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COMPUTATIONAL THINKING AND THE NEW CURRICULUM STANDARDS OF INFORMATION TECHNOLOGY FOR SENIOR HIGH SCHOOLS IN CHINA

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CHALLENGE FOR IT EDUCATION

As information and communication technology (ICT) spreads rapidly around the world, digital technologies have influenced the way in which we learn, live, and work. Furthermore, in recent decades, intelligent technologies, including artificial intelligence (AI) and emerging advanced technologies empowered with AI techniques, such as the Internet of Things (IoT), virtual reality (VR)/augmented reality (AR) enhanced by AI and intelligent terminal devices, have risen to the forefront of public discussion. The impact of digital technologies is already being felt across all sectors of society, such as transportation (e.g., smart cars), health care, the education of low-resource communities, public safety and security, employment and the workplace, and entertainment (Stone et al. 2016). Digital technologies not only enable societal changes but people also depend on technologies to cope with the information society. The new generation of students is often labeled “digital natives” or the “Net generation.” However, these students’ ICT use is much more limited in scope than originally portrayed both in the Western and Eastern context (Aesaert and van Braak 2015; Li and Ranieri 2010). Consequently, it is essential for the education system to provide students with adequate competencies to cope with such a society. In the context of the digital age, several terms have been proposed over the last few decades. Digital competence, ICT literacy, and digital viability have all been used to identify and describe what students should be able to achieve within a digital context. School-based initiatives, in particular the information technology (IT) curriculum, is considered as an essential way to prepare students for the digital age.

Liu, Ren, Li, and Zhao (20018) emphasize that the IT curriculum in China has passed through three stages over the last forty years. The first stage (up to the 1980s), often called pilot computer education, was integrated into nineteen pilot high schools as an elective course in 1982, aiming to promote students' computer literacy, especially focusing on "the ability to use a spreadsheet and a word processor and to search the World Wide Web for information" (National Research Council 1999, 11). The second stage (1980s through 1990s), often called computer education, still focused on computer literacy and began to be integrated into IT application in primary and secondary schools. In the third and current stage (1990s through 2000s), the Ministry of Education released the guidelines for ICT curriculum in primary and secondary schools (trial), and computer education was renamed "IT Education" (Liu, Ren, Li, and Zhao 2018). By 2015, 100 percent of high schools, 95 percent of junior high schools, and 50 percent of primary schools had already set IT as a compulsory subject.

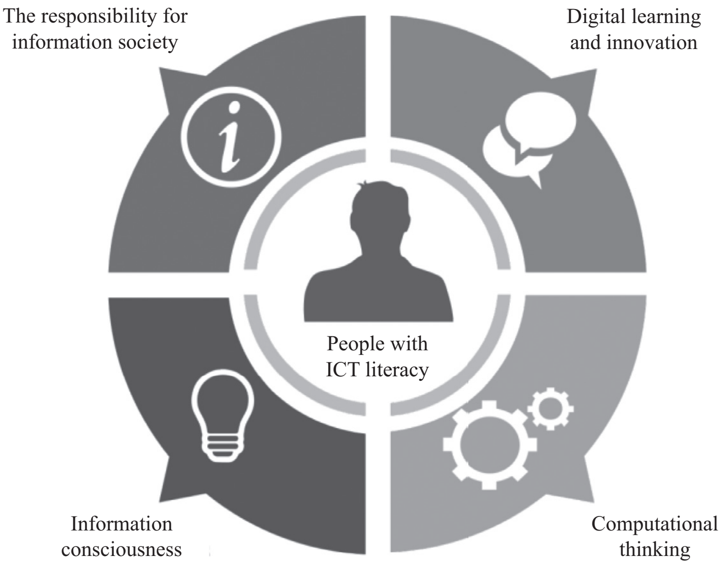
However, the K–12 IT curriculum in China currently faces many challenges. Firstly, the education objective still focuses on fostering students' basic technical skills (Liu, Ren, Li, and Zhao 2018). In the context of the digital age, the objective of the IT curriculum should not only cultivate students' ability in applying technology but also include problem-solving ability and understanding the principle of technology. Secondly, the framework and content of IT curriculum standards need to be revised according to current technology development (Dong, Liu, and Qian 2014). Technologies, especially intelligent technologies, are taking over repetitive work and even changing the very nature of employment. It is essential that the younger generation has the opportunity to develop an accurate understanding of technology—what it is, how it works, and how it might impact their lives—to equip them with the necessary "digital survival skills" for the workplaces of the future. Therefore, the content of the IT curriculum should be revised according to technology development. Thirdly, the teaching approach deployed to develop students' ICT literacy mainly focuses on introducing technical knowledge and exercising technical skills (Xiao and Huang 2016). More effective methods should be implemented to foster students' ICT literacy, such as inquiry-based learning, problem-based learning, and collaborative learning.

