Teaching Strategy for High School Information Technology Courses Aiming at the Cultivation of Computational Thinking: Take Building a Small Information System as an Example

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***Abstract*—Computational thinking is one of the four core competencies of the general high school information technology curriculum. When implementing the teaching of Compulsory 2 Information System and Society, front-line teachers often are struggled to the way how teach students well to develop of computational thinking. Through the combing of the eight levels of Gagne's learning theory and the connotation of computational thinking, combined with the foothold of computational thinking training in the Compulsory 2 module, a "Four Stage Cumulative Learning" strategy for building a small information system is proposed. The training in the module provides an exploratory teaching design idea and implementation strategy.**

***Keywords*—computational thinking, four stage cumulative learning, build a small information system**

I. Statement of the Problem

With the progress of technology and the development of society, learning no longer only emphasizes the memory of knowledge and the acquisition of high scores, but prepares for the application of what we have learned to solve practical problems in the future and adapt to the society [1]. Consistent with this concept, the new curriculum concept for the cultivation of core literacy is gradually landing in the classroom of ordinary high school. There are two compulsory modules in the information technology curriculum of senior high school. Compulsory 1 mainly focuses on the two major concepts of "data" and "algorithm", while Compulsory 2 further carries out the study of the two major concepts of "information system" and "information society" on the basis of Compulsory 1, so as to completely construct the four major concept systems and achieve the cultivation of discipline core literacy. In the specific course implementation process, many front-line teachers believe that the learning of two major concepts related to Compulsory 2 is difficult to implement the cultivation of computational thinking, and there are puzzles of "difficult implementation" of computational thinking.

II. Analysis of the Problem

The reasons for this problem may be as follows. The first one is people has less understanding of the intrinsic, by nature people believe computational think is only related with computation process. For example, they think it is only generated during data calculation, computer programing and so on. The second one is not fully understood about the goal set in compulsory module 2. They simply categorized this into "information system" while ignored the fundamental concepts of this module, which should include much more disciplinary approach. The third one is people might misunderstand the term "experiment" in the subject, so they could not find the key points of subjects resulted in teaching experiment just follow the process instead of situational teaching.

The reasons for the problems are essentially related to the lack of specific teaching strategies and methods implemented by computational thinking in Compulsory 2. When teaching in Compulsory 2, the major challenge is how to deal with the complexity of the system [2]. As a high-level thinking, the cultivation process of computational thinking needs the support of challenging subject learning. Therefore, we can solve the problems by using the ability level and training stage of computational thinking, carrying out challenging subject learning in Compulsory 2 through specific teaching strategies.

A. The Connotation of Computational Thinking

Computational thinking refers to a series of thinking activities that individuals use in the field of computer science to form solutions to problems. Students with computational thinking are able to define problems, abstract features, establish structural models, and rationally organize data in information activities in ways that computers can handle; by judging, analyzing and synthesizing various information resources, use reasonable algorithms to form problem-solving methods; summarizes the process and method of using computer to

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solve problems, and migrates to other related problem solving [3].

B. Ability Level of Computational Thinking

Computational thinking is a problem-solving way of thinking [4]. Observing the capabilities of students with computational thinking mentioned above, it is not difficult to find that it is a kind of high-level thinking, and its development needs a process from low-level to high-level. If the capabilities of computational thinking can be divided into levels, the process can have a step-by-step target. According to the capabilities of "Computational Thinking" in the High School Information Technology Curriculum Standards, and refining the description of the capabilities of "Computational Thinking" in the Curriculum Standard, and studying the ability performance of students, the division of the ability level of computational thinking is shown in Table I.

TABLE I. LEVEL DIVISION OF STUDENTS' COMPUTATIONAL THINKING ABILITY

Levels	Capability characteristics	Course standard [3]
1	A smattering of knowledge	Prep
2	Simply accumulated	Level 1
3	System construction	Level 1
4	Ability transfer	Level 2

C. Cultivation Stage of Computational Thinking

The above analysis of the level of computational thinking ability shows that its cultivation cannot be achieved overnight. Referring to the stage of cultivating computational thinking proposed by the development of thinking based on Piaget's cognitive development stage theory [5], four stages of cultivating computational thinking are set, as shown in Table II. The thinking characteristics of each stage are consistent with the ability level characteristics of computational thinking. The stages of cultivating computational thinking should also be proceed step by step in an orderly way.

