A 3C3R teaching model applied to a C programming language course

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ABSTRACT: A C programming language course is a computer-related basic course. Traditional programming language teaching takes *knowledge* as the core of what is to be learnt, and the teacher is central to the entire teaching process. Teaching content is passed from teachers to students. In itself, this teaching model does not cultivate a student's enthusiasm, initiative, creativity or practical ability. Therefore, some scholars have tried to reform the C language curriculum, so as to use case teaching methods or *problem - inquiry* teaching. However, even then, teachers still strongly guide students and it is easy to overlook knowledge links. Hence, students still find it difficult to develop their own knowledge base. Based on these considerations, the authors developed a teaching model using open-ended questions for C language teaching based on the 3C3R (content, context, connection, researching, reasoning and reflecting) model. This teaching model is presented and discussed in this article.

INTRODUCTION

The 3C3R model is a problem-oriented learning model for teaching and has three core components (content, context, connection) and three processing components (researching, reasoning and reflecting); hence 3C3R. It was proposed by Dr Hong Wei from North Dakota State University, USA, in 2006, as an adjunct to the problem-based learning (PBL) model [1].

The core components involve the acquisition of knowledge, e.g. concepts, rules and principles. The process components involve students applying knowledge to solve complex problems. The model develops students' higher-order thinking and self-directed study abilities [2][3]. The 3C3R model provides a good conceptual framework for designing problems in support of problem-oriented learning.

Problem-oriented learning mimics natural human learning, that is, when a learner encounters a problem, the learner acquires the relevant knowledge and skills to find a solution to the problem. Problem-based learning places problems at the core of learning. Under the teacher's guidance, students explore problems from different angles, using different methods, through independent research, reasoning and reflection (the 3R in the 3C3R model), to solve complex practical problems. Thus, students extend their knowledge and develop a higher-order thinking capability. Problem-oriented learning in the design phase is a matter of asking crucial questions, which the 3R in 3C3R supports.

TEACHING A C LANGUAGE COURSE USING THE 3C3R MODEL

The Teaching Mode for a C Language Course

Using 3C3R as the theoretical foundation, the authors proposed a 3C3R teaching model for a C language course, as shown in Figure 1. The model uses a series of open-ended questions reflecting the structure of the knowledge.

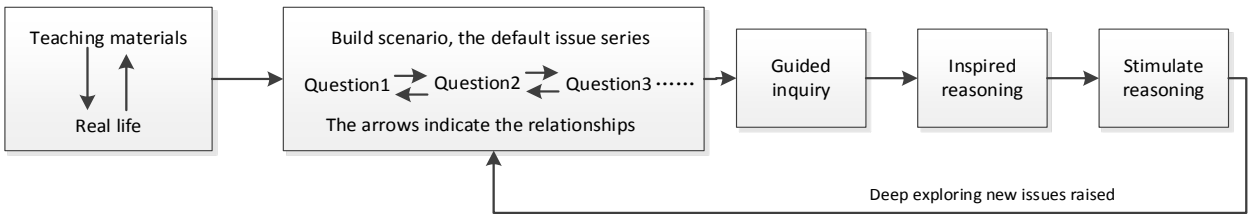

Figure1: Problem-oriented teaching model flowchart.

Teaching Model Stages

The problems set in the problem-based learning process must be practical and based on real-life issues. Open-ended questions are designed to reflect the range of required knowledge that is implicit in the problem. The open-ended questions are designed according to the following principles: the questions deal with real situations; the question series reflects the structure of required knowledge; each question should explore specific knowledge about a clear problem with linkages to related issues; finally, the question series should guide and inspire students to explore deeply the issues and problems.

Exploring the Problem and Student Reflection

The students by self-study examine the problem and, hence, come to understand it. They determine what required information is known to them, and what is unknown. Then, they determine how to acquire the unknown information [4].

Teachers should guide students to understand the problem and prevent them deviating from the intended target knowledge. Teachers should guide students to target the issues to be explored, to ensure they all contribute to the final solution.

By reasoning students explore the information acquired to solve problems, i.e. students are able to creatively generate and test hypotheses and accept or discard putative solutions. Teachers should inspire students to reflect on the problem-solving process and systematically organise and integrate new knowledge into their existing knowledge base.

Teachers draw up new problems, which are variations of existing problems by, for example, changing parameters or the application environment or the data of the original problem. This encourages students to adjust their thinking strategies to re-explore a problem and, then, by reasoning and reflection, to become self-directed and independent learners.

Open-ended Questions

The open-ended question is the essence of teaching based on the 3C3R model. A *good* question should relate to a real problem that can lead to a variety of hypothetical assumptions. This helps students to expand their own knowledge and develop their intellectual skills.

