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Research on Computer Fundamental Education Based on Computational Thinking

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***Abstract*—According to the difficulty of computer fundamental education, introduced the idea of computational thinking, discussed the essence and essential contents of computational thinking, and based on this, designed the curriculum System for computer fundamental education as well as the content framework for key courses, finally put forward some strategies for teaching practice.**

Keywords-Computational Thinking; Computer Fundamental Education; Curriculum System; Instructional Strategy

The computer fundamental education has been launched for more than 30 years in China, during this period, the computer technology develops rapidly, as a result, the curriculum was adjust constantly, and the position of computer fundamental education was adjusted accordingly.

In 2006, professor Jeannette M.Wing of CMU advanced the concept of "computational thinking [1]", which aroused extensive research in the educational field. In this paper, the author will introduce the problems of current computer fundamental education, research on the essence and connotation of computational thinking, then discuss the curriculum system and teaching method of computer fundamental courses based on computational thinking.

I. THE TASK AND DIFFICULTY OF COMPUTER FUNDAMENTAL EDUCATION

For a long time, the position of computer fundamental education was ambiguous, there exist the following misunderstanding.

- Simple tools notion: take computer as simple tools, and concentrate on the usage of some frequently-used software in computer fundamental courses.
- Programming notion: take the key task of computer fundamental education as learning a programming language, and ground for the programming in subsequent Specialized courses.
- Concentrating notion: Think that most of the knowledge that related with computer science should be involved in the Curriculum, but can not be study deeply.
- Useless notion: for that the usage of computer is more and more easy, it is not necessary to keep on the computer fundamental education .

Based on these opinions, it becomes difficult for computer fundamental education: For lack of principal line, it is hard to build the know ledge architecture; for constantly changes of software tools, the syllabus changes as well, always go with the product manual of some company; students have no interest on learning , teachers also have no interest on teaching.

On this situation, the Steering Committee on college computer fundamental education of China has put forward two turns of reforms. The first one started at 1997, proposed the 3-levels curriculum system, meanwhile, designed the syllabus for 5 key courses. The second one start at 2004, put forward the Knowledge architecture of "4-fields * 3-levels", the "1+x" curriculum framework, and in addition, set the 4-targets of ability culture: the cognitive ability of computer, the ability of solving problems with computer, the ability of cooperate via network, and the ability of self-learning at information society.

After the idea of computational thinking been presented, the third turn of reform is now in gestation, that is, the computational thinking oriented reform for college computer curriculum, mainly include the following topics:

- On Theoretical level, research on the connotation, expression of computational thinking, as well as its influence to the instruction of computer technology.
- On system level, make scientific plan on knowledge structure and course framework of computer fundamental education.
- On operational level, make the computer fundamental courses an effective way for training the ability of computational thinking, meanwhile, develop a series of resources.
- On practice level, push forward the explore of reform on college computer education that in accordance with different objectives and different majors.

II. THE ESSENCE AND ESSENTIAL CONTENTS OF COMPUTATIONAL THINKING

According the paper of professor Jeannette M. Wing, Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science. Computational thinking is a fundamental skill for everyone, not just for computer scientists. we should add computational thinking to everyone's analytical ability.

Computational thinking is not a new way of thinking, but something that developed simultaneously with the thinking of human. The development of computer have greatly promoted the research and application of computational thinking, but essentially, computational thinking does not depend on computer.

Summing up current research on computational thinking, we can draw the following conclusions:

- The essence of computational thinking is the thinking of solving problems based on computing environment and its constraints.
- The main contents of computational thinking involves: research on the model of computing, design and construction of computing system, features and constraints of a computing system, solutions that solve problems effectively by utilize of computing system, evaluation and validation of the solutions.
- Key features of computational thinking includes: abstraction, automation, formalization, and mechanization.

In Ref [2], Peter Denning proposed 7 great principles of computing: computation, communication, coordination, recollection, automation, evaluation and design. In Ref [3], Chen and Dong proposed abstraction as an additional great principle. Based on these principles, we can expand to a series of knowledge, thus construct the framework of computational thinking, As shown in Figure 1.