TABLE II. STAGE DIVISION OF CULTIVATING COMPUTATIONAL THINKING

Stage	Description	Thinking characteristics	Capability characteristics
1	Pre-stage	Sentience	A smattering of knowledge
2	Preparation stage	Symbolic	Symbolization of knowledge
3	Formation stage	Systematic	Systematic construction of knowledge
4	Development stage	Hypothetic	Hypothetical construction of knowledge

III. COUNTERMEASURES AND IMPLEMENTATION OF PROBLEMS

In summary, it provides ideas and methods for formulating teaching design strategies pointing to the cultivation of computational thinking. The formulation of classroom teaching strategies is inseparable from the theory and basis of cognitive psychology. The famous educational psychologist Gagne's theory explains most of the classroom learning and proposes practical teaching steps [6]. The complexity level system of intelligence and skills based on Gagne's learning theory well explains the development and formation process of students' thinking and cognitive ability.

A. The Construction Idea of "Four Stage Cumulative Learning" Strategy

As mentioned in previous page about the struggling to foster computational thinking, it is key to find a solution to fix it, as well as a tactical plan of subject learning. The "complexity level of intellectual skills" [7] based on the Gagne's theory provide an outstanding tool that help us to generate the "Four Stage Cumulative Learning" methodology shown in Fig. 1.

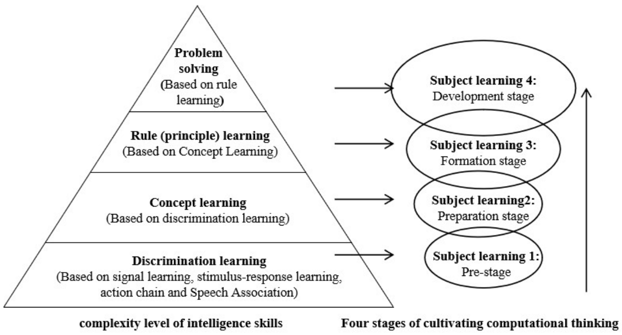

Figure 1. Four stage cumulative learning strategy.

With the "Four Stage Cumulative Learning" methodology, it is able to break a complex case into 4 different learning phases, and the subject of each phase is independent with full learning cycle. There is incremental goal setting and complexity through the entire 4 learning phase, the teaching methodology is also identical from simple to complex, details to virtualization gradually.

B. Implementation of "Four Stage Cumulative Learning" Strategy

In view of the cultivation of computational thinking in Compulsory 2, we need to find a foothold before implementing the "Four Stage Cumulative Learning" strategy. The content of Compulsory 2 focuses on the four elements of "information system", such as hardware, software, data and personnel. Among them, the study of building a small information system is based on a full understanding of the composition of the information system and the working principle of the information system, and has the advanced ability to deal with complex problems, such as system planning, scheme design and final technical realization. This is an important foothold for the cultivation of computational thinking in Compulsory 2. Although a small information system is built, but "a sparrow may be small but it has all the vital organs" which is faced with complex system problems and needs to be implemented step by step. Therefore, the learning of building a small information system is regarded as the foothold of the teaching practice of cultivating computational thinking in the Compulsory 2.

The specific implementation stages are as follows:

1) Pre computational thinking stage with a smattering of knowledge

The implementation of Stage 1 discrimination learning mainly focuses on “deconstructing the model and identifying elements”. By deconstructing a small information system model, we can determine the elements and structure of the information system, and begin to prepare for the construction of the information system. For example, with the help of the small information system model shown in Fig. 2, we can intuitively learn that the system with B/S structure needs elements such as a computer network, Browser, Server, so on. So as to form an intuitive understanding of these elements and the structure and environment of the system. However, the non intuitive parts of the model are easy to be ignored such as protocols and databases in information systems. It seems that although the knowledge is incomplete, students need such intuitive cognition to meet the challenge of system complexity.

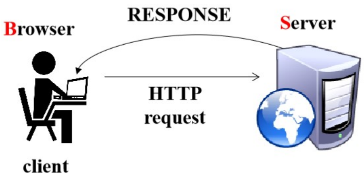

Figure 2. A small information system model.

The thinking ability at this stage belongs to the degree of “half understanding” through entity perception. From the perspective of thinking intensity, it is in the low-level pre computational thinking stage, which accumulates strength for subsequent learning.

2) The preparation stage of computational thinking with the concept understanding capability

The implementation of Stage 2 concept learning mainly focuses on “following logic and learning concepts”. Through a set of folder structure in the information system, we can sort out the construction logic of the information system, and understand the location and functions of various types of files in the information system, and understand the operation and principle of the information system, so as to learn how to configure an ordinary computer in the information system to become a server in the system.

The small information system with B/S structure needs a series of different types of files, which are designed by special software. These files can play their functions only in the appropriate folder. They perform their respective duties and work together to make an ordinary computer play a service role in the information system. As shown in Fig. 3, it clearly shows the role of several important software and important documents in the working process of information system. For example, the Flask for publishing web services, the python language for designing hypervisors (such as logistics.py), the HTML language for designing web files (such as index.html), and the SQLite3 database for data storage (such as data.db) *et al.*

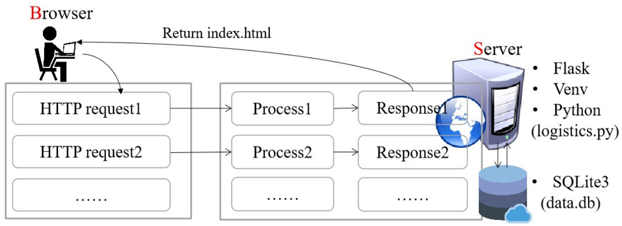

Figure 3. Working process example of a small information system.

