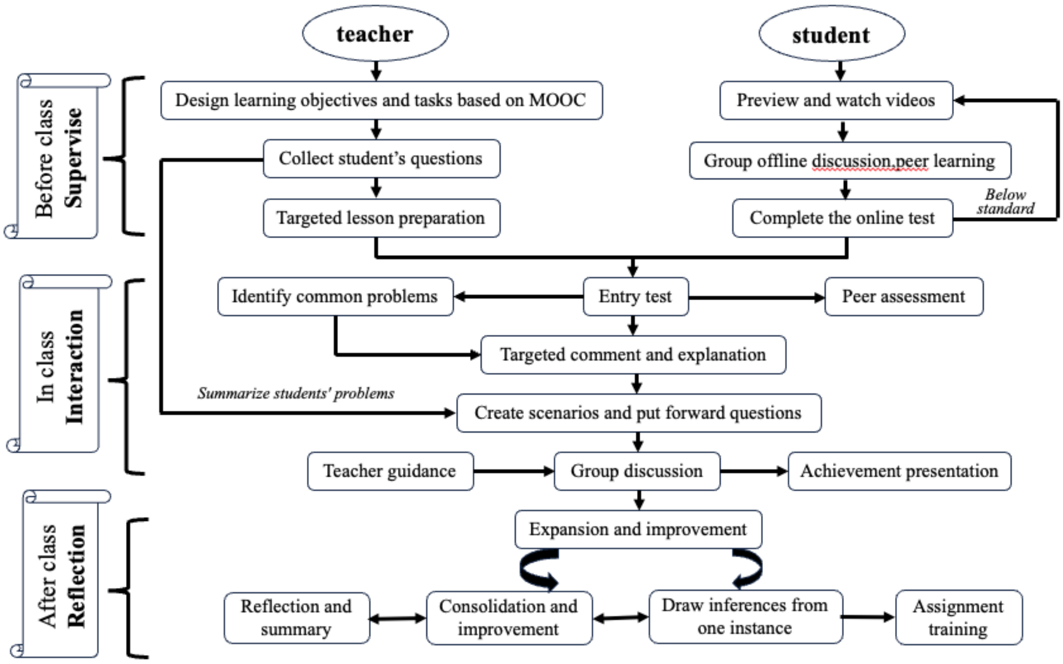

Figure 3: *Knowledge Graph-Assisted Teaching*

3.1.1 Before Class

As shown in Figure 4, teachers can use the AI assistant in the knowledge graph to automatically generate knowledge point teaching plans, curriculum ideological and political cases and test questions, which greatly reduces the workload of lesson preparation.

Figure 4: *AI Assistant in the Knowledge Graph*

Teachers carefully construct the knowledge graph of course chapters or units, aiming to provide students with a comprehensive learning blueprint and help them plan their learning paths clearly. Based on this graph, the author designed personalized learning materials and task lists to guide students to carry out independent exploratory learning. At the same time, by analyzing the data of students' mastery of various knowledge points, teachers can accurately understand the mastery of key and difficult points of the course, so as to plan the classroom teaching content in a targeted manner. Figure 5 shows a sample of an actual learning task list, reflecting the actual effect of this personalized teaching.

Independent Learning Task Sheet (17)

Class: Automation Grade 22 **Teacher:** Wang Xiuhua **Student** Name: ____________

I. Learning Guide

1. Task Name:
Sorting Algorithms

2. Learning Objectives:

Knowledge Objectives: Master the principles of bubble sort and selection sort; understand the flowcharts of sorting algorithms; write the main code for bubble sort and selection sort.

Competency Objectives: Learn to use the ideas of bubble sort and selection sort to design algorithms for solving simple sorting problems; further understand the basic methods of programming and realize the role of programming in reality.

Affective Objectives: Cultivate students' ability to analyze problems and discover rules, stimulate their learning enthusiasm; develop good programming writing habits.

3. **Learning Methods:**

(1) Browse the Independent Learning Task Sheet to understand the objectives and tasks.