III. CURRICULUM SYSTEM FOR CULTIVATION OF COMPUTATIONAL THINKING

Once known the essence and knowledge framework of computational thinking, we can reform the curriculum of computer fundamental education, so as to highlight the cultivation of thinking ability.

Firstly, divide the courses of computer fundamental education into two parts: the key courses and the optional courses. The first part will be arranged for all majors, include "Introduction of Computational Thinking" and "Fundamental of Algorithm and Programming"; The second part will be choose to study by different majors, include "Database System", "Multimedia Processing", "Fundamental of Information Security", "Fundamental of Computer Network" and so on. We will discuss the content framework of the key courses in following chapters.

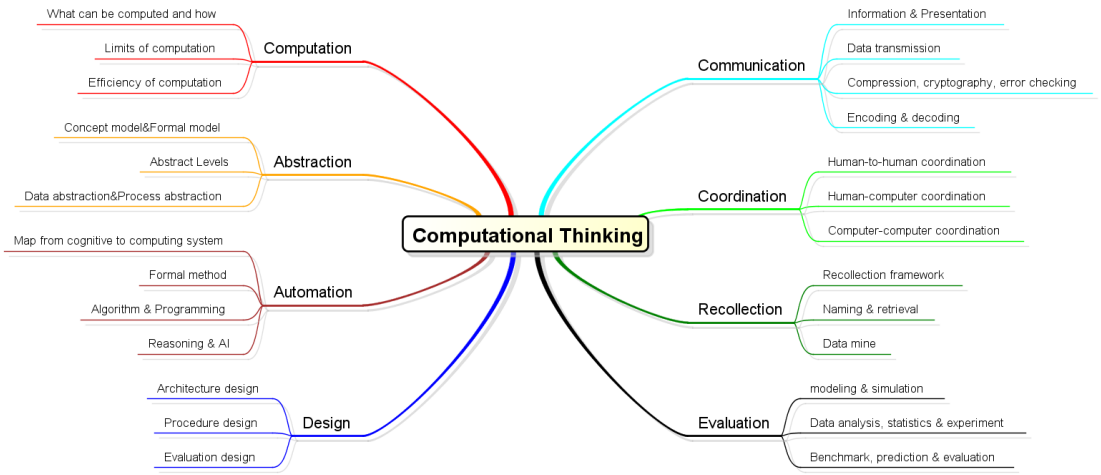

Figure 1. The knowledge framework of computational thinking

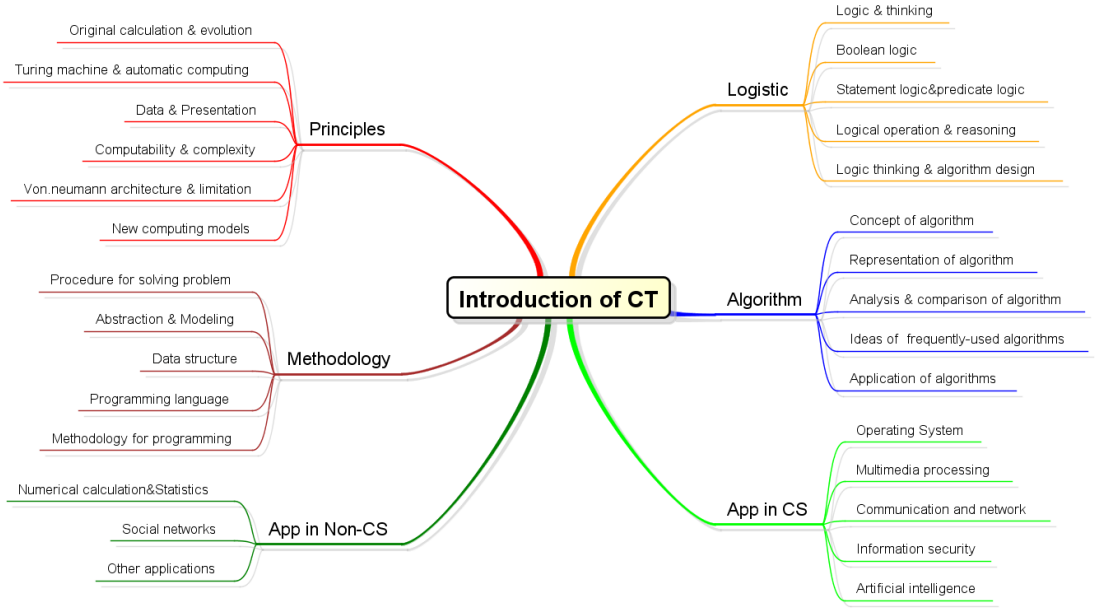

Figure 2. The content framework of introduction to Computational Thinking

A. *Content framework for "Introduction of Computational Thinking"*

"Introduction of Computational Thinking" is the first computer fundamental course for college students, we should alter the syllabus that concentrate on operation of computer, thus, turn to foster the cognition of computing environment, and the thinking ability of solving problems by means of computational methods. The core knowledge framework is shown in Figure 2.

The first unit is about the theoretical principle of computational thinking. Starting from the methods and evolution of original calculation, make students understand the history of calculate, the evolution of methods and tools for automatic calculation; then, based on the principal of modern computer, explain the representation of data, the normalization of calculation, thus address the fundamental issues of computing. According to the design of computer, explain the automatic calculation model and formal methods by the Turing machine, then study on the architecture of

Von. Neumann, analyze its limitations and then lead to the new models and technologies that developed in recent years, thus set up clear understanding of computing environment for students; next introduce the complexity of computation, explicating that some problem can be solved by computation but some can be hardly.

The second unit is about the logic basis of computational thinking. Start from the relations between logic and thinking, learn the pattern and procedure of thinking through logic; then introduce the Boolean logic, Statement logic, as well as Predicate logic, know the presentation, calculation, and deduction of logic, understand the formal method of computational thinking, finally, associate the algorithm with logic thinking, and achieve logic calculation and deduction by algorithm.

