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The Teaching Reform of *Data Structure* Centered on the Cultivation of Innovation Ability: Taking Local Undergraduate College as an Example

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Abstract. *Data Structure* is the core course of the major of computer science and technology, and it plays an important role in cultivating students' creation ability. Firstly, the present situation of *Data Structure* teaching was analyzed. Then, to reach the goal of cultivating students' innovation ability, specific measures of the teaching reform was discussed, including task modules division, problem driven teaching and visual teaching.

1. Introduction

At present, the competition in the society is mainly reflected in the level of talent competition, especially in the aspects of creativity. Therefore, a major issue in higher education reform is how to cultivate high-quality talents with innovative consciousness and ability. Jiang et al [1] pointed out that innovation ability is the ability that continuously provides new ideas, new theories, new methods and new inventions with economic, social and ecological values in science, art and practice fields by using knowledge and theory. Chen et al. [2] suggest that to cultivate students' innovation ability is to cultivate their ability to learn new knowledge and use acquired knowledge to solve practical problems. For students majoring in computer science, their innovation is especially reflected in the following aspects, i.e., they can design, implement and analyze algorithms, and they also have great innovation and adaptability in exploring new technology and new methods.

2. An analysis of the present situation of teaching

Data structure is an important professional course in computer science and technology. The course aims to enable students to master the definition and realization of important data structures, to understand the design thought of related algorithms, so as to select the appropriate logical structure, storage structure and corresponding algorithm for specific applications. Besides, it should enable students to grasp simple algorithm analysis methods, including time and space complexity analysis, and lay a foundation for subsequent learning of software development courses. Algorithm is an important foundation for computer science and software engineering, and has been applied to almost all frontiers (artificial intelligence, database, network, information security, etc.). CS2013 (Computer Science Curricula 2013) [3] defines algorithms and complexity (abbreviated as AL) as an independent knowledge body, of which *Data Structure* constitutes an important part. Therefore, *Data Structure* is in the central position of the computer course system. Since the course emphasizes both theoretical study and experimental operation, at present, it has been listed as an important part of the national software examination and a compulsory subject for computer professional students in the national postgraduate entrance examination. For local universities, because the level of students is

limited and the content of the course is abstract and difficult, whether the course can be taught with high quality determines the results of talent training to a certain extent.

3. The teaching reform measures centered on the cultivation of innovation ability

For most students, *Data Structure* is a difficult course. This is mainly manifested in: 1) Lack of learning motivation. Except for the students who are determined to take the postgraduate entrance examination, most students are not interested in the teaching content, and thus lack the motivation to study deeply. 2) The course is very theoretical and contains many abstract concepts, and most students are not willing to think deeply. The consequence is that the preceding teaching contents (such as linear list, stack and queue) are not well grasped. When learning relatively complex content (such as trees and diagrams), many students can no longer keep up with the teachers' teaching progress. 3) For many important algorithms in textbooks, though many students can understand their design and execution process, they lack the ability to transform algorithm descriptions into executable programs, and thus lose interest in experimental classes. 4) Most students can't combine the contents of *Data Structure* with subsequent programming courses, so they think it is useless.

3.1 The task module division of curriculum

In order to change the current teaching situation, improve teaching quality and cultivate students' innovation ability, we have carried out a targeted teaching reform. We reconstructed the teaching content of *Data Structure* and divided it into seven task modules, i.e., basic knowledge module, linear structure module, extended linear structure module and so on. At the same time, we used the last "innovation and entrepreneurship education" module to strengthen the important role of innovation education in the process of talent training. Moreover, we added specific cases (as shown in Figure 1) at the end of each module, which are closely integrated with the applications in reality [4]. The purpose of these cases is to help students understand the wide use of the knowledge they have learned.

