The Evolution of Computing Education and Paths of Realization in China

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Abstract That the rapid development of engineering science in the fields of artificial intelligence, internet of things, and big data marks the human society entering into the intelligent stage, which increases the awareness of computing skills cultivations for engineers and technicians. Yet the path of the realization of computing education is not generally defined in China. Within this context, this study intends to firstly list the key nodes and landmark events of Chinese computing education by literature review technique, and summarize its historical context and anticipate the trends. Secondly, using structured case study method, the study selects and analyses four typical cases conducted within Chinese computing education system, and subsequently extracts two paths named integrated path, and specialized path for sustainable development of computing education. Different characteristics of computing education models have been outlined and summarized as four typical paths which are underlying computing education. The concept of computing education is consequently refined and suggestions are put forward for various hierarchies like government, university, and industry, to effectively improve the quality of talent cultivation in computing education in China.

1 Introduction

The development of technology and society sparked reform and transformation of traditional engineering disciplines following the widespread application within industry. The new trend of intelligent industrial revolution brings new requirements of the concept, foundation, structure, and goals of engineering education. That is, the intelligent social trend puts forward requirements for a higher-quality computing education. And computing education lays the foundation for intelligent development.

Studies have pointed out that computational thinking is the use of a method that uses basic concepts of computing to solve problems, design systems and understand human behavior[1]. The report "computing as a discipline" clearly states that computing is the systematic study of the algorithmic process of describing and transforming information[2]. The computing disciplines originated from interests in using the computer to solve problems, the theory of computation, and the development of the computer and its components[3]. It is a combination of mathematics, management, engineering and business applications. While not specifically designed for computing programs, CDIO’s general principles and engineering educational framework can be adapted to better understand computing education curriculum models[4].

Based on the existing researches, this paper proposes that computing education is a system that aims to cultivate students to construct computational thinking, master theoretical knowledge, and practical methods in the computing field to solve practical issues. This study sorts out the development background of computing education in China to form a more comprehensive and clear understanding of it, and refine the path of the realization of computing education through the structured case study.

2 The development of computing education in China

The training for computer science and technology professionals started in the United States since the 1950s. Later the training programs adopted by other countries including China, all referred to the US system.

In 1995, on the basis of extensive research, the Ministry of Education approved the plan for the reform of educational contents and curriculum for computer science and technology. The project is undertaken by a team of teachers from 9 universities including Fudan University, Shanghai Jiaotong University and Xiamen University[5]. This project marks that China's computing education is entering a new phase. In 1998, the textbook "Introduction to Computational Science" for the 21st century was formally published and used as teaching reference book in dozens of universities on a national scale. After entering the 21st century, the Department of Intelligent Science of Peking University established the major called intelligent science and technology in 2003. The establishment of intelligent science and technology is the inevitable result of intelligent era. The major has a high level of comprehensiveness and cross-cutting features[6].

Considering the obvious features of different periods of computing education, the development of computing education in China has experienced three major periods: knowledge oriented period, cognitive tools oriented period and universal value oriented[7] period.

In the first period (1960s-1995), the majority of computing education was educating computing knowledge and skills. Lecturers aimed to promote students' competence by improving students' programming skills and using computer language. Time to the new century (1995-2003), computing education gradually evolved from "knowledge learning" to "tool utilization" that concentrated on improving students' ability to use information technology to solve problems. For the third period (2003-present), the widespread use of big data, cloud computing and mobile communication technologies have created a completely new digital environment which accelerated the shift of computing from "technical tool updates" to "information data changes".

Today China's computing education has made great progress in the direction of development and training depth. But there are still some problems. For instance, that the extensional development model for subject teaching and curriculum system could not meet the needs of discipline development[8]. The study attempts to explore the typical paths of computing

education through the structured case study.

3 Exploring multiple paths of computing education based on structured cases study

3.1 Case selection and collection

Through in-depth analysis of computing education cases in China, the typical practices of engineering education combined with computing were selected from two dimensions including basic research and industrial demand. The study comprehensively considered the overall quality and professional characteristics of computing education in target universities, and selected typical practice cases of computing education at the departmental and professional level.

3.2 Structured case study: typical practice of computing education

The research aims to explore the possible paths of computing talent training, summarizes the talents training model, and provides reference for the reform of computing talents training and engineering education paradigm in China.

3.2.1 Beijing University of Posts and Telecommunications: Intelligent Science and Technology

(1)Background analysis

Along with the popularization and application of information networks and robots, the major of intelligent science and technology has a great talent demand in many industries. Therefore, it has received extensive attention from the Ministry of Education and various universities in China. This program aims to develop students' basic competencies in computing, so that students could be prepared to acquire and continuously learn the relevant knowledge and skills of computing in profession.