The third unit is about the methodology of computational thinking. First analysis the thinking procedure of human that solve problems, then lead to the procedure that for computer, and make a comparison between the two procedures. The first step for computer to solve a problem is abstracting and modeling, we call this problem description; then designing of suitable data structure and algorithm, and implementing of the algorithm by programming language, this means designing and implementing of a system. Lastly, we'll verify the correctness and efficiency of the system. Those activities of thinking and practicing that made to solve problems by computer make up the methodology of computational thinking, thus, abstraction and construction should be the core concepts of the methodology. The procedure that comes from problem to programming is a level of abstraction, and based on this we construct a computing system to solve the problem, then construct a validation system to verify the effectiveness of our solution.

The fourth unit is about the algorithm fundamental of computational thinking. Algorithm is a way of thinking for solving problems, research on algorithm will train our thinking, made it clear and logical, so the training of algorithm is crucial for computational thinking. This unit will be spread around the following 3 topics: the first one is algorithm fundamental, we will learn the concepts, characters, and classifications of algorithm, focus on the representation of it, learn to describe an algorithm by different methods, thus make clear that a problem can be solved by different algorithms; the second topic is the idea of some commonly used algorithms, include exhaustive, recurrence, recursive, backtracking, decomposition, parallel processing and so on, enlighten the thinking of students through these algorithms; the third topic is about typical application of those algorithms, based on typical scenarios, introduce different algorithms and there implementations for a same problem, then evaluate for each algorithm, thus made students get real ideas of algorithm and computational thinking.

The fifth unit is about the applications of computational thinking in computer science. Starting from the key issues and basic approach of fields such as operating system, multimedia processing, communication and network, database system, information security, artificial intelligence, briefly introduce the application of computational thinking in each area, enable students to really understand the basic ideas of computer science. Take communication and computer network as example, starting from the construction of a communication system, first discuss the key issues to be considered when designing such a system, recognizing that it is such a complicated system that can not be implemented in one step, and that most of the complicated problems should be solved step by step, thus draw forth the layered architecture; being the key element of network, protocol means a series of agreement for communication, according to the layered architecture, introduce the concepts of protocol stack; To achieve effective data transmission, we need further introduction of topics such as information presentation, encoding and decoding, error checking and recovery, data encryption and security transmission.

