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Problems and solutions for cultivating innovation talents who have computational thinking quality

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ABSTRACT

Computational thinking involves the essences of computer science, and theoretical thinking and experimental thinking are consisting with scientific thinking architecture, is the cognition of primary quality of innovating talents. At present, "computer instrumentalization" and "computer professionalization" problems exist on computational thinking education. This paper analyzes the cause of the problem, point out ways to solve problems is embodying the essences of calculation thought in computational thinking education, suggests that based on the computer knowledge system, extract the feature point of computational thinking, construct computational thinking tree. As a result, convert it from instrument oriented education, knowledge oriented education, to computational thinking education, convert it from skill-based, ability-based to innovation-based education. Moreover, through concrete examples show the process of conversion.

KEYWORDS

Computational thinking; Computer instrumentalization; Computer professionalization.

INTRODUCTION

Cultivating innovating talent is the fundamental task of advanced education. It is also the main way to participate in the construction of national innovation architecture as colleges and universities. Different countries have the different definitions of innovative talents, but it is in full agreement about of primary quality of innovating talent. The innovating talents are the all-round developed talents.

Its characteristic of computational thinking is formalization and automatication. It is the important concept involves the essence problems of computer science. Computational thinking is a key component of the architecture of scientific thinking. As the formation and development of modern society, "using computational thinking to consider and declare question" become a universal behavior. It deepens the effect of computational thinking, and makes it become the primary qualities required of everyone. Therefore, innovating talents should have abilities of computational thinking. Shown in Figure 1.

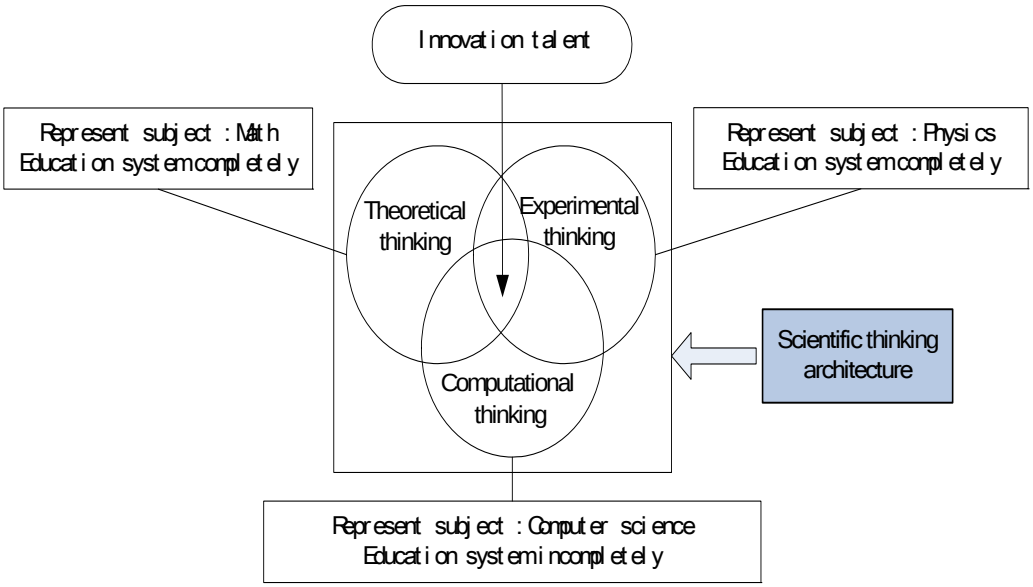

Figure 1 : Think architecture of innovation talents

As indicated in Figure 1, scientific thinking architecture consists of theoretical thinking, experimental thinking and computational thinking[1,6]. Further, mathematical subject represents theoretical thinking; physical subject represents experimental thinking. It has formed a relatively complete education process and developed education architecture in the long history whether mathematics education or physical education from beginning, intermediate, to advanced education.

Computer science subject represents computational thinking[2-4]. Because of the newest concept, shortest introducing time, there are many problems. Its education architecture is not developed. It is an important project in the advanced education; especially computer education at present is dealing with the problem of computational thinking and finding a correct function to conduct computational thinking education.

