A Study on the Curriculum Reform of "Data Structures and Algorithms" Based on Competency-Based Education

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Abstract: Under the background of Industry 4.0 and artificial intelligence, computer education is facing a transformation demand from knowledge transmission to ability construction. In order to better deal with the dilemma of data structure and algorithm in the current teaching, This study constructs a systematic teaching system, the research mainly focuses on three aspects: theoretical knowledge understanding, algorithm analysis and design, and high-level quality education. By establishing a knowledge-linked question bank to aid students in understanding the content of each module, and by implementing a "problem analysis–algorithm design" model to meticulously cultivate students' algorithm analysis and design capabilities, the study also focuses on students' holistic development through an innovative "teacher-student collaborative discussion" model for ideological and political education. The practice shows that the teaching system has stimulated students' enthusiasm and initiative to a certain extent, and effectively improved students' ability to solve problems in the course, including the ability to understand basic concepts and analyze algorithms.

Keywords: Competency-Based Education; Data Structures and Algorithms; Teaching Reform

1. Course Background

With the rapid development of fields such as cloud computing and artificial intelligence, the demand for talents in computer related majors is increasing day by day. Students are expected not only to master the fundamental knowledge of their specialized courses but also to be able to quickly analyze complex problems and propose design solutions. While the course "Data Structures and Algorithms" is a foundational course for computer-related majors. The content covers basic concepts such as queue, stack and tree, and requires students to master the algorithm design of various structures. Research on the integration of data structures and intelligent algorithms has also become a current research hotspot, offering efficient solutions for large-scale data processing problems [1]. Furthermore, as this course is a key subject for graduate school entrance exams in computer science, a thorough grasp of the "Data Structures and Algorithms" curriculum profoundly influences students' future academic pursuits and career development [2, 3].

A series of problems have been exposed in the traditional teaching method in the course of "data structure and algorithm", which are mainly reflected in the following aspects. First, the teaching model is dominated by one-way transmission of theoretical knowledge by instructors, leading to low student interest, as well as low levels of initiative and engagement. Second, the course content is seriously out of line with the actual needs of the industry, and the cases are old. It is difficult for students to really improve the ability of algorithm design and system optimization through such training, and many students are unable to solve medium difficulty algorithm problems after the course. Third, students' foundational C programming skills—particularly their grasp of pointers and structures—are generally weak, creating a significant barrier to practical application. Fourth, the assessment method mainly relies on the final written test, which is too single in form and cannot comprehensively and objectively measure students' performance in multiple dimensions such as theory, hands-on experience, and innovation. It also cannot provide effective basis for the continuous improvement of course quality .Reference [4] analyzes the problem that, under traditional educational models, students struggle to fully master the knowledge and skills required by this course.

In this context, educational reform in the course "Data Structures and Algorithms" has become a key area of research. Competency-based curriculum reform is an approach to educational

reform grounded in the principles of Outcome-Based Education (OBE), which focuses on the desired learning outcomes and employs backward design to develop specific measures and methods to achieve them [5]. Since its inception, this philosophy has been widely adopted in higher education and has yielded positive results. Chen Ying [6] and colleagues explored the integration of competency-based principles to evaluate students across multiple dimensions, including knowledge, skills, and the development of personal qualities; however, their focus was primarily on the diversification of evaluation metrics, without providing specific pedagogical measures to explain how to cultivate these qualities in students. Xiang Zhihua [7] and colleagues explored the cultivation of students' innovative abilities under the OBE framework, placing greater emphasis on the demands of the computer industry for students while overlooking the mastery of foundational concepts required for graduate entrance exams. The OBE closed-loop teaching model proposed by Jinghua Zhang et al. features an integrated design spanning from the curriculum plan and assignments to testing and feedback evaluation [8]. Although competency-based teaching reforms have achieved certain results in various studies, there are still shortcomings in the specific implementation measures. Therefore, future research must fully consider the cultivation of students' foundational knowledge, algorithm design, and quality education, and provide concrete implementation measures.

