Undergraduate Computer Science Education in China

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ABSTRACT

This paper examines the current status of *professional computing education* for undergraduate majors and *fundamental computer education* for non-majors in China. We describe the evolution of computing education over the past decade and its role in meeting society's requirements for IT talent, and we discuss developing trends for computing education at China's universities. We conclude with a description of the Computer Science major at Peking University, one of the nation's leading research-based computer science departments.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer science education, curriculum.

General Terms

Design, Management, Standardization

Keywords

Computer science education, China, Peking University, School of Electronics Engineering and Computer Science

1. INTRODUCTION

In the 21st century, information technology has permeated every sector of life in China. The capabilities of collecting, presenting, storing, transferring, processing, controlling, and applying information are fundamental to daily life and have become an important aspect of basic literacy. The field of *computer science and technology* plays a pivotal role in the rapid growth of China's economy through the training of a talented pool of scientists, engineers, and IT professionals.

In this paper, we present developments in *professional computing education* for undergraduate majors and *fundamental computer education* for non-majors in China, as the nation moved from an elite computer education model to a "mass education" model.

While some aspects of the evolution of computer science education are unique to China, many issues are those faced by computer science educators worldwide regarding innovation, internationalization, and relevance to society's needs. As an example of the changes in computer science education in China, we describe the Computer Science major in the School of Electronics Engineering and Computer Science at Peking University, one of the nation's leading comprehensive research-based universities.

2. BACKGROUND IN COMPUTING EDUCATION IN CHINA

The flagship computing discipline in China is *Computer Science and Technology*. Established in 1956, this field has gone through over 50 years' development to become the largest undergraduate major in China [2].

The current curriculum for Computer Science and Technology was proposed in 1996, modeled after ACM Computing Curricula 1991. This curriculum emphasized computer software and computer applications, built on the foundations of computer science and engineering. However, the ACM curriculum model for computing education did not completely meet the economic needs nor the scale of the Chinese educational system.

In 1998, the policies of the Ministry of Education (MOE) in China promoted the transition from "elite education" to "mass education" by dramatically increasing university enrollments. Before 1998, only a very small elite group of students were admitted to China's universities through an intensely competitive national examination system. The change to "mass education" was driven by the huge growth in the high tech economic sector in China as well as the desire to expand educational opportunities to a greater portion of China's talented youth. Correspondingly, more and more universities built up their computer education programs. At the end of 1994, there were only 318 universities offering the computer specialty programs in China; and by 2002, there were 484 programs; by 2003, 505 programs, an increase of 4%; by 2004, 652 programs, an increase of 29% [6].

By the end of 2007, there were 598 universities that had departments of computer science running 847 computing related specialty programs, with total enrollment of over 430,000 undergraduates. In addition to these Computer Science and Technology programs, there were more than 10 computing related

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disciplines and nearly 2,000 related specialty programs with nearly 1,000,000 undergraduates. Table 1 gives the size of some of the key disciplines.

Table 1: Key Computer-related Disciplines (2005)

Discipline	Number of Departments
Computer Science and Technology	771
Information Management and Systems	501
Information and Computing Science	441
E-commerce	280
Educational Technology	202
Software Engineering	149
Geographic Information Systems	137
Network Engineering	115
Information Engineering	51
Information Security	49

Realizing the fact that increasing enrollments had adverse effects on the quality of education, the Ministry of Education in China started the "Quality Engineering Plan" (http://www.zlgc.org/) in 2003. The following six initiatives were carried out to improve and ensure the quality of higher education graduates: approval of novel specialty disciplines; recognition of national best courses, best textbooks and qualified course repositories; innovative practical education and training of China's talent pool; certification of distinguished teachers and qualified educational teams; evaluation of education quality; and higher education backup for China's western region. In addition, efforts were made to reform and improve creativity and to develop excellent quality curricula. In the same year, the Advisory Committee for the Computing Discipline of the Ministry of Education kicked off a program of reform for China's Computing Curricula. The main tasks of the Advisory Committee were as follows: advise the MOE regarding strategic directions for undergraduate disciplines; provide curriculum guidance to educational institutions; and supervise the evaluation of computing education.