(2) Carefully watch the teaching video in the MOOC course, and pause or replay it at any time.

(3) Write a program to implement bubble sort according to the algorithm flow chart in the video.

4. **Learning Resources:** Teaching video of Chapter 5, Section 2 "Examples of Using One-Dimensional Arrays" in the MOOC course

II. Learning Tasks

(1) Watch the teaching video of Chapter 5, Section 2 "Examples of Using One-Dimensional Arrays" in the MOOC course, master the basic principles of bubble sort, understand the flow chart of bubble sort; write the main code of bubble sort.(Video URL: https://course.zhihuishu.com/coursePreview/videoList?courseId=2100668)

(2) Complete the homework "Array Objective Exercise 1" in the flipped course "Fundamentals of Computer Application A (C Language)" on the Zhihuishu platform.(Homework URL: https://hiexam.zhihuishu.com/atHomeworkExam/tch/homeworkQ/homeworkDetail/673586/homeworkDetail/1/10326603)

(3) Think about whether the algorithm can be optimized by reducing the number of data comparisons in each pass of the bubble sort algorithm.

Self-Evaluation	
1. I think the difficulty of this course is:	☆☆☆☆☆
2. I think the importance of the technology in this course is:	☆☆☆☆☆
3. I think my mastery after independent learning is:	☆☆☆☆☆

III. Learning Feedback

Figure 5: *Sample of Course Learning Task List*

With the help of the knowledge graph, students can fully understand the course structure, learning path and key difficulties, and adopt a goal-oriented learning strategy. Based on the accurate data analysis of their own mastery of knowledge points, they customize personalized learning paths to identify and fill knowledge gaps. Through the targeted self-tests recommended intelligently, students focus on overcoming weak links until they reach the set learning goals. They interact with AI to ask questions and discuss in depth, or adopt in-depth learning resources recommended by AI to continuously improve the depth of understanding. In addition, the knowledge graph helps students preview and solve problems with clear goals, share insights in the discussion area, and students can also explore interdisciplinary knowledge points according to their personal interests to broaden their academic horizons.

3.1.2 In Class

Teachers use knowledge graph tools to build a complete and systematic knowledge structure for the course explanation, and present those abstract theories that are originally elusive to students in a concrete way. By in-depth analyzing the obtained data, teachers can accurately locate students' doubts and confusion points, and create personalized solutions for them, thus ensuring the teaching quality while significantly improving the teaching efficiency. In the teaching process, teachers skillfully integrate knowledge graph technology into classroom explanation, not only imparting knowledge, but also revealing the deep-seated connections behind the knowledge and strategies for solving problems. They deliberately design complex problems to stimulate students' team spirit and cooperation ability, and encourage them to conduct in-depth discussions and cooperation within the team to explore answers together. Through such interaction and communication, students not only improve their depth of thinking and dialectical thinking ability, but also complete the task of team cooperation in the process of solving problems, facing challenges and overcoming difficulties together.

Under the guidance of teachers, students use the knowledge graph to deeply explore the internal connections between knowledge points, deepen their understanding of core and difficult content, and strive to achieve the preset knowledge learning goals.

At the same time, they solve practical problems through AI interaction or team cooperation, which not only improves their ability to analyze problems, but also hones their team cooperation skills.

3.1.3 After Class

After classroom teaching, teachers adopt a hierarchical strategy to plan after-class exercises and in-depth exploration activities according to the changes in knowledge graph data. Through a timely feedback mechanism, teachers promote students to reflect on knowledge and solve problems, so as to consolidate learning results. This strategy aims to help students enhance their learning effect in continuous reflection and practice.

With the help of the knowledge graph, students can systematically review and organize course materials, comprehensively sort out knowledge points, and timely find and fill cognitive gaps, thus effectively avoiding learning blind spots. Under the guidance of the knowledge graph, students actively participate in after-class exercises and in-depth exploration activities, aiming to deepen their understanding and mastery of problem-solving strategies. This process not only improves students' learning effect, but also cultivates their independent learning ability and critical thinking.