COMPUTATIONAL THINKING IS A PRIMARY QUALITY FOR THE INNOVATING TALENT

In March 2006, the dean of the Department of Computer Science of Carnegie Mellon University, Professor Jeannette M. Wing published articles Computational Thinking in Communication of the ACM journal, proposed concept of computational thinking first, caused extensive research and discuss in computer world, educational circles, philosophical circle and sociology at home and aboard.

At present, computational thinking has become a wide concerned important concept in the international education, especially in computer world. The view that "Computational thinking will become everyone's skill set" has been recognized widely and reached broad consistently in the community, received unprecedented attention. Since computational thinking is required skills for everyone, it should be the primary quality of innovating talent first.

The cultivation of innovating talents who have the quality of the computational thinking is very seriously at home and abroad. In the United States, for example, in 2005, the Information Technology Advisory Committee reported the Computational Science: Ensuring America's Competitiveness proposed, "Computational science is an area that is central to the Nation's long-term technological leadership". In 2007, the NSF (National Science Foundation) started CPATH plan, invested 6 million dollars in that year, invested 5 million dollars in 2008, invested 10 million dollars in 2009 in succession, used for training innovating talent who master the core concept of computational thinking. Meanwhile, the NSF came up with a plan that in "computational thinking and innovation "as the core, approved 72 projects in that year, invested 42 million dollars. And it invested 26 million in 2009, invested 36 million in 2010 in succession, aims to cultivate " computational thinking " to promote the field of natural sciences and engineering technology revolution. In recent years, the United States invested in projects with the core of computational thinking continues to grow[5,6].

In 2009, Chinese Academy of Sciences reported China - 2050 information technology development roadmap pointed out "Cultivation of computational thinking is the basis of other information technology challenges. The fourth national conference in 2010 reached a common view that "Computational thinking is an indispensable link in the cultivation of talents", and carried out a project application with "Computational thinking: ensuring students' innovating ability" as its theme on nationwide. In April, May and July 2013, three national meetings reached a common view that "Cultivating computational thinking by sticking to application - oriented process". The National Natural Science Foundation of China, the Ministry of Science and Technology, the Ministry of Education organized several project applications, to support research on the computational thinking.

The above events and data show that the cultivation of innovative talents cannot be separated from the computational thinking education. At home and abroad for "computational thinking is an indispensable link in the cultivation of innovating talents" have a common understanding and have put in a lot of effort to it. China in the process has been through "cognition-value- implement" three development stages, now in its third stage[2,6]. In order to implement computational thinking, it is necessary to solve the problems of computational thinking education.

EXISTING PROBLEM AND CAUSE ANALYSIS IN COMPUTATIONAL THINKING EDUCATION

Analysis of the current situation, has many computational thinking issues in education, the cultivation of innovation talents is the key to solving the problems of computational thinking, study on the each level of computational thinking education policies and programs. Although we have a common understanding of the importance of computational thinking, there is no better way to promote and implement it. The computational thinking education is not conducive to the desired results now. This is because a considerable number of people have an incorrect concept, defined cultivation of innovation talents' computational thinking education as knowledge of computers or computer instrumentalization education. For specific performance as shown in 3.1 and 3.2.

Computer instrumentalization

One of the incorrect orientation in computational thinking education is that evaluates the education of computational thinking to "computer instrumentalization". Because computer science is treated as a tool subject for a long time, the many practitioners of computational thinking are trying to get the educational target through instrumentalization of education. Obviously, computer instrumentalization education is only skill education, but at present, the two sides of teaching and

learning neither have well measures to convert the skills development of calculated tools to the training of computational thinking ability.

Computer professionalization

The other one of the incorrect orientations in computational thinking education is that evaluates the education of computational thinking to "computer professionalization", what attempting to teach computer courses system for cultivation of computational thinking ability. Computer subjects have their own curriculum system. That makes other subjects must attach a simple computer professional courses in order to achieve the purpose that pervading computational thinking education and training innovation talents. The drawbacks are obvious, its cost, feasibility and effectiveness are far from satisfactory.

The cause of this problem

The fundamental cause of these issues is that the current implementation of computational thinking education has not yet been reflected on the essences of computer science. Before the computational thinking education, you first need to understand what is calculation, what a computer is. Computational thinking is not taught as calculate machines; instead of calculate science. By computational thinking education wants to achieve learning to use the basic approach of computational thinking to the problem, not learning to use computers. Specifically, it requires the following capabilities: ① can converting professional issues to instructions that computers can be processed; ② can using computational thinking methods and patterns in real work; ③ can integrating rules of computational thinking into personal characters and qualities.