The series of questions that is developed follows from analysing the teaching objectives, identifying learning goals, and identifying the knowledge *theme* to be covered. Then, a real-life scenario is developed.

Learners build their own knowledge framework based upon the teacher's design, reflecting a relationship between knowledge appropriate to the scenario the problem is based on.

Relationship between knowledge can be divided into sibling, hierarchical and summarising relationship [5]. These three kinds of relationship are summarised in Figure 2, where the knowledge is assumed implicit in the question. Sibling relationship is knowledge that can be presented in different ways, e.g. in computing when analysing different algorithms to determine their advantages and disadvantages.

A hierarchical relationship is knowledge contained in a hierarchy, e.g. exploring progressively improvements of optimisation algorithms. A summarising relationship contains knowledge questions as a summary or reflection of the previous question.

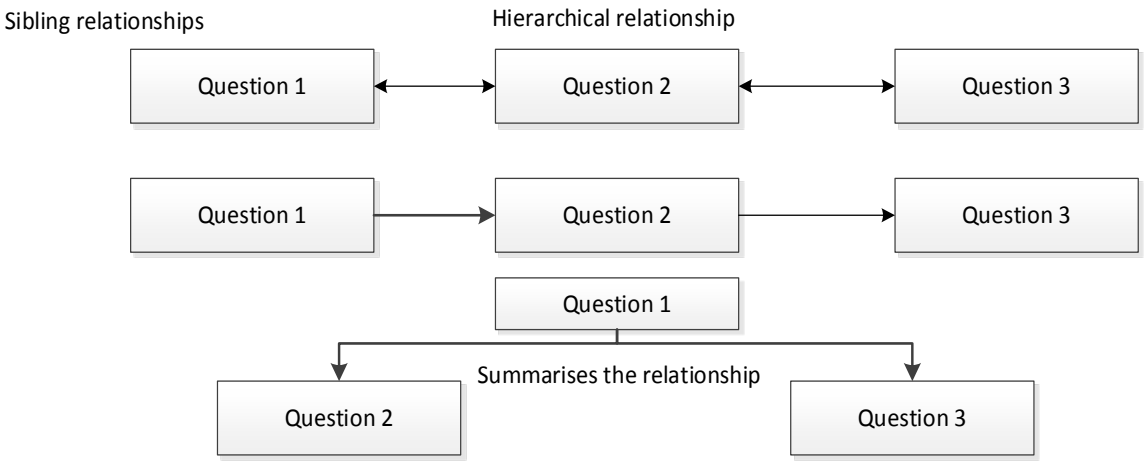

Figure 2: Knowledge relationships.

AN EXAMPLE OF C3R3 LEARNING

Creating a Scenario and Presenting a Problem

Sort algorithms in computing were chosen as an example. Teachers must first analyse the knowledge points in the textbook chapter on sorting in-depth. These knowledge points are arranged guided by the three kinds of knowledge relationship. Questions suitable for students are, then, produced for these knowledge points. For example, the sorting section deals with various sorting algorithms relating algorithmic complexity to computational time [6].

In real life, things often need to be sorted, such as soldiers according to height and students according to performance. These sorting problems require the use of an attribute(s) as a sort key (height for the soldiers, examination score for the student). There are many sorting methods covered in the teaching material, together with practical applications and a series of questions designed to guide the student in exploring the sorting algorithms.

An example, of a sorting problem: given an Excel table called *C score sheet*, shown in Figure 3, sort the students' scores so that they are ranked from high to low.

Data structures transcript

StudentID	Name	Sex	Age	Score	Rank
20130X1	Student 1	Female	19	95	
20130X2	Student 2	Female	20	88	
20130X3	Student 3	Male	20	88	
20130X4	Student 4	Male	19	73	
20130X5	Student 5	Female	19	65	
.....	.....	.....	.....	.....	

Figure 3: Results transcript.

For this scenario, the relationship between the questions is shown in Figure 4.