(2)Talent training

Graduates of this major should acquire the following knowledge and abilities:

- Having a solid foundation in natural sciences, humanities and social sciences, and the comprehensive application of foreign languages.

- Mastering the skills of artificial intelligence, computer, information processing, information networks and system optimization.

- Having the ability to analyze, design, manufacture, integrate and test intelligent systems and smart products.

➢ Understanding the guidelines, policies, regulations and development plans of the information industry.

(3)Summary of features

The major aims to cultivate computing talents for the design of search engines and algorithms for IT companies such as Baidu through developing students' technical competence. The main characteristics are as follows.

➢ It is a mature degree award system. The major entirely covers undergraduate, master and doctoral levels so that it has a relatively complete degree award system in the process of discipline construction.

➢ Skills related to practice and communication are emphasized. The development of students is more extraverted, preferring to collaboration and communication with the industry.

➢ The emphasis of computing competence. The major of intelligence science and technology is more inclined to information processing. The big data major was set up specifically focusing on network structure and topology.

3.2.2 Beijing Union University: Robotics Institute

(1)Background analysis

Beijing Union University Robotics Institute aims at "area service, nationwide radiation and facing the world". Meanwhile it takes the development trend and demand of China's intelligent robot industry as background, the intelligent robot technology as foundation, the cultivation of high-end intelligent robot industry talents as goals.

(2)Talent training

The college of robotics transforms all aspects of advantages to improve the quality of talent training, such as bringing together top-notch faculty, creating a strong academic atmosphere and a good environment for talents, and motivating students to apply research.

➢ Problem-solving oriented. The talent cultivation highlights the completion of scientific research tasks and the solutions of scientific research problems. The model adopts a new progressive learning of knowledge learning, ability orientation, scientific research training and application innovation, cultivates excellent artificial intelligence engineers and application innovation talents in the robot industry.

➢ Future development driven. The college will give priority to recommending outstanding graduates to apply for co-operative colleges such as Tsinghua University and the Chinese

Academy of Sciences. For the graduates going to work, the college will continue to promote in-depth cooperation with the globally influential science and technology innovation centers.

(3) Summary of features

The college of robotics of Beijing Union University realizes the joint exploration of school and enterprises, upholds the concept of integration and innovation, strengthens multi-disciplinary and multi-field exchanges, stimulates innovative and technological breakthroughs.

3.2.3 Xi'an Jiaotong University: Artificial Intelligence and Robotics Institute

(1)Background analysis

In the era of big data, artificial intelligence technology has received increasing attention globally. Facing the demands of computing talents in the background of Made in China 2025 and the convergence of informatization and industrialization, the institute mainly conducts intelligent information processing based on computer vision, pattern recognition and the frontier of discipline development.

(2)Talent training

- The institute pays attention to the integration of research, education and the synergetic cultivation of talents. The research institute has a long-term technical accumulation and a well-structured talent team in the field of visual information processing research.

- The institute focuses on international cooperation and cross-domain communication. The partners of the institute include research institutions, enterprises and government departments at home and abroad.

(3)Summary of features

Through a project-oriented approach, the institute organically integrates teaching and research, and is committed to solving scientific research problems while cultivating cutting-edge research talents in the fields of artificial intelligence and robotics.

3.2.4 Zhejiang University: Software College of Software Technology

(1)Background analysis

The college relies on the strength of the faculty of Zhejiang University, and combines with the advantages of Zhejiang University's comprehensive education and the development of China's software industry. Facing the market demand, the college aims to cultivating high-level applied, composite and international software engineering management talents.

(2)Talent training

The college of software focuses on cultivating high-level talents in software engineering and mid- to high-end technical talents in the software industry. It develops students' ability to directly enter the software industry after graduation, and quickly adapts to the current software industry's expertise and skills.

(3)Summary of features

The talent training mode of Zhejiang University Software College adopts the teaching framework of production, education and research integration, the enterprise internship training system and the platform of service locality as the core elements. Through the "Computer+X" compound talent training mode, computer technology and other engineering majors are combined to build a software talent training system that is supported by universities, governments and enterprises for industrial and practical application needs.

- **The deep convergence of engineering and computing.** With the advancement of science and technology and the continuous development of the Internet, engineering and computing have become an integral whole. It is an inevitable trend to solve engineering problems more efficiently and accurately by using computing knowledge and skills.