NEW CURRICULUM STANDARDS OF IT FOR SENIOR HIGH SCHOOLS IN CHINA

To cope with the previously mentioned challenges and cultivate digital citizens in China, the Ministry of Education in China has released the new curriculum standards of IT for senior high school (hereafter referred to as New Standards) in 2017.

THE FOUR-KEY LITERACY OF THE NEW STANDARDS

The aim of the New Standards is to cultivate people with ICT literacy who have information consciousness, computational thinking skills, digital learning and innovative ability, and responsibility for the information society, which is called the four-key literacy of the standards (see figure 4.1).



4.1 The four-key literacy.

Information consciousness refers to the individual's sensitivity to information and his/her judgment of the value of information. Students who have information consciousness can consciously and actively seek appropriate ways to obtain and process information according to the need for solving the problem, and they will be able to notice the changes in the information to analyze the information contained in the data. Students with information consciousness could also use effective strategies to make reasonable judgments on the reliability of the source of information, the accuracy of the content, and the possible impact of the information to provide a reference for solving the problem. Students with information consciousness would be more likely to share information with team members to solve problems in a collaborative way.

Computational thinking refers to a series of thinking activities in the process of finding solutions by using the methods of computer science. Students with computational thinking can define problems, abstract features, establish structural models, and organize data reasonably in the way that computers can handle; they can form solutions by using reasonable algorithms through judging, analyzing, and synthesizing various information resources and summarize the process and methods of solving problems using computers and transfer to other issues related to it.

Digital learning and innovation refer to the ability of individuals to effectively manage the learning process and the learning resources by evaluating and selecting common digital resources and tools, and to solve problems creatively to complete learning tasks and produce innovative works. Students with digital learning and innovation literacy can understand the advantages and limitations of the digital learning environment, adapt to the digital learning environment, and develop the habit of digital learning and innovation; they can master the operational skills of digital learning systems, learning resources, and learning tools and use these to carry out independent learning, teamwork, knowledge sharing, and innovative creation as well as to promote lifelong learning ability.

The responsibility for the information society refers to the individual's responsibility in the information society in the aspects of culture, ethics, and behavior. Students with the responsibility have a certain sense of information security, and they will abide by information laws and regulations, abide by the moral and ethical norms of the information society, and abide by public norms in real and virtual spaces. They can effectively safeguard the legitimate rights and interests of themselves in information activities, and they can actively safeguard the legitimate rights and interests of others. They will pay attention to the environmental and human problems brought about by the information technology revolution, hold positive learning attitudes to new ideas and new things arising from IT innovation, make judgments rationally, and act responsibly.

Each part of the four-key literacy has three levels, and the rules and conditions of each level are defined in the standard, which could be used to determine the level achieved by high school students after completing the IT course. To solve the problem of poor connectivity between high school and primary or middle school, the New Standards specifically determines the preparatory level of each key literacy, which points out the level of four-key literacy that students should have when they enter high school. The identification of the preparatory level provides a reference standard for the IT course in K–9, which makes a clear distinction between the task of the IT course in primary and junior school and in high school.

Taking computational thinking as an example, the rules and conditions of the preparatory level and other three levels are shown in table 4.1.