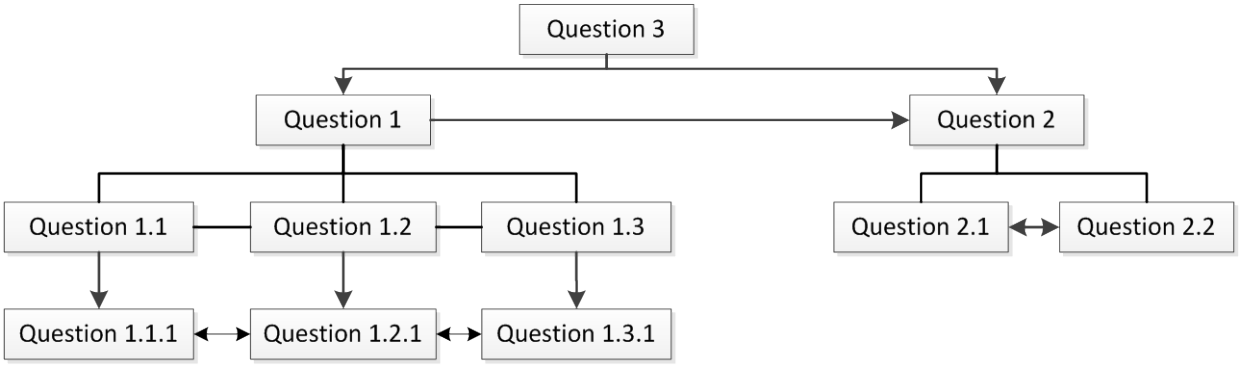

Figure 4: The relationship between questions in the sorting algorithm case.

Question 1 and Question 2 are Level 1 questions. Relationship; Question 3 and Question 2, the problem of the relationship between Question 1 is summary relationship; Questions 1.1, 1.2 and the problem 1.3 are at the same level.

Discussion of the Questions for the Sort Example

Question 1: *You are an Excel developer. Design the sort algorithm*. In the inspired reasoning stage of the teaching model (Figure 1), three sub-questions can be generated, viz. Questions 1.1, 1.2 and 1.3, concerning three possible algorithms, i.e. insertion sort, selection sort and bubble sort. Hence, students are guided to consider these algorithms. In the reflection stage, optimisation of the algorithms can be considered leading to Questions 1.1.1, 1.2.1 and 1.3.1.

Question 2: *You are a technical staff member supporting a bank's database and are required to sort 10 records in the database. You must decide which sorting algorithms are applicable, i.e. which would take the least time*. Upon completion of all the sub-problems in Question 1, during the stimulating reflection stage, the teacher generates problem 2 by adjusting the data scale of a problem, so that the student's previously designed algorithm is not efficient.

Question 3: *Student 5 and Student X have the same grades. After sorting, Student 5 came ahead of Student X. Explain.*

Question 3 is a summary and reflection of Questions 1 and 2.

Guided Inquiry

Question 1 guides the students to the target problem, i.e. the sort key in the table is *score*. The initial order of the five integers (each not exceeding 100) is 60, 75, 89, 92, 89. The target sorted order is 92, 89, 89, 75, 60.

Inspired Reasoning

Teachers should inspire students to explore deeply the nature of prior knowledge and issues [7].

The target for Question 1: *Students infer three kinds of sorting algorithms; namely, select, insert, bubble*. Students, guided by the teacher, can compare the speed of the three algorithms. This encourages students to communicate with each other in natural language or using flowcharts or program code to express their sorting algorithms.

Teachers can try to make abstract theories concrete, to facilitate students' understanding and remembering. For example, for the bubble sort algorithm, software, such as Flash can be used to produce an animation of the sort. In addition, teachers could use a game to explain the insertion sort algorithm. Such techniques can enhance intuitive reasoning, as well as being inspiring and interesting.

For example, students could draw cards randomly from a deck of cards. Each card is, then, inserted into the correct location in an already ordered deck that is being built up. At the end, the deck has been sorted. Thus, students infer the algorithmic process.

To obtain a deep understanding of the insertion sort algorithm, teachers provide some explanation or tips to students. Students are encouraged to express their ideas, which teachers will, then, evaluate and provide guidance on them to the students [8][9].

To Stimulate Reflection

Question 1 leads teachers to formulate three kinds of sorting algorithm, i.e. issue 1.1 (insertion sort), issue 1.2 (selection sort), issue 1.3 (bubble sort) and to discuss the relationship between these algorithms, as well as their advantages and disadvantages.

Students review the three kinds of algorithm for a specific sort. This guides students on reflecting how to improve and optimise the algorithms. This, then, leads to Questions 1.1.1, 1.2.1 and 1.3.1. After using the three algorithms, the teacher by adjusting the data, stimulates students to reflect, which leads to Question 2.1 and 2.2 (quick sort, merge sort). Hence, the teacher's preset questions guide the students.

CONCLUSIONS

A C programming language learning mode based on the 3C3R model (content, context, connection, researching, reasoning and reflecting), is described in this article. Teachers inspire students to explore by exercising reasoning and reflection.

This teaching mode allows students to both reorganise personal learning and to challenge existing learning models. This C programming language teaching mode based on 3C3R helps students to construct knowledge, to develop high-level thinking and to develop self-directed learning.

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