Based on a set of field trips to 10 universities and 12 IT companies and based on information obtained through thousands of questionnaires, the following observations were made [7]: First, it takes too much time to train graduates to be ready to work in industry given the nation's intense workforce needs. In 2004, the MOE predicted that the incremental demand for computing talent is 1 million people per year. Second, students are losing confidence in the overall competence achieved through the Computer Science and Technology major, compared with other majors. "What is my core competence? The other majors seem to be able to do all I can do!" Seniors and graduates complain about the education/training received. Third, Computer Science and Technology has fallen from its rank as the 1st or 2nd choice by high school students when they chose majors in university to its current rank of 5th or 6th. Finally, despite government statistics that show a big shortage of IT professionals, the future for graduates is unbalanced. Top-level graduates in China are in very high demand and there is a severe shortage of these highly qualified individuals. Conversely, the unemployment problem for the graduates from lower-level institutions grew significantly after 2000 due to enrollment surges.

The Advisory Committee for the Computing Discipline identified four new challenges for computing professional education: (1) broadening of the discipline's intention; (2) development of greater independence of sub-disciplines within the discipline of computing; (3) addressing the diversity of society's needs for information technology; (4) coping with the popularization and huge scale of computing education. These factors impelled the Ministry of Education to analyze the precise role of computing education within the university educational system and the maximum utility of resources. Merely applying the name "Computer Science and Technology" to hundreds of new departments and programs was clearly not enough.

3. PROFESSIONAL COMPUTING EDUCATION FOR MAJORS

3.1 Pyramid Model of Computing Education

Based on research conducted by the Ministry of Education regarding the role of computing education and society's needs for computing professionals, a new pyramid model of computing education was developed that identified three basic directions for training the nation's high tech workforce: *Science-oriented, Engineering-oriented* and *Technology-oriented*, with the smallest talent pool at the top, and the largest talent pool at the bottom.

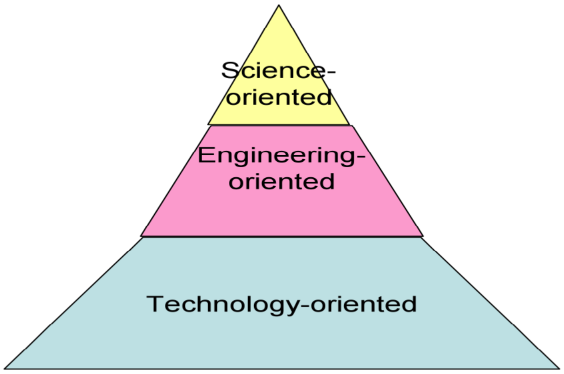

Figure 1: Pyramid Model of Computing Education

According to Denning et. al, the fundamental question underlying the discipline of computing is "what can be automated and how to compute effectively," approached through the three paradigms of theory, abstraction and design [5]. The goal of the pyramid model of computing education is to develop different talent pools working within various sub-disciplines and to utilize appropriate problem-solving methodologies within the three tiers of the pyramid.

Science-oriented talent focuses on "what can be automatically computed effectively." Education in this tier focuses primarily on theory and abstraction paradigms. This group comprises the nation's distinguished scientific talent pool. Their role in scientific discovery is innovation and creativity through research-oriented careers. *Engineering-oriented talent* is concerned with "how to implement automatic computing effectively and at low cost." Their focus is on theory and design paradigms through engineering solutions. Talented students in this pool are trained to master fundamental theories in order to guide engineering design and implementation. *Technology-oriented talent* is concerned with the goal of "making it convenient to use computer systems for automatic computing." The focus here is on the design paradigm. This talent pool learns theories of system construction and receives training in fundamental methods for problem description. With engineering at the forefront, this group is prepared to construct application-based computing systems that meet customers' needs.