The sixth unit is about the applications in other disciplines. Through cases in various fields, reveal the power of computational thinking that be applied in non-computer area, so as to make students from other majors to concern on it.

B. Content framework for fundamental of algorithm and programming

To solve problems by computing, the essence is to make abstraction and modeling for the problem, and then express the model by algorithm, and implement the algorithm by programming, so key ideas of computational thinking will finally embodied in algorithms and programs. The fundamental of algorithm and programming will be a course that offered for students of science and engineering departments, its content framework is shown in Figure 3.

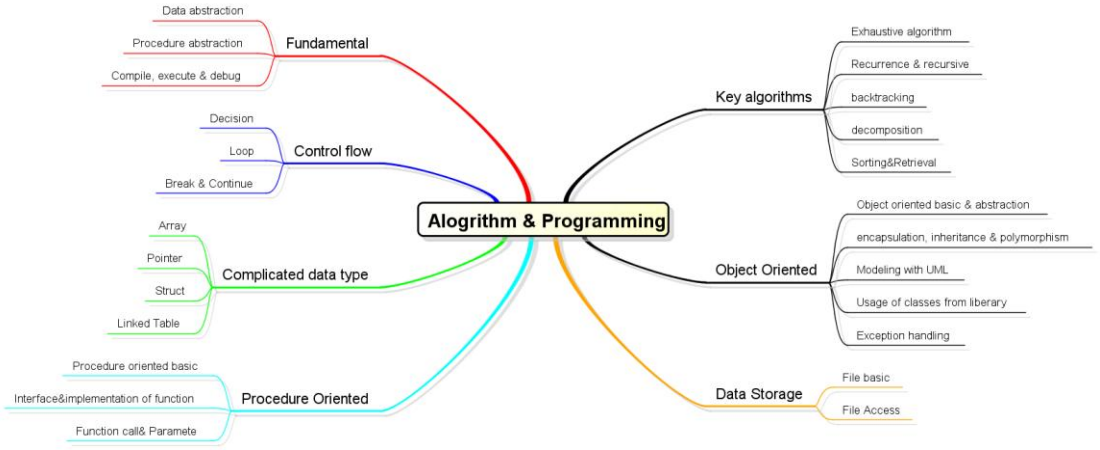

Figure 3. Content framework for fundamental of algorithm and programming

The first unit is about program fundamental. First introduce key concepts and ideas of programming by examples, so as to establish basic understanding for programming. Then introduce the great principle, abstraction, on two aspects: data abstraction and procedure abstraction, thus introduce data structure and algorithm. For data abstraction, start from basic data type, make clear the features of discreteness and finiteness, and the representation and recollection of data; then briefly introduce the usage of array, struct, pointer and other complicated data types. For procedure abstraction, starting from the steps of solving problems by programming, lead to the structure of programs, and then introduce the methods of input/output, processing, procedure call by examples.

The second unit is about the control flow of programs. Starting from the representation of algorithm, lead to the basic ideas of structured programming as well as the three basic control flows; centred on the concept of construction, make students know that we can achieve arbitrarily complex control by means of combination of basic control flows. Next, introduce the coding of these control flows by examples, make students to master the usage of basic control flow, as well as the construction method for combination of these flows.

The third unit is about complicated data type. Aims at data abstract, introduce data types of array, pointer, struct, and linked list. For each type, start from an application scenario, analysis why we need this type, and based on the principal of “Construction”, lead to the construct of this complicated type. It is obviously that there are Close relationship between these types, so need to pay more attention to these relations, and make students clearly understand the venation of knowledge. Lastly, demonstrate the usage of these types by code examples.

The fourth unit is about procedure oriented programming. The principal line of this unit will be “Construction”. First, understand the key ideas of “Top-down successive refining”, “Modular designing” and “Structured coding”, and construct the total framework by mapping modules to functions; then for function, mind to separate its interface and implementation, and construct the coding blocks for each function; thirdly to call the function, mind the method of parameter passing and return value.