DISCUSSION ON WAYS AND STEPS TO SOLVE THE PROBLEM

The fundamental way to solve problems is to embody the essences of computer science in computational thinking education. As studying mathematics and physics is not to become mathematicians and physicists, learning computer courses are not to be a computer scientist, but rather form the quality and ability of the scientific thinking through the training of computer courses. Study on the essences and core concepts of calculation contained in the computer knowledge, to get multi-level computational thinking characteristics and form architecture of education, is the effective way to solve current problems of computational thinking education. Only computational thinking education goes out of the quagmire, it is possible to cultivate innovation talents with computational thinking.

However, the essence of computer science is not brief texts can description clearly; it is a scientific issue. Needed work through practical, in-depth studies, scientific extract and summarize from the computer knowledge system. The overall approach is to analysis the essence and the core idea of computer problems by studying the main computer system, extract the feature point of computational thinking, construct computational thinking tree, research concepts and methods of computational thinking, discuss the multi-level computational thinking education policies and strategy, in order to solve problem that computational thinking is reduced to "computer instrumentalization" and "computer professionalization", eventually contribute to the implementation of the education of computational thinking, make the effort for the cultivation of innovation talents. Specific methods and implementation procedures as follows:

Step 1: Extracting the feature point of computational thinking

Study on the core ideas and methods of solving problems in computer science, to analysis the essence of solving calculation; be summed up in characteristics of computational thinking concepts, the target is divided computational thinking into some characteristics points.

Computational thinking represent by computer science. Computer knowledge is not the only choice for computational thinking, but is the best way. The core ideas and methods to solve problems in computer science is reflecting the essence of the calculation, also embody the characteristics of

computational thinking. Thus, the study of computational thinking should start by studying computer science.

At present, it is recognized, "computational thinking is a human scientific thinking on the characteristics of abstraction and automation"[1][2][3][5][7]. In reality, a real problem to expect solving by the machine calculation, you must have it formal expression, and the formal expression must be limitations and calculable automatically. Thus, computational thinking can also be said to it has formal, procedural and machinery characteristics of the thinking form. Through research the core ideas and methods for solving problems in computer science, can be summarized the concept of typical computational thinking characteristics, divided into a number of feature points, like computing, abstraction, encapsulation, compatibility, representation, storage, concurrent, parallel, communication, collaboration, recursion, embedding, decomposition, transformation, redundancy, fault tolerance, balance, optimization, tiered, qualified, independent, backtracking and so on.

Step 2: Constructing computational thinking tree

Seek to prove these computational thinking feature points divided from early stages; extract the essences of calculation on architecture concepts. The target is classifying, supplement and merging, optimization and standardization the computational thinking feature points, in order to construct computational thinking tree.

Computer science exist several levels and branches. The different branch faces to different issues, have different emphasis to solve the issues, used different abstract methods, achieved different formal results, but many methods have the same core ideas and the same the essence of calculation. The difference lies in different direction or different stages of development. For example, from structured programming to object oriented programming, the concept has changed a lot. Somebody even say learning structured program interferes with the establishment of object-oriented concepts. This view ignores the essences of the calculation. Whether structured programming or object oriented programming, always follow abstract, information hiding and encapsulation, modularity, etc. Throughout they obey the coherent principles of software design. For example, whether structured programming or object-oriented programming; the information hiding is done through the abstract, achieve the purpose of encapsulation; the result is a modular. Just an abstract level, methods of information hiding and granularity of the encapsulation, modular logic is different. In other words, whether structured programming or object oriented programming, they are the same strain, never conflict. This means that extracting computational thinking feature points from the structured and the objects oriented knowledge only complements one another perfectly, not depart from each other. This conclusion applies to all the courses of the computer.