3.2 Constructing a Comprehensive Teaching Evaluation and Feedback System

This system covers in-depth analysis of learning paths, accurate evaluation of knowledge mastery, personalized learning feedback mechanism, intelligent recommendation of educational resources, optimization suggestions for teaching strategies, forward-looking prediction of learning results and a comprehensive evaluation system. Its core concept is to provide students with personalized learning assistance, while empowering teachers with data-driven teaching guidance, aiming to achieve the educational goal of mutual improvement between teaching and learning.

3.2.1 Learning Trajectory Analysis

Collect multi-dimensional data of students in the process of learning C language, such as learning time, completion of chapter exercises and summary of wrong questions, and then combine the nodes (knowledge points) and paths (learning sequence) in the knowledge graph to construct a detailed learning trajectory map for students. This not only monitors and records students' learning behavior patterns in real time, but also provides clear learning progress and direction guidance for both teachers and students, making teaching and learning more efficient and targeted.

3.2.2 Evaluation of Knowledge Mastery

With the help of the knowledge graph and teaching syllabus, we have established evaluation standards and weight ratios for each knowledge point to realize the quantitative evaluation of students' scores. By matching student data with the evaluation model, the score of each knowledge point can be accurately calculated, as shown in Figure 6. By synthesizing the scores of each knowledge point, teachers can infer students' overall mastery of knowledge and generate a detailed evaluation report to comprehensively analyze students' learning status. This evaluation method can effectively help students understand their own learning situation, guide them to learn in a more targeted manner and improve learning efficiency. At the same time, it also provides an important reference for teachers to adjust teaching methods and content in a timely manner, better guide students' learning and promote the improvement of teaching quality. Through this comprehensive evaluation method, teachers can better understand students' learning situation and realize the organic combination of teaching and evaluation.

Detailed Data of Knowledge Point Learning

Knowledge Point Name	Knowledge Module	Number of Studied Students	Total Number of Student Practices	Average Learning Duration of Students	First-time Practice Accuracy
Program and Programming Language	C Language Overview	65	58	1168 min	48
Classification of Programming Languages	C Language Overview	57	34	628 min	97
Development of C Language	C Language Overview	48	30	505 min	96
Features of C Language	C Language Overview	38	27	402 min	67
Composition and Structure of C Language Program	C Language Overview	39	45	491 min	63
Steps to Run C Program	C Language Overview	47	17	509 min	69
Method to Solve Window Flashback After Program Running	C Language Overview	40	26	277 min	68
Data Types, Constants and Variables	Sequential Structure Programming Design	54	63	1161min	72

Figure 6: *Detailed Data Display of Knowledge Point Learning*

3.2.3 Teaching Resource Recommendation

In order to help students learn C language more effectively, the team teachers have summarized and organized a variety of learning materials, including textbooks, course materials, MOOC video courses and exercise sets. At the same time, an intelligent recommendation strategy is designed according to students' learning paths and personal interests. This strategy can accurately match students' needs and recommend the most suitable learning resources for them. A resource recommendation area has been added to the learning management platform to present personalized learning material recommendations for students. Through these measures, the teaching team is committed to helping students master C language knowledge faster and better, and improving their learning efficiency and grades. Figure 7 shows the learning resources and learning paths recommended by the system after entering the keyword "function definition" .