This study aims to translate the macro-level OBE philosophy into micro-level, actionable teaching practices, with the goal of providing a practical pathway to enhance the teaching quality of this course and cultivate computer engineering talent that meets the demands of the times.

2. Theoretical Framework and Overall Design of Competency-Based Teaching Reform

Educational reform in data structures courses must take into account various factors, including instructional objectives and content, teaching methods and approaches, and assessment methods [9]. The core of competency-based teaching reform lies in constructing a clear three-dimensional competency objective system and, using this as the core, driving the systematic restructuring of teaching content, teaching methods, and the evaluation system in a backward-design approach.

This reform plan explicitly quantifies the expected student outcomes into three interrelated yet distinct core competency dimensions. (1) Theoretical Knowledge Comprehension: Students are required to systematically master core theories such as the fundamental concepts of data structures, the properties of logical structures (linear lists, stacks, queues, trees, graphs), storage methods (sequential and linked), and the analysis of time and space complexity of algorithms, while achieving a comprehensive integration of knowledge modules.(2) Algorithm Analysis and Design Competency: This emphasizes students' ability to abstract real-world problems into appropriate data structure models, select and design efficient algorithms, and ultimately implement solutions through programming (using the C language). This encompasses the complete engineering thought process, from problem analysis and algorithm conception to code implementation.(3) High-Level Comprehensive Competencies: Going beyond mere skill development, the course focuses on cultivating students' computational thinking, innovative mindset, collaborative spirit, and professional ethics through instruction, achieving an organic integration of value-driven guidance, knowledge transfer, and competency development. Specific corresponding content is shown in Figure 1.

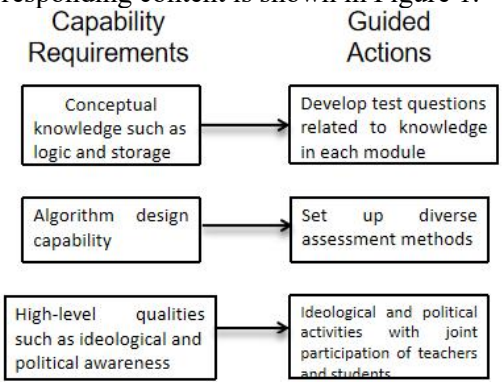

Figure 1. Correspondence Chart of Competencies and Oriented Behaviors for the Data Structures and Algorithms Course

3. Specific Reform Measures and Practices Based on Competency-Oriented Approaches

Based on the aforementioned competency objectives and guided by the backward design and closed-loop improvement model, the reform follows the OBE closed-loop logic: "Define expected learning outcomes → Design

diversified assessment methods → Organize targeted teaching activities → Evaluate achievement of outcomes → Continuously improve teaching." This means that the revision of the course syllabus, the instructional design for each class, and the setup of each laboratory project all have as their starting point and ultimate goal whether students can achieve the predetermined "three-dimensional competencies." Centered on these three competency dimensions, the reform has undertaken in-depth and concrete e-xplorations across three levels: instructional content, teaching methods, and assessment and evaluation.

(1) Reconstruction of Teaching Content: From Discrete Knowledge Points to Interconnected Knowledge Networks

Given that the course involves numerous theoretical concepts and students often find it easy to learn but difficult to retain the material, establishing a question bank can help students reinforce key concepts through practice [10]. This reform has moved away from the traditional approach of teaching isolated chapters and instead focuses on building an interconnected question bank that covers the core knowledge modules throughout the entire textbook. This bank is organized using a knowledge graph approach. For example, when examining the characteristics of "stacks," it will pose related questions such as "the logical structural differences from queues," "the similarities and differences in C language implementations between sequential and linked storage," and "general methods for time complexity analysis." For instance, the theoretical key points of linear lists—such as the characteristics of sequential and linked lists, and the time complexity analysis of insert, delete, update, and query operations—can be extended to the subsequent concepts of "stacks" and "queues" as restricted linear lists.