Step 3: Implementing the computational thinking education

To be guided by computational thinking trees, construct concepts and methods performance computational thinking. The target is with computational thinking as the core, implementing strategies for the computational thinking education and multi-level computational thinking training scheme; achieve the talent education convert as "skill (instrumentalization) →ability (professionalization) →innovation (thinking)"

In terms of two major problems existing in computational thinking educations, the fundamental reason is not embody the essential features of calculation. "Computer instrumentalization" is organized education in a one-sided concept of computer, only skill oriented education that can be completed. This mode of education is for neither the computer professional students nor others. It is unreasonable for computational thinking education and a simple computer education, its harmful education methods without any profit. "Computer professionalization" is organized education on computer knowledge points, relatively access close to ability-based education compared to "computer instrumentalization". Then the computational thinking is organized education on the essence of calculation, its innovation-based education. The computational thinking should achieve the conversion from skill-based, ability-based to innovation-based.

Step 4: Internalizing the good factors in personal character and quality.

Many features points of computational thinking extracted from computer knowledge system are factors of good character. For example, coordination, backtracking, compatibility, the principle of compromise, tiered, relative independence, reliability, robustness, and so on. And many of them are could be referenced by everyday life, such as the standard expression, log backups, perform their respective duties, modularization, and load balancing, so on. Features points of computational thinking combine with development of character and quality, live up to impart knowledge and educate people.

EXTRACTING THE ESSENCE OF CALCULATION FROM COURSES

Here are two typical cases from which reflect the understanding of the essences of computer science, show the sample of features points of computational thinking. The cases extract features points of computational thinking based on programming language course. Programming language is a good media to educate computational thinking.

"Language minor" programming education

In "computational thinking" education model, program design thinking become teaching mainstay of programming subjects, it emphasizes that using architecture concept to treat programming, educates programmer following the guidance of theory of programming and software engineering ideas. Languages are as a tool for expression design ideas. It emphasizes choosing suitable language tools to code and express calculation according to characters of issues.

In order to achieve the target that computational thinking education, need to adopt "language minor" education model, to replace "language major" education model. Shown in Figure 2 & Figure 3.

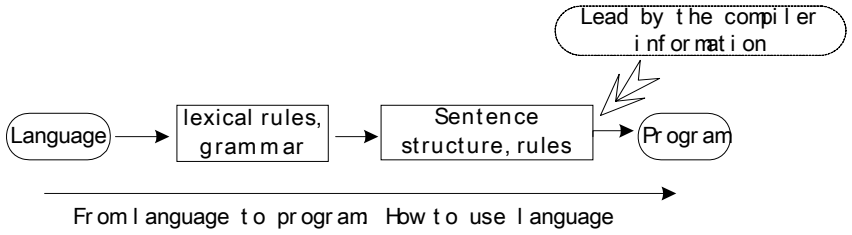

Figure 2 : "language major" education model

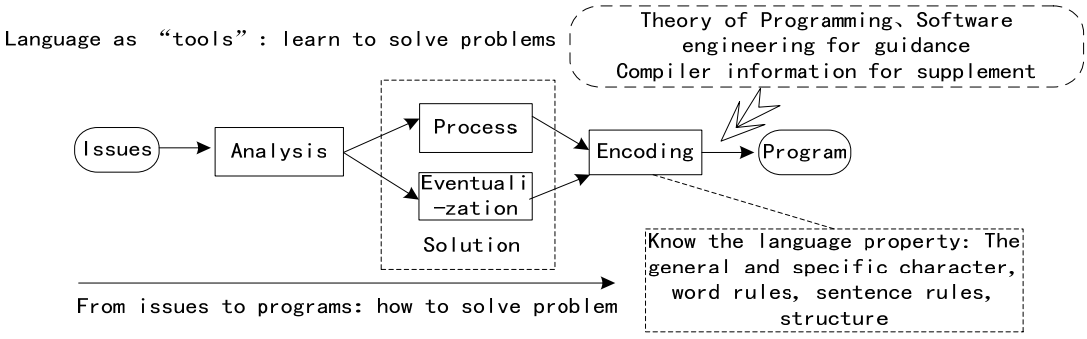

Figure 3 : "language minor" education model

"Language major" education model are not longer adapt to the need of cultivation of innovation talents. Teaching process from language to program spends many teaching resources on lexical rules, grammar, and sentence structure. The result is that the programmers have learned a language, not learned the methods to analysis and solve problems. In other words, the students have not the ability of computational thinking.