Then, by creating folders on the computer, as shown in Fig. 4. Through the study of a series of different types of files required by the system, we know how they are related and how to work together. It lays an important foundation for the next process of information system construction.

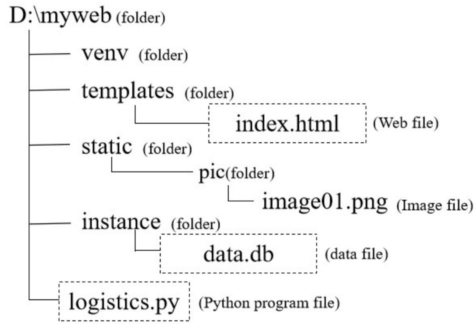

Figure 4. The files of a small information system.

From the analysis of thinking intensity, it is in the formation stage of computational thinking with the systematic construction of knowledge.

3) The formation stage of computational thinking with the systematical thinking capability

The implementation of Stage 3 rule learning mainly focuses on “clarifying rules and learning methods”. On the basis of the above stages, we can learn how to “assemble” various elements of the information system, and learn the rules and specific methods of constructing the information system, so as to realize the “seamless” assembly of the system. This is not only an important stage of information system construction, but also the formation stage of computational thinking and knowledge system construction.

For example, as shown in Fig. 5, the request is submitted by the client to the server, and then the service listens to this response and makes the correct response. We need to understand the “connection” rules between “request and response” and how to design them. In this stage, students need to learn more rules like this, and design more “connection” points to realize “seamless connection” between adjacent elements and make the system run smoothly.

This learning process needs the thinking ability of systematic construction. From the analysis of thinking intensity, it has been in the formation and growth stage of high-level computational thinking.

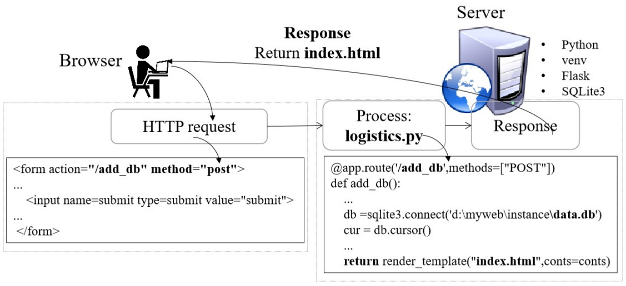

Figure 5. Request and response in a small formation system.

4) The development stage of computational thinking with the system development capability

The implementation of Stage 4 thematic learning mainly carries out the learning with the theme of "overall scheme". Based on the cumulative learning in the above stages, this stage mainly focuses on the scheme template design of small information system, as shown in Fig. 6.

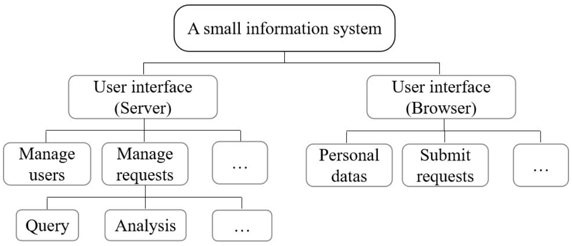

Figure 6. A scheme template for a small information system.

As a system designer, students carry out the overall design according to the data flow in the information system and the logic of "input" → "storage" → "transfer" → "output", so as to form a system scheme template. Therefore, it not only trains the students' ability of induction and generalization, but also develops the ability of hypothesis and logical reasoning, so as to obtain the computational thinking ability to solve problems.

C. Hierarchical Assessment to Promote Capability Transfer

The reason why it is called "cumulative learning", the former stage should be the learning basis of the latter stage. The evaluation plays a very important role in all stages of cumulative learning and should be maintained from the beginning to the end.

The "Structure of the Observed Learning Outcome" proposed by Biggs, inherits and develops Piaget's theory of children's cognitive development stage, which is a qualitative evaluation method characterized by hierarchical description [8]. SOLO classification theory is not only a systematic evaluation method from point, line and surface to three-dimensional, but also a cognitive process from simple to complex [9]. Using SOLO classification evaluation theory to design hierarchical ability evaluation, so as to promote students to consciously improve their problem-solving ability, and then realize the layer by layer transfer of capabilities.

According to the stages of cultivating computational thinking mentioned above, students' computational thinking ability should be improved step by step, as shown in Table III.