THE CONTENT OF THE IT CURRICULUM IN THE STANDARDS

To select suitable content for the high school information technology curriculum, the new curriculum standard takes the key literacy as a guide and defines the general concept of information technology discipline. The new curriculum identifies four core concepts, including data, computing, information systems, and the information society. Data is the carrier of information, which is the basic processing and calculation object for information technology, and the effective processing of various types of data produces development information technology. The algorithm is the basis of the data processing method, affecting the effectiveness of data processing, which is also the basis of developing new information technology. The information system is the materialization of information technology that comprises the basic objects for people to use, recognize, and understand information technology. The information

Table 4.1 The rules and conditions of the levels for computational thinking

Level	Computational thinking
Preparatory level	• understand the advantages of digitalized information in daily life • be able to identify key features for a given simple task and draw a flowchart for completing the task • understand the value, processes, and tools of processing information and be able to select the right tools according to the needs
Level 1	• be able to conduct a needs analysis for a given task and identify the key issues that need to be addressed • be able to extract the basic features of the problem, abstract the problem, and express the problem in a formalized way • be able to use basic algorithms to design solutions to problems and use a programming language or other digital tools to implement this solution • be able to use the appropriate digital tools or methods to obtain, organize, analyze data, and transfer the process to other related issues
Level 2	• be able to use formalized methods to describe problems and use modular and systematic methods to design solutions to complex problems • be able to correctly distinguish the various data involved in the problem-solving process and use the appropriate data type for representation • be able to design or select the appropriate algorithm for different modules and use the programming language or other digital tools to implement the functions of each module • be able to integrate the functionality of each module with the appropriate development platform to achieve a total solution
Level 3	• be able to use the principles of information system design to conduct a more comprehensive evaluation for information-based solutions and use appropriate methods to iteratively optimize solutions • be able to transfer the process of using IT to solve problems to the solution of other related problems in daily life and the learning process

society is the result of the influence of information technology on human society. Recognizing and understanding the social form of the economic, political, and cultural activities of the information society, adapting to and obeying the corresponding rules, is the premise of the survival and effective self-development in the information society.

According to the key literacy and big concept of information technology discipline, the New Standards determines the structure of the curriculum content, as shown in table 4.2.

The required part of the information technology course aims to realize the all-around development of students, and the selective required part aims to promote the deep development of students' personalities. The foundation content emphasizes that students can understand the essence of information technology from the theoretical level and scientific point of view, which is the common basis of all students' learning, and the contemporary content focuses on making students understand the latest technology and mastering the basic methods of application, design, and development of new technologies to form the consciousness of innovative application of new technologies.

Both practice and theory are emphasized in the new IT curriculum. In the practical aspect, the emphasis is placed on developing students' practical skills to adapt to the needs of the new era, such as 3D design and creativity, open-source hardware project design (engineering), and mobile application design (network). On the theoretical aspect, the content

Table 4.2 Content structure of the IT curriculum

Big concepts	Required part	Selective required part	Selective part	Character
Data algorithm	Data and computing	• Data and data structure • Data management and analysis • Basics of artificial intelligence	Basics of algorithm	Foundation
Information system Information society	Information system and society	• Basics of network • 3D design and innovation • Open-source hardware design	Design for mobile app	Contemporary

of data and computing, information systems and society, data structure, data management and analysis, artificial intelligence preliminary, and algorithmic preliminary are set to cultivate students' computational thinking ability.

COMPUTATIONAL THINKING AND KEY LITERACY OF IT

The concept of computational thinking (CT) was originally introduced in Seymour Papert's book *Mindstorms: Children, Computers, and Powerful Ideas* (Papert 1980) with his creation of the programming language LOGO. Papert (1980) refers to CT primarily as the relationship between programming and thinking skills. Unlike Papert's, many definitions of CT in the twenty-first century emphasize the concepts that are commonly engaged in programming or computer science (Zhang and Nouri 2019). In one of the most popular definitions, Jeannette M. Wing (2006) defines computational thinking as "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science, which includes a range of mental tools that reflect the breadth of the field of computer science." Wing argues that computational thinking is a fundamental skill for everyone, not just for computer scientists, and is a basic literacy of people's understanding of problems, analyzing problems, and proposing solutions in the information society. Computational thinking is essentially a kind of thinking method or thinking activity that can solve problems flexibly by using computational tools and methods. Its value is not only reflected in the effective overcoming of the knowledge gap, building an interdisciplinary dialogue bridge, but more importantly, it plays an irreplaceable role in promoting the overall development and lifelong development of human beings (Fan, Zhang, and Li 2018).