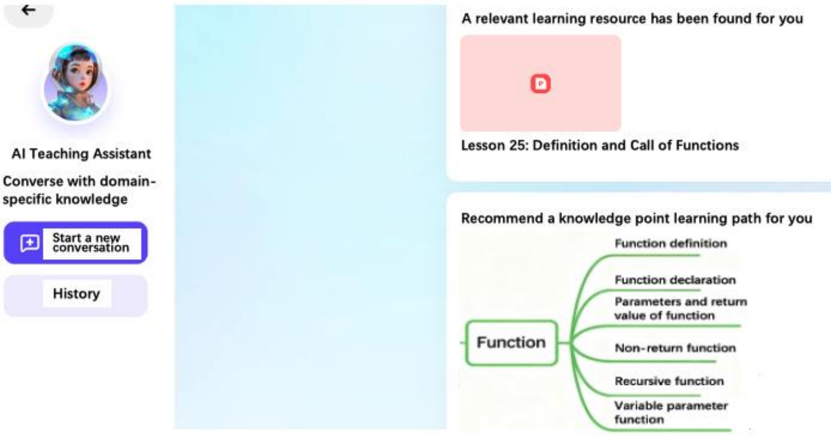

Figure 7: *Learning Path Recommendation*

3.2.4 Teaching Optimization Suggestions

By comprehensively evaluating students' learning effects and feedback information, the teaching effect is evaluated, and targeted suggestions are provided to teachers. These suggestions include adjusting course content, innovating teaching methods, etc., which are supported by data to help teachers make wise decisions. This comprehensive evaluation method can not only help teachers improve teaching quality and enhance students' learning effects, but also promote the innovation of teaching methods and improve teaching efficiency. Through continuous evaluation and feedback, teachers can adjust teaching methods in a timely manner to make teaching more in line with students' needs and improve teaching quality and learning effects.

3.3 Planning Personalized Learning Paths for Students

With the help of the knowledge graph, the system can comprehensively analyze students' learning history, interests, abilities and other data to realize multi-dimensional personalized evaluation. Through specific tests and practical exercises, the system can accurately evaluate students' mastery of each knowledge point, and then combine the evaluation results with the in-depth analysis of the knowledge graph to customize personalized learning paths for students. This path planning not only focuses on the learning of knowledge points, but also considers improving learning efficiency and stimulating learning interest. The system will flexibly adjust the learning path according to the real-time needs of students in the learning process to ensure that every step is effective.

4. Teaching Practice Effects

In the teaching practice of knowledge graph-assisted courses over the past three semesters, the teaching effect has changed significantly, mainly reflected in the following aspects:

The average scores of the final exams and hands-on experiments have improved remarkably. The average amount of code written by students in practice exceeds 4,000 lines, and the average course achievement degree of the latest semester is over 0.78, as shown in Figure 8.

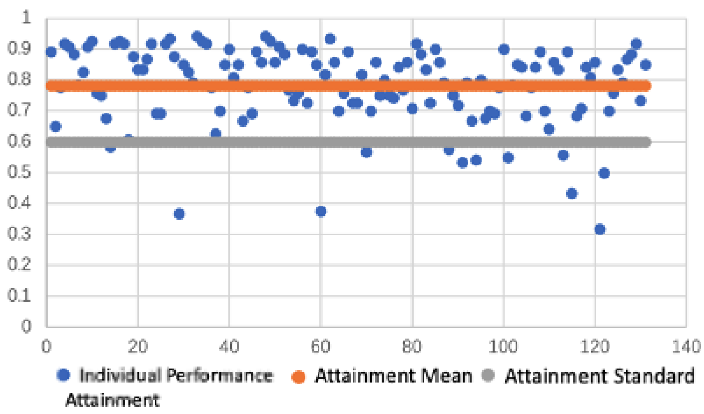

Figure 8 : *Course Achievement Degree in the Spring Semester of 2025*

(1)The number of students participating in algorithm and programming competitions such as ACM and Blue Bridge Cup, as well as their competition results, have increased year by year. In 2025, the number of participants exceeded 300, and more than 40 national-level awards were won.

(2)The phenomena of students feeling intimidated by difficulties, being slack in learning, or giving up halfway during the course have been significantly improved, and students' motivation for independent and continuous learning has been obviously enhanced.

5. Conclusion

The integration of knowledge graph technology in the education field has brought revolutionary changes. By establishing a sound knowledge graph system, personalized learning paths can be customized, educational resources can be intelligently integrated, content recommendations can be accurately matched, teaching interaction methods can be diversified, and learning progress can be adjusted flexibly. These advantages have greatly improved the teaching effect and learning achievements, and also provided a new way for the all-round development of students. Looking forward to the future, with the continuous innovation of technology and the expansion of application scenarios, the prospect and development potential of knowledge graph in the education field will be broader.

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