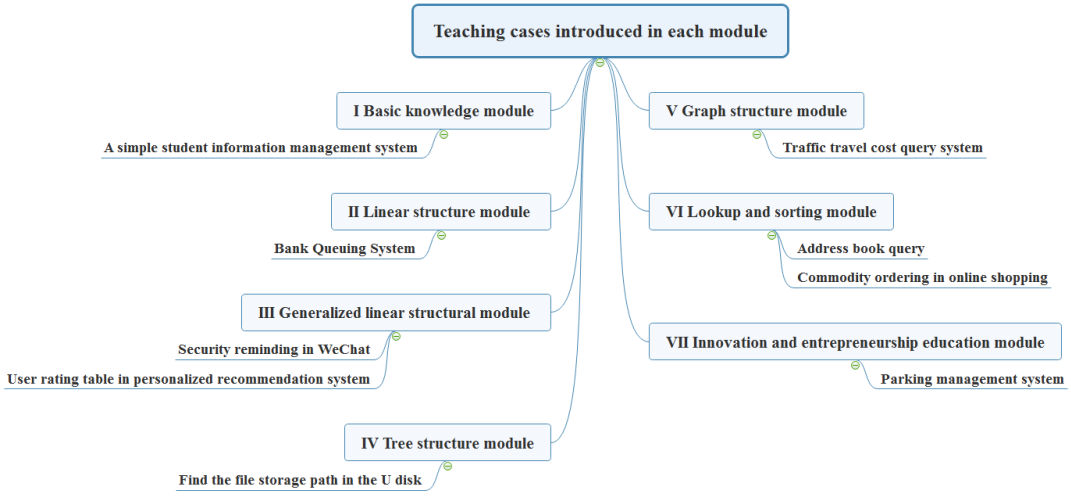

Fig. 1. The case setting of each task module

3.2 The application of problem driven teaching method

The problem driven teaching refers to the communication and interaction between teachers and students concerning problems in the classroom. The problem can be raised by any of the teacher or students, and a series of problems are constantly thrown out and the solution is finally drawn by discussion [5]. In view of the situation that students are not willing to think deeply and not good at using knowledge flexibly, it is necessary to take problem driven teaching methods. Taking the Huffman code as an example, the teacher can achieve the final teaching goal by putting forward the following questions in turn:

Question 1: In the process of communication, how to encode an English message?

By organizing the students to discuss, the following teaching objectives are finally reached: any information can be expressed in a 0-1 coding manner.

Question 2: how to determine the length of the code?

With discussion, the teacher finally achieved the following teaching objectives: Obviously, each binary number can be used to represent two cases. We assume that this English message is made up of N different letters, so the encoding length of L should satisfy the relation of $2^L \geq N$.

Question 3: Is it possible to further improve the coding efficiency?

With discussion, the following teaching objectives can be reached: The number of occurrences of each letter in the message can be counted. The goal is to allocate shorter codes for the letters with high frequency, thus shortening the length of encoding.

Question 4: When this coding is used, whether problems are encountered in the decoding process?

With discussion, the following teaching objectives are finally reached: Although the coding efficiency is improved, there are sometimes ambiguities that lead to the concept of prefix coding.

Question 5: How to design an efficient prefix coding?

With discussion, the following teaching objectives are finally reached: Introduce the Huffman coding method to students.

Question 6: Why Huffman coding must be the shortest?

With discussion, the following teaching objectives are finally reached:

Because the total length of the Huffman code is exactly equivalent to the length of the weighted path of the Huffman tree. Because the Huffman tree has the advantage of the shortest path length of the weighted path, it is concluded that the Huffman code must be the shortest.

At the same time, we adopted the heuristic teaching method based on 3W in the implementation process [6]. First of all, teachers use specific examples to tell what the problem is (What). Then, the teacher guides the students to think about how to do it (How). Finally, the teacher let the students understand what to do (Why). For example, in teaching the practical application of Huffman tree, the teacher first put forward the following question: how to implement the conversion of 10000 students' test scores, i.e., to convert their scores expressed in centesimal system to the ones expressed in the five level system [7]? Then, the teacher guides the students to consider the solution from the following aspects, that is, the main factor that affects the efficiency of the algorithm is the number of comparisons performed during the conversion process. For example, a student's score is 88, because the relationship of "80≤88≤89" is established, therefore his score can be converted to "good" in the five level system by 2 comparisons. To this end, the score of 10000 students is required to be counted (assuming that the statistical results are shown in Table 1).

Table 1. A statistical result of the number of students in each score section.

Serial number	Score section	Percentage of students
1	0-59	0.05
2	60-69	0.15
3	70-79	0.40
4	80-89	0.30
5	90-100	0.10

Obviously, the following conditions must be met to achieve high efficiency, that is, the algorithm performs the least number of comparisons in the two cases of fractional "70-79" and "80-89". Finally, the teacher made the following hints, that is, the number of students in each segment can be regarded as the weight of leaf nodes, so that a Huffman tree can be constructed (as shown in Figure 2). Similar to question 6 above, students finally understood that Huffman tree can be used to solve the practical problems proposed by the teacher in the most efficient way. Through the implementation of this teaching method, students' deep thinking is promoted and their confidence in finding problems and solving problems is also enhanced.