From the development trend of the international information technology curriculum, the content of scientific and principled content in information technology courses has been greatly increased. Computational thinking has been incorporated into the Computer Science Teachers Association (CSTA) K–12 standard (2011 revision), the UK's new curriculum plan for 2013 is to develop computer science as an important teaching element of information technology teaching, and the new curriculum program developed in Australia in 2015 has made computational thinking an important part. In addition, the European Union core literacy, the United States's "21st century skills," "Horizon Report," and other international research results as well as the Programme for International Student Assessment (PISA); science, technology, engineering, arts, and mathematics (STEAM) education; and the concept and practice of the content of the creator education have greatly emphasized the theoretical and scientific content of the information technology curriculum.

Computational thinking has become an important factor for people to adapt to the survival and development of the information society in the future as well as to build their own development. Cultivating students' computational thinking is the current requirement and task in developing the education system. After considering the problems in the implementation of China's information technology curriculum and the development trend of international information technology education, the high school information technology curriculum will train students' computational thinking as an important goal of the curriculum and greatly increase the content of computer science to train students in preliminary computational thinking.

The curriculum of information technology in senior high school should be aimed to cultivate students' abilities at a high level. High school is still in the basic education stage and connects with higher education, so the information technology curriculum in high school needs to train students in the most critical and necessary basic literacy, rather than the professional ability at the university level. Based on the consideration of various conditions, computational thinking is identified as one of the core literacies out of the four-key literacy in the New Standards.

THE BASIC METHODS OF TEACHING CT

In the information technology classroom, when cultivating students' computational thinking abilities, the instruction should be guided by problem-solving, and the teacher should guide students to think and analyze problems based on the thinking methods in computer science (Huang and Xiao 2019). In the instructional practice, teachers are required to master the following three main points.

First, the instruction should begin with setting the right context for problems. At the beginning of a class, an authentic (real-world) problem should be given to students to solve, with the background and conditions of the problem clearly described. The reason the authentic problem should be given to students first is that computational thinking is problem-oriented and students need to concentrate on thinking about the real-world problems with the thinking methods of computer science. Unlike the computer professional education that imparts professional knowledge, students need to master the thinking methods instead of computer expertise. It should be noted that the problem should not necessarily be difficult and complicated, but there should be a clear computer science–oriented feature that can provide a solution from a mathematical and engineering perspective rather than setting a simple application of a particular tool software as a solution.

Second, the teacher should guide students to explore solutions to the problem by using the method of computer science. In the New Curriculum Standard, the general process of problem-solving with computational thinking is clearly stated. The first step is to use ideological methods in computer science to define problems, abstract features, build structural models, and organize data; the second step is to form problem-solving schemes by using reasonable algorithms through judging, analyzing, and synthesizing all kinds of information resources; the third step is to summarize the processes and methods of using computers to solve problems and apply them to other problem-solving related to them. In this process, students should use the thinking methods of computer science to characterize the problem, abstract features, and build models as well as to use relevant resources and algorithms to produce solutions, and each step is inseparable from computer science. However, students do not naturally understand computer science, and therefore instructors should teach the computer science knowledge and thinking methods involved in the problem-solving process to help students lay the necessary foundation. Teachers' guidance is the necessary condition for students to explore solutions smoothly, and teachers need to analyze and design the process of problem-solving in advance, closely track students' problems and progress in each process, and give the necessary guidance and help in a timely manner. The guidance should enable students to gain a deep understanding of the internal mechanisms of the solution to promote knowledge transfer.