3.2 Strategies for Professional Computing Education

Integrating the analysis and ideas of ACM-IEEE CC2005, the Ministry of Education suggested the following development strategies for professional computing education:

(1) Encourage universities to develop a variety of directions under the name "Computer Science and Technology" based on the trade-offs between societal needs and local or regional conditions, allowing local decision-making for curriculum development. Each university could name its departments as it saw fit and were no longer constrained to use the names of the major specialties currently approved by the Discipline Program Approval Committee of the Ministry of Education, shown in Table 1.

(2) Provide further educational opportunities for young teachers, enhancing their academic capabilities. Young teachers can study abroad with support from the China Scholarship Council, MOE and universities; visit other domestic universities; take free courses provided by the High Education Institutions Teacher online training center, paid by MOE, (http://www.enetedu.com/). Many places also provide summer seminar and training courses with very low registration fee. In 2001, the Ministry of Education sponsored the first University Course Forum of Computer Science to encourage teachers to exchange experiences and course materials.

(3) Enhance the practical and hands-on ability of students. With the increasing emphasis on engineering and technological education, experimental courses and internship opportunities are seen as important ways to help students improve their practical skills.

In a 2007 survey of 53 Chinese universities, 49 said the strategy was good for their departments, and 46 departments volunteered to serve as pilot programs. With the endorsement of MOE, the new strategies are being piloted in 14 universities and large scale practice is anticipated in the near future, followed by evaluation of these initiatives. In Section 5, we describe specific strategies employed by the School of Electronics Engineering and Computer Science at Peking University in Beijing.

4. FUNDAMENTAL COMPUTER SCIENCE EDUCATION FOR NON-MAJORS

China is also grappling with the challenge of providing *fundamental computing education* for non-computer science majors [4][5]. In 1999, courses in the fundamentals of computer science became required in most Chinese universities, challenging teachers with the role of educating huge number of students from many disciplines and with diverse computing backgrounds. During the next few years fundamental computing education made significant strides: the knowledge structure became more mature, integrated and systematic; the quality of teachers, textbooks, and the hardware environments greatly improved. However, university-level fundamental computing education has the following essential problems and challenges at present:

(1) The growth of computing-related disciplines. The universities need guidelines to keep abreast of the recent evolution in professional computing curricula into the five major computing areas identified by IEEE-ACM CC2005: CS (Computer Science), CE (Computer Engineering), SE (Software Engineering), IT (Information Technology) and IS (Information Systems) [1].

(2) Relationship to professional education in other disciplines. The requirements for IT skills in support of other disciplines are complex, diverse, and rapidly changing. The problem of designing fundamental computing education to fit the computing needs of a wide range of disciplines is truly daunting.

(3) The quality of fundamental computing education. The training of *huge* numbers of *high quality* IT professionals to meet China's needs has become the problem hotspot of fundamental computing education.

The current trends in fundamental computer education are characterized by "diversification, modularization, networking and integration" [8], meaning *diversification* in educational objectives, knowledge body, and teaching methods; *modularization* of the body of knowledge that is maximally adaptive to developments in IT and "student-oriented" educational ideology; embracing of *network-based* educational technologies available through the Internet; and *integration* of fundamental computer education with the professional education of other disciplines and of fundamental computer education with application-driven computer science. In addition, computer education for non-majors will "orient[ing] to applications, emphasizing on practice, focusing on information literacy and fitness" [8] [9] With the rapid growth of information technology, students should achieve basic information literacy as a foundation for lifelong learning and innovation, which is the final goal of higher education.