The fifth unit is about implementation of typical algorithms. this unit will convert from ideas of computational thinking to function codes, and is of great significance. Starting from application scenario, carefully design examples to solve problems of this scenario, analysis there algorithm, design the prototype and thus implement the algorithm. Core algorithms to be introduced includes: Exhaustive, recurrence and recursive, backtracking, decomposition, sorting and retrieval.

The sixth unit is about object oriented programming. The key idea of OO is abstraction, and it is also a key principal of computational think. The main features of OO include encapsulation, inheritance and polymorphism, make emphasize on these features, guild students to follow these principals when designing their class by examples. When set up the ideas of OO, learn to use classes and objects of system lib and third-party lib, pay attention to the classes such as String, I/O stream, and some typical container class as ArrayList, Vector, HashTable and so on, make clear the interface of them and learn to use their API. Lastly, according to the potential errors in program, introduce the idea of exception handling, which is also the mechanism of "Protection" in computational thinking.

The seventh unit is about data storage and file. One of the key concept of Computational thinking is "Recollection", Data structure considers memory recollection of data, yet file make persistent storage of data. Through examples introduce the types of file, storage and access method of file; lastly, introduce the API of File and Stream, and learn to coding with them.

IV. THE STRATEGIES IN TEACHING PRACTICE

It's obviously that the computer fundamental teaching is quite different with the major teaching. We need to pay more attention to the width rather than the depth of knowledge, and concentrate on the cultivating of thinking instead of Involving with details. The following strategies should be implemented in teaching:

A. Make use of Heuristic Teaching

To cultivate the thinking of students, its important to adopt heuristic teaching. Firstly given an application scenario, inspire students to think deeply and summarize the main issues that may encounter, secondly, put forward corresponding solutions for each problem, thirdly, Solving problems by means of algorithm and programming, as well verify the results.

B. Focus on problem abstraction

The first step of solving problem is to express the problem clearly, this can be think of a process of abstraction. We need firstly foster the generalization ability of students, to abstract the essential contents of the problem, and build the data model, this means data abstraction; Secondly, foster the logic thinking ability, to abstract the procedure of solution and build the process model, which means procedure abstraction. Once constructed the models, it will be easy to implement by programming.

C. Focus on construction of system

The key ideas of computational thinking involves design and construction, we need to construct a computer environment, construct an algorithm, construct a program according to the algorithm, and finally, construct an environment to verify the system. Through these constructions, we can foster the structural thinking ability of students by following steps: first, analysis the problem carefully and make clear the issue; secondly, construct the model by means of abstraction to express the key feature of the problem; thirdly, analysis the model, construct the algorithm and program to solve the problem; fourthly, construct a verify solution to validate the correctness and efficiency of the algorithm; and finally, summarize for the above efforts, and explore for different solutions.

D. Take advantage of case study

The most effective way to foster thinking ability is by case study. Through cases, students can be trained on problem abstraction, system modeling, algorithm designing, coding, and result evaluation. In this process, understanding theory by practice, and then, applying theory to practice, the thinking and knowledge progressively deepened, thus shapes the conscious of computational thinking.

E. Following interactive learning

Being different from imparting knowledge, it needs a slower and more gradual process to train an ability of thinking, needs constant interactions between teacher and students, need sustained problem discovering and solving, so it is quite important to follow interactive learning.

There are two ways to launch interactive learning: first, to interact between teacher and students, it needs the teacher to propose some questions, guild the students to think and answer, and finally summarize and evaluate by teacher; second, to interact between students, by assigning some open questions, let student to discuss thoroughly, in this discussing, the problem will be more and more clear, meanwhile, their thinking will be more and more deepen.

V. CONCLUSION

This paper starts from the present situation of computer fundamental education, researched on the essence and essential contents of computational thinking, discussed the curriculum and strategy of computer fundamental education based on computational thinking. The authors suggest that, computational thinking will be a fundamental skill for everyone, thus all majors should offer courses that related to computational thinking for their students, so as to foster their ability of solving domain problems by computational methods.

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