Usually, “language major” education needs 10-12 class hour to finish the program “multiplication table”. These class hours mainly are used for learning lexical rules, grammar, and sentence structure. In “language minor” education, “multiplication table” can be finished in 2-4 class hours. After several years of practice, we reached good results. These class hours mainly introduce what is programming, lead students to think from computational logic on multiplication table to the thought of algorithm, lead students to express algorithm in language.

Through the “language minor” computational thinking education, make the trained personnel have the quality of software developers, with potential of system designing and analysis. The relationship in the system implementation, design and planning, as well as the relationship in the skills, abilities and thinking, were shown in Figure 4.

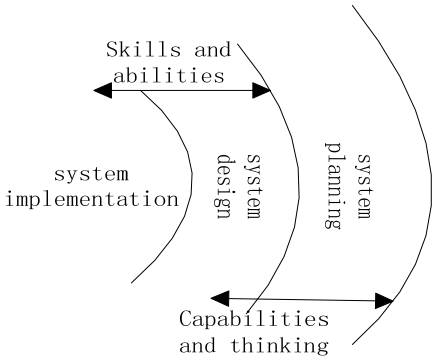

Figure 4 : Talents quality of system development

Extracting the recursive thinking

The methods of computational thinking can list a lot, the typical ideas of them involve the thinking models of processing the whole and the part, in order to simplify the complex issues, to miniaturize the large problems; the structural thinking, find models for solving problems; the thinking models of classification; the goal conversion; the contrary thinking; the guess association and so on. In which the recursion is a way to miniaturize the large problems, it is very worth for the training of thinking. However, the teachers and students who have the experience all know, the recursion is often difficult to interpret and understand, especially in the case of confined to a specific language.

Extraction the calculation essences of recursion, interpreted as “deliver” and “return”. Each process respectively is expressed from “issues”, “issues description” to “coding achieving”, better conveys the core issue of the calculation. Shown in Figure 5.

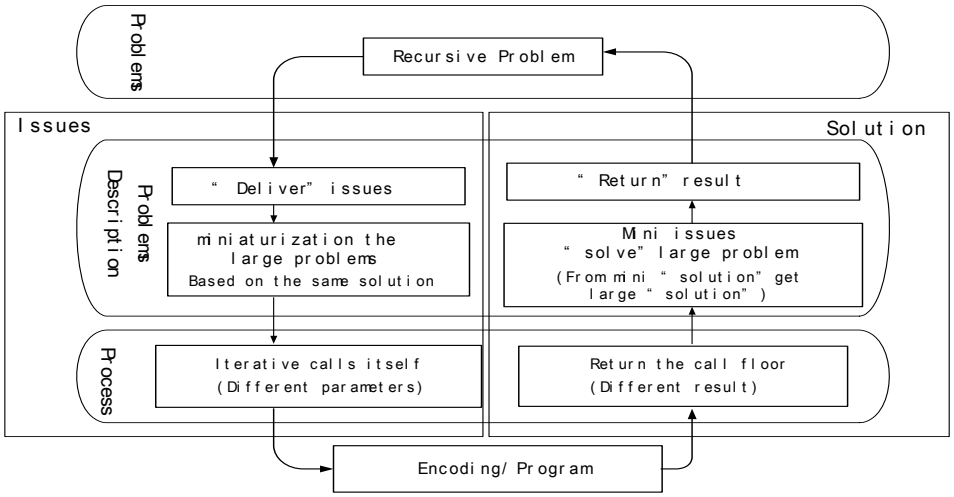

Figure 5 : Recursive computational thinking

CONCLUSION

Computational thinking involves the essence problems of computer science, is the basis of other information technology. Computational thinking is a primary quality of innovation talents, and will be the essential primary skills for modern peoples. At present, the problem existing in computational thinking education is “computer instrumentalization” and “computer professionalization”. Neither “computer instrumentalization” skills education nor “computer professionalization” abilities education is able to achieve the fundamental target of computational thinking. They could not get the expected results of computational thinking. One of a solution is reflecting the essence of the calculation in computational thinking education, rather than forming the complete knowledge of computer systems without the characteristics of computational thinking. The paper showed the process that is forming a the architecture of computational thinking education completely through construct computational thinking tree, in order to resolve fundamentally the existing problems of computational thinking education, to achive the target that cultivating innovating talent through computational thinking education.

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