5. COMPUTER SCIENCE AT PEKING UNIVERSITY

Peking University, often referred to as the Harvard of China, is one of China's premier research universities.[1] At present, Peking

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[1] Peking University and Tsinghua University, China's two most prestigious universities, as well as the Chinese Academy of Sciences, are located in the Haidian District, a western suburb of Beijing. Their campuses are adjacent to Zhonguancun (China's Silicon Valley) providing rich opportunities for interaction with the leading Chinese and international high tech companies.

University has 99 key national disciplines (among them 9 disciplines are nationally ranked number one), 271 research institutions and research centres, including 2 national engineering research centres, and 13 national key laboratories. Peking University is a comprehensive university with research and educational programs in the basic and applied sciences, social sciences, the humanities, engineering, medicine, law, journalism, management, and education. As an example of the many dimensions of computer science education in China, we briefly describe the Computer Science major at Peking University, housed in the School of Electronics Engineering and Computer Science (EECS).

5.1 Computer Science Major Requirements

Each year approximately 3600 new undergraduates matriculate at Peking University of which 340 are admitted to the School of Electronics Engineering and Computer Science.[2] EECS administers four majors: Computer Science and Technology, Electronics, Microelectronics, and Machine Perception. About 140 to 160 choose to major in Computer Science, and 40 to 60 choose to major in Machine Perception which is very close to Computer Science. The School of EECS sits at the top level of the computer education pyramid and provides science-based education for its highly talented group of students.

Those declaring CS as the major must fulfill the course requirements shown in Tables 2-4, and must further specialize in one of 9 subareas: theoretical computer science, software engineering, database and data management, computer networking, computer architecture, digital media and HCI, artificial intelligence and intelligent perceptiveness, knowledge discovery, or natural language processing. About 80% of the undergraduates apply to work in a faculty research lab. All students must complete a one-year experimental thesis and pass an oral defense. These requirements were instituted in 2007 as part of EECS's new strategies for curriculum reform and innovation.

Table 2. School of EECS Foundation Classes

Intro to Information Science and Technology *	
Mathematics Analysis I/II/III Advanced Math I/II Advanced Algebra I/II Linear Algebra	**Physics** Mechanics (A,B) Electromagnetism (A,B) Physics C
Programming Intro to Computing * Programming Lab Data Structures and Algorithms * Data Structures and Alg Lab	**Microelectronics** Microelectronics and Circuit Design Circuit Design Lab

Table 3. Computer Science Major Foundation Classes (in addition to EECS Foundations; * denotes core course)

Software	**Hardware**
Compiler and Compiler Lab * Operating Systems and Lab * Programming Languages Intro to Networking *	Digital Logic and Lab Microcomputer Architecture and Lab Computer Architecture and Lab
Theory Set Theory and Graph Theory Algebraic Structures and Combinational Theory Mathematical Logic Probability and Statistics Analysis of Algorithms	**Intelligence** Human Brain and Cognition Information Theory Artificial Intelligence Numerical Computing Signals and Systems

Table 4. Computer Science Electives

Programming	**Software Engineering**
Problem Solving and Programming Linux Programming MS Windows Programming Java Programming	Software Engineering Intro to Object-Oriented Design Intro to Middleware Software Testing Service Oriented Architecture
Theoretical Computing Intro to Theoretical Computer Science Intro to Random Processes Application of Primary Theory of numbers	**Data Management** Intro to Databases(Required) Database Theory and Practice Data Warehouse and Data Mining Web Data Management Spatial and Multimedia Database Systems
Computer Networking Networking (Required) Intro to Web Technology Network and Web Programming Network Protocol Analysis and Design Information Security Network storage	**Digital Media and HCI** Intro to Digital Media Digital Video Processing Computer Graphics Visual Computing and Processing Digital Art Human Computer Interfaces
Computer Architecture Assembly Language Embedded Systems Digital Signals and Multimedia Processing	**Natural Language Processing** Intro to Natural Language Processing Statistical Linguistic Analysis Intro to Modern Information Retrieval
Computer Intelligence and Knowledge Discovery Intelligent Information Processing Intro to Machine Learning Intelligent Information System Lab	**Intelligent Perspectives** Pattern Recognition Biological Signal Processing Digital Signal Processing Voice Signal Processing Digital Graphics Processing
Scientific Writing	**Adv. Information Technologies** Various courses
Senior Thesis (required)	