- **Accelerated integration of hardware and software.** The rapid development of artificial intelligence, robotics and other industrial fields put forward requirements to the in-depth integration of hardware and software. These fields require the use of the knowledge and skills of diversified disciplines such as computers, machinery, and power electronics.

- **The core module of computing has become the bridge of traditional engineering.** Computing knowledge and skills are requested to be attached to application fields. And a systematic curriculum design is formed through the establishment of the core module of computing.

Thus, two paths of computing education has been identified through structured case analysis. The first one is using computing knowledge and skills as the basic module for other engineering majors, which is called integrated path. Another path is integrating computing into engineering professional curriculum systems and training models, which is called specialized path.

3.3 The refinement of computing education paths

Combining case study could deduce that: Computing education integrated path is using computing competencies as general knowledge and skills for all engineering disciplines. It can be analogized to physical reaction between traditional engineering disciplines and computing. And computing education specialized path combines computing with various engineering disciplines. It can be analogized to chemical reaction between engineering and

computing.

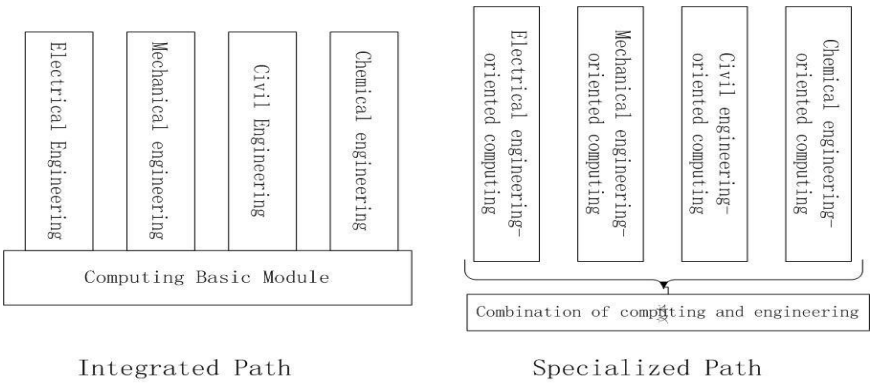

Fig. 1. Two paths of computing education

In the integrated path we propose two detailed way of computing education through the case study as follows.

- Software application-based integrated implementation path. Software is a collection of computer data and instructions organized in a specific order. It is the combination of computer programs, procedures, rules, possibly files, documents and data related to the operation of a computer system. This path takes software as a carrier to cultivate engineering students' computing competences to prepare them for the workplace in the intelligent age.

- Computing general foundation-based integrated implementation path. Solving real-world problems through computing involves digitizing the physical world and automate this process through computers, mathematics, programming etc. Computational foundation based computing education is of great significance in cultivating computational thinking, solid computing fundamentals, and applying computing and information technology to solve practical problems in the future.

Computing education specialized path emphasizes the role of computing education in different engineering disciplines, designing appropriate computing education models for different engineering majors, using computational methods and models to clarify and simplify engineering problems and propose more efficient and accurate solutions. The research proposes two specialized path as follows.

- Engineering discipline based specialized path. By the combination of computing education and traditional engineering, it is possible to apply computing related methods to solve corresponding engineering problems. At present, there is a lack of independent design talents for industrial basic software in China. The industrial basic software basically relies on the purchase of foreign software. The core industrial software technical talents are not enough to support the needs of industrial intelligent development. Therefore, it is so important to strengthen the ability of students to code industrial basic software in the traditional

engineering disciplines.

- Computational R&D based specialized implementation path. Computational thinking and computational methods, as the basis of engineering education, also need to be continuously developed and improved. Based on the specialized path of computing field, focusing on the research and development of computing related knowledge and technology, it provides the basis for the expansion and development of computing education.

4 Discussion

With the rapid development of information technology, computing knowledge and skills are playing a key role in various fields, especially engineering. This research extracts four typical paths of computing education through structured case studies and summarizes the characteristics of each path. A number of recommendations are proposed within this setting in order to effectively improve the quality of talent cultivation in computing education in China.

Table 1 Suggestions for computing education

Subject	**Suggestion**
The government	Optimize the computing education policy.
The university	Explore diversified computing education model facing industrial needs.
The industry	Strengthen the industrial base and build an innovative engineering talents support system.

The future research direction could be exploring the model and future trends of computing education through quantitative study like data analysis and questionnaire method.

5 Acknowledge

This study belongs to the research programs funded by the National Natural Science Foundation of China(program number: L1724047 and 71750003), and funded by Chinese Academy of Engineering(program number: 2018-XY-51).

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