TABLE III. PROMOTE THE GOAL OF COMPUTATIONAL THINKING ABILITY IN LAYERS

Structure	**Cultivating Stage**	**Levels of capability**	**Level**
Single point structure	Pre-stage	A smattering of knowledge	A
Multipoint structure	Preparation stage	Simply accumulated	B
Relational structure	Formation stage	System construction	C
Extended structure	Development stage	Ability transfer	D

According to the goal of computational thinking ability in layers, we further formulate the "Evaluation form of phased learning activities" in the "four stage cumulative learning" of building a small information system to monitor the learning level of each stage, as shown in Table IV.

TABLE IV. EVALUATION FORM OF PHASED LEARNING ACTIVITIES

Levels of capability	**Description of the ability and goal of Computational Thinking**	**Level**
A smattering of knowledge	Be able to identify and learn information systems.	A
Simply accumulated	Be able to complete the construction of small system; Learning related concepts	B
System construction	Can extract the construction rules, principles and methods of small information systems	C
Ability transfer	Be able to complete the construction of small logistics system	D

In the sense of structure, the structural level of SOLO classification theory can clearly correspond to the complex process of thinking level from shallow to deep, so as to provide theoretical support for the evaluation of students' learning "what goal to achieve", "what level to be at present" and "how to develop" [10]. It has strong operability to evaluate with the goal of computational thinking ability with the characteristics of problem decomposition.

IV. PRACTICAL REFLECTION ON THE STRATEGY

The strategy of "Four Stage Cumulative Learning" takes the logic of information technology subject in senior high school as the clue, takes the discipline thought method of "top-down and stepwise refinement" as the core, reforms the content and presentation mode of Compulsory 2 teaching materials, and breaks through the unit barriers of chapters, so as to create a four stage cumulative theme learning sequence integrating "concept, method and ability". It follows the cognitive law and pays attention to the joint action of internal and external factors. Meanwhile, it emphasizes problem decomposition, overall planning and orderly implementation. Besides, it pays attention to the ability improvement of accumulation over time.

A. Following the Cognitive Law for a Better Reflection of the Gradual Ability Improvement

When teaching to build a small information system, people usually start with system analysis and planning, and then design and operate. However, when students really want to establish an information system, it is difficult to apply their knowledge to practice. Therefore, it is difficult for them to start with analysis and planning. They are generally used to starting with simple basic skills. In view of this, when the strategy is applied to build a small information system, the learning of building a basic system framework is carried out step by step from recognition model to concept learning and rule refining. On this basis, as a system designer, further consider the needs of the system, expand the functions of the system, improve the system scheme, and make it universal. The implementation of "Four Stage Cumulative Learning" strategy is based on students' intuitive cognition. Through four stages of cumulative learning and evaluation, students' ability is significantly improved. In this process, computational thinking has been gradually cultivated, and good results have been achieved in practice.

B. Effectively Implementing the Cultivation of Computational Thinking

The four teaching steps are defined against the "four stage cumulative learning" strategy, which is based on the Gagne's theory. Referring to the Piaget's cognitive stage theory, four levels of capability for the cultivation of computational thinking are set. The evaluation structure is reference to the Hypothetical Cognitive Structure proposed by Biggs. Integrated these three theories, and developed the "Four Stage Cumulative Learning" strategy, implemented in Compulsory 2. Building a small information system as an example, the computational thinking is effectively cultivated in four stages.

C. The "Four Stage Cumulative Learning" Strategy Needs to Be Further Improved

However, there are still a few issues existed during the implementation, and need be further optimized. Such as how to synchronize teaching and learning. The duration of class is not enough sometime, and the learning capability is different among students. Although they are "digital natives", their ability to operate computers is quite weak. Students need teachers' "patient guidance" to master an operation method. There are some limitations of time-consuming and class hours required to carry out stage evaluation. Therefore, the "Four Stage Cumulative Learning" strategy needs to be further optimized.

V. Conclusion

The "Four Stage Cumulative Learning" strategy aims to cultivate the computational thinking in Compulsory 2, and take building a small information system as an example, through the four learning stages, the computational thinking is effectively cultivated step by step. In the process of studying the "Four Stage Cumulative Learning" strategy pointing to the cultivation of computational thinking, classical cognitive theories are sought as an important theoretical support. When implementing this strategy, we decompose the complex problem, carry out systematic planning and phased implementation, experience the cumulative learning process, and achieve obvious teaching results in practice.

The cultivation of computational thinking is a process of continuous accumulation from "quantitative change to qualitative change". In addition to strengthening the learning of subject knowledge, we also need to further study the classical pedagogy theory, explore the characteristics of the learning cognitive ability of the new generation of digital aborigines, and explore the teaching and learning strategies under the environment of new technology.

Conflict of Interest

The author declares no conflict of interest.

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