In this way, students are naturally guided to connect and compare knowledge points from different modules during the process of completing assignments and exercises, thus forming a structured knowledge network in the brain instead of fragmented memory fragments, fundamentally strengthening the internalization and transfer ability of theoretical knowledge.

(2) Innovation in Teaching Methods: From Teacher-Centered to Teacher-Student Collaboration, Integrating Theory and Practice

The step-by-step teaching method of "problem analysis-algorithm design" is designed in the ability of algorithm design, which directly faces the pain point of students' "difficulty in algorithm design" and decomposes the whole process of solving problems into two levels. In the Problem Analysis phase, the instructor uses examples from everyday life, such as "searching for bus routes in the city" or "evaluating formulas." Through guiding questions and group discussions, students are encouraged to abstract real-world problems into data structure models—such as diagrams or stacks—and to seek potential solutions. This link encourages creative thinking and does not pursue standard answers. In the process of algorithm design, students focus on transforming recognized excellent ideas into specific C language programs, and teachers focus on guiding and solving grammar and debugging problems in this process.

In quality education, a "teacher-student discussion" model of ideological and political education is established, which breaks through the limitation of teachers' one-way indoctrination of ideological and political cases and creatively integrates value shaping into professional knowledge learning. For example, after studying the level-ordered traversal of "binary trees," students are organized to discuss "how this concept of order and hierarchy is reflected in team management or the structure of social organizations." After students share their perspectives, the teacher then elevates the discussion by integrating concepts such as "systems thinking" and "the spirit of collectivism." This mode enables students to become active thinkers and co builders of value consensus from the audience. It has significantly improved the affinity and effectiveness of Ideological and political education, which is a major feature of this reform.

(3) Diversification of Assessment: From Summative Assessment to Formative Assessment Throughout the Process

In order to comprehensively and objectively reflect the growth of students in the three ability dimensions, an evaluation system suitable for the teaching mode is established. The specific composition is as follows.

Attendance accounts for 10% and assesses students' learning attitude and participation in ideological and political education. In-class exercises account for 10% and assess students'

understanding of theoretical knowledge during class. After class homework accounts for 10% to test students' understanding of theoretical knowledge after class. The questions include the questions in the associated test bank. Computer programming accounts for 20% and assesses students' algorithm analysis, design, and practical skills, evaluating the implementation results and code quality of core algorithms (such as binary tree traversal and sorting). Phased assessment accounts for 10% to test students' mastery of the knowledge at the current stage, which is used to diagnose the teaching effect. The final exam accounted for 40% of the students' comprehensive knowledge and problem-solving ability.

The evaluation system not only meets the requirements of paying attention to the combination of process evaluation and result evaluation, and improving the comprehensive evaluation, but also better reflects the students' learning input, thinking progress and practical results in the final score, and stimulates the students' learning motivation.

4. Conclusion

Today's higher education is facing great changes. The research on the teaching reform of data structure and algorithm Course Based on the ability orientation proposed in this paper is not only to solve the problems of talent training in Colleges and universities at present, but also to solve the problem of better adapting this course to the future development of students. This study has established a clear three-dimensional competency-based objective framework and designed detailed implementation measures centered on this framework. A knowledge-linked question bank was developed to help students master theoretical knowledge, while an interactive teaching model with clear step-by-step guidance assists students in improving their algorithm analysis and design capabilities. The "teacher-student dialogue" theme increases students' engagement in ideological and political education, enhancing their high-level comprehensive competencies. Additionally, a diversified assessment system has been established. From the perspective of the implementation effect, students' participation in the classroom has been significantly improved and the pass rate of the course is also good. Students have met the requirements of the research design to a certain extent, and are ready for students' postgraduate entrance examination, further education or employment in the future.

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