5.2 Innovation in Computer Science Education

The desire to foster creativity and innovative thinking has motivated redesign of the requirements within EECS to allow more free electives, research mentoring of students, close interactions with industry, and greater exposure to international opportunities. In 2007, the Computer Science Department set up an experimental program, the *Accelerated Course Plan*, to foster the development of a new generation of talented individuals

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[2] Peking University is also home to the School of Software and Microelectronics which houses the engineering and application-based departments: Digital Arts and Design, Network and Communication Technology, Embedded Systems Engineering, Software Technology, E-Services, Management and Technology, IC Design and Engineering, Financial Information Engineering. This school was ranked number one of 36 schools of software established by the MOE's national initiative in engineering and technology-oriented education.

whose education emphasizes creativity, leadership, and international competence. The ACP was modeled after Peking University's *Yuanpei Project*, a university-wide initiative designed to train the best and brightest as the nation's future leaders. Under the *Computer Science Accelerated Course Plan*, eight accelerated core courses are offered in lieu of the normal courses: Advanced Introduction to Computer Science, Advanced Programming Practice, Advanced Data Structures and Algorithms, Advanced Operating System, Advanced Database System, Advanced Software Engineering, Advanced Compiler Theory and Advanced Computer Architecture. The nation's stellar high school students are recruited to this intensive program which allows them to quickly move into upper level courses and creative research.

Another area of innovation promotes cutting-edge academic-industry interaction. The department's Advanced Technologies course group sponsors courses to introduce new trends and developments in industry to our students, such as "Advanced IT Technology" taught by researchers from IBM's Computer Research Lab; "Parallel Computing in Multicore Architectures" taught by engineers from Intel; "Fundamental Storage Technology" taught by engineers from EMC.

In the arena of internationalization, our department hosts many international lecturers, and during the summer sends students to international exchange programs at UCLA, UC Berkeley, Stanford, Yale, the University of Illinois at Urbana-Champaign, and the University of Oregon, among others. We also offer a wide variety of international collaborative courses. From 2001 to 2006, we taught the introduction to web technology course in collaboration with the University of New England with total enrollment of over more than 500 students. Supported by University of Zurich, Switzerland, we successfully offered the Artificial Intelligence course broadcast by videoconference in 2004, which will be continued in fall 2009. See http://shanghailectures.org/.

In 2010, we will offer a collaboratively taught course in Global Distributed Software Engineering with the University of Oregon. Project teams made up of students from Peking University and the University of Oregon will work together across geographic, time zone, and cultural differences. This project is affiliated with the NSF CPATHi18n project.

6. CONCLUSION

Reform and innovation in computing education in China faces many challenges. In order to meet China's rapidly changing social and economic needs, higher computing education should update its educational objectives and ideology, rethink and re-invent the knowledge body of computing curricula, address the individualized needs and talents of its students, and be responsive to regional conditions. Furthermore, it is necessary to evolve pedagogical methods, re-educate faculty members and evaluate the efficiency and quality of education.

In addition, China should pursue forums for dialog with colleagues from other countries on the advances in computing education. In 2008, the First ACM Summit on Computing Education in China took place in Beijing, hosted by Tsinghua University. In October 2009, the Ministry of Education convened the 5th University Course Forum of Computer Science featuring leading U.S. computer science educators as the keynote speakers.

During the past decade much of the groundwork was laid for a renaissance in China's approach to computer science education. The next decade will be a time for continuing innovation, increasing internationalization, and broader expansion as we evaluate the outcomes of recent educational initiatives and explore the exciting future of computer science education in China and its role throughout the world.

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