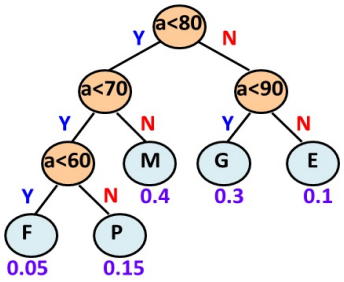

Fig. 2. The Huffman tree based on the comparison strategy (E: Excellent, G: Good, M: Medium, P: Pass, F: Fail)

3.3 The visual teaching based on mind map

The teaching content of *Data Structure* is very abstract, so the beginners often feel that the course is dull and boring, and lost learning interest. In fact, both the abstract concept and the execution process of complex algorithm can be visually displayed by drawing, thus reducing the difficulty of understanding. [8] pointed out that teachers should always use diagrams in the teaching process of *Data Structure*, so as to visualize the problems and algorithms. [9] focused on the visualization of the abstract concept and the execution process of complex algorithms in *Data Structure*, and pointed out that the advantages of teaching content visualization lie in the following aspects. 1) Stimulate students' interest in learning. 2) Train students' intuitive thinking and enhance memory. 3) Cultivate students' ability to solve practical problems. 4) Improve classroom teaching efficiency. Mind map is a common graphic method, and it is a radiative way of thinking. At present, millions of people are using this tool and applying it to brainstorming, document drafting, and project planning [10]. Similarly, mind map can also be applied to all aspects of the teaching process and have a good teaching effect. We draw lessons from the methods of [8, 9], and combine the graphic method with the tool of mind map, and have achieved good teaching effect. Suppose we need to design an algorithm to create a single linked list with a header node, and the data in the list is $a_1,a_2,\ldots,a_n$. In Figure 3, we show the creation process of the header node (the first step), the creation and insertion process of the node an (step 2~5), and the insertion process of the node a_{n-1} (the sixth step). Obviously, after understanding the 6 steps above, it is easy for students to understand how to use the "reverse sequence" method to create and insert the remaining nodes $a_{n-2},\ldots,a_1$ in turn.

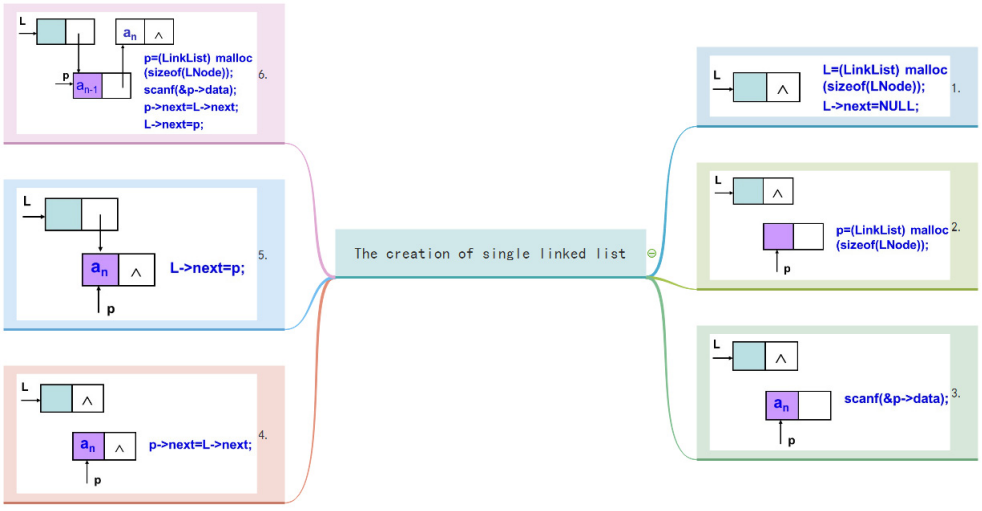

Fig. 3. Show the process of creating a single linked list in a "reverse order" way by using mind map

4. Summary

This paper discusses the specific ideas of *Data Structure* teaching reform centered on the cultivation of innovation ability in local undergraduate colleges, and provides specific examples of problem driven teaching and visualization teaching. The focus of future work is to set up a scientific and

complete hierarchical experimental teaching system and strengthen the visualization teaching of complex algorithm, so as to further explore the training of more excellent applied talents in local undergraduate colleges.

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