Third, the relationship between computational thinking and programming should be correctly handled. In the process of finding a solution to a problem, writing the necessary programs and turning them into an automated solution is a necessary part of problem-solving based on computational thinking, which is likely to take up a lot of teaching time. If the teaching methods are not appropriate, or the emphasis is inappropriate, it is likely that the teaching of computational thinking will be transformed into programming-oriented teaching. The key is the orientation of teaching: the teaching of computational thinking is problem-oriented with the goal of finally obtaining the solution to the problem, while the goal of programming is usually to master a programming language, which is oriented by learning grammar knowledge.

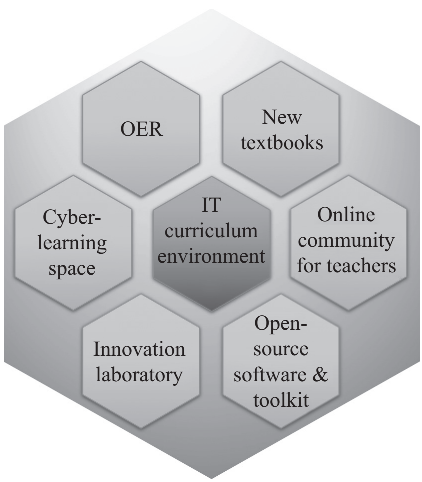
The New Standards advocates project-based learning and comprehensively promotes the formation of the four-key literacy in the process of students' participating in the project. Project-based learning (PBL) is a teaching method in which students learn by actively engaging in real-world and personally meaningful projects. PBL usually requires authentic learning contents that come from real life. Under the guidance of teachers, students engage in solving real-world problems and in experiencing the complexity, comprehensiveness, and integrity of problem-solving.

PBL activities often require students to use certain technical tools and research methods to solve the problems. There is a natural advantage to using the PBL method in the IT course. First of all, the problems in the IT course often come from real life, and many of them are closely related to students' daily lives and learning. Second, the IT courses are often taught in technology-rich environments that can provide proper technical tools and learning environments. Third, the process of completing the project is also the process of applying, improving, and innovating IT, and it is also the process of improving computational thinking.

THE ENVIRONMENTS FOR TEACHING CT

According to the traditional understanding, many people think that the teaching environment for IT courses is a multimedia network classroom, which was previously sufficient for implementing IT courses. However, the multimedia network classrooms cannot meet the requirements of the new IT curriculum standards. In the IT course, students should go through a series process of thinking, identifying problems, proposing solutions, exploring solutions, evaluating solutions, and migrating applications, and they gradually develop the four-key literacy in the process of solving problems. The environment should support the student's learning process and also support the teacher's project-based instruction, with the aim to cultivate the four-key literacy.

As shown in figure 4.2, the learning environment to support PBL in cultivating computational thinking should include new textbooks, an online community for teachers, open sources and toolkits, an innovation laboratory, a cyberlearning space, and open educational resources (OER). New textbooks considering the New Standards should be adopted to guide students to experience the process of computational thinking through solving problems and accomplishing projects. An online community for IT teachers is important to provide a platform for communication and reflection on the teaching methods and solving problems. Open software and toolkits are important tools for conducting learning activities for computational thinking, with which students and teachers can work together to solve real-world problems.



4.2 The IT curriculum environment to support PBL.

The innovative laboratory provides a physical learning environment where students can explore problems, inquire about solutions, and make artefacts by using different kinds of software and tools. Information technology can also be used to create a cyberlearning space for students with convenient applications, abundant resources, reliable contents, and environmental security. The cyberlearning space combined with physical space can provide students an environment suitable for self-directed and inquiry learning, provide convenient ways for teacher-student communication, and also enhance the teaching methods. In the technology-enhanced learning environments, students can experience the digitalized learning process, which promotes the habit of lifelong learning. The Internet should be best utilized to promote the sustainable development OER, with the mechanism of transforming students' learning processes to learning resources, guiding students to become both the user and builder of learning resources.

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International Implementations

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