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A student working in the library of Shanghai University.

Undergraduate Computer Science Education in China

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Over the past decade, Chinese educators have dedicated efforts to reforming the country's undergraduate computer science (CS) education, to better prepare students for their future professional endeavors. This paper provides an overview of CS education in China, covering the educational landscape; nationwide requirements and current conditions; an analysis of two prominent reform initiatives; an exploration of challenges and opportunities; and a projection of future developments. The objective is to offer a valuable reference for global undergraduate CS education, highlighting the proactive role that Chinese CS educators play in reshaping the international landscape of CS education.

Computer science education encompasses the study and practice of principles and concepts integral to computer science, including programming, algorithms, data structures, computer systems, software engineering, and the societal impact of technology [1]. In an era where computers play an integral role in daily life, the field of computer science education has witnessed rapid growth. This surge prompted a comprehensive overview of undergraduate computer science education in China, presented at the 2010 SIGCSE Technical Symposium [18]. Since then, Chinese CS educators have devoted substantial efforts to reforming undergraduate CS education, aiming to align with the dynamic evolution of the computer science discipline and the heightened demands of related job opportunities.

This paper delves into the multifaceted landscape of undergraduate CS education in China, acknowledging the collaborative endeavors of educators from academia and industry that have yielded remarkable success. With "computer science and technology" ranking among the top three most sought-after majors in China, as evidenced by approximately 3.5 million applications in 2021 [3], the popularity of this field is undeniable. The number of institutions offering undergraduate CS education has surged to 950 in 2023. As depicted in Figure 1, showcasing enrollment growth in computer-related majors from 2019 to the present. This expansion is fueled by a soaring demand for technology-related skills in the job market and the increasing allure of CS as a field of study. Graduates with CS majors find lucrative positions in global tech giants like Alibaba, Google, and Microsoft, contributing to the continued growth and relevance of this field.

This paper, authored by active voices in both the Chinese and international CS education communities, serves as a conduit for presenting the experiences of Chinese CS educators to the global computer science education community. It unfolds across five sections, providing a comprehensive review of undergraduate CS education in China. The sections are:

1. **The Overview of CS Education in China:** A thorough examination of fundamental components such as education history, distribution, curriculum settings, and the alignment of CS education with regional demands and industrial needs in China.
2. **Two Representative CS Education Reform Initiatives in China:** A spotlight on two pivotal initiatives, the "Talent Training Plan" [17] and the "101 Plan" [19], with case studies featuring Shanghai Jiao Tong University (SJTU) and Xiamen University.
3. **Challenges and Opportunities for Undergraduate CS Education in China:** An exploration of the challenges and opportunities faced by Chinese educators in the ever-evolving landscape of CS education.
4. **The Future of CS Education in China:** A forward-looking discussion on the imperative for Chinese CS education to strengthen global ties in the face of increasing globalization.
5. **Conclusion:** A Very Brief Summation of The Past and Looking Ahead

1. THE OVERVIEW OF CS EDUCATION IN CHINA

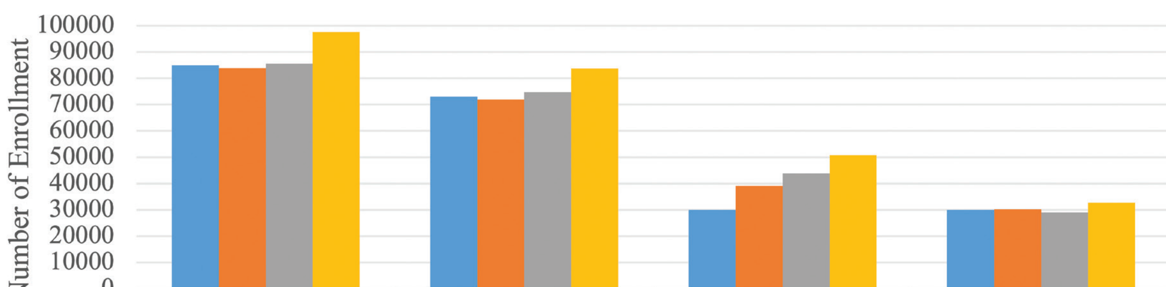
Education history. When the People's Republic of China was founded in 1949, there were no computer disciplines, computer professionals, or computer research and development. Notably, Hua Luogeng, a renowned mathematician, played a pivotal role in founding the computer industry in China. From 1956 to 1962, the Chinese Communist Party (CCP) conducted one- to two-year training courses for computer and computational mathematics. These courses aimed to develop expertise with undergraduate-level knowledge, producing professionals who became the backbone of computer teaching, research, and development.

During 1956-1959, several universities, including Tsinghua University, Harbin Military Engineering Institute, Peking University, and the University of Science and Technology of China, established computer and computational mathematics-related majors. This laid the foundation for the popularity of computer science (CS) majors in China today.

Education distribution. Undergraduate CS education in China is geographically distributed across the Chinese mainland, Hong Kong Special Administrative Region (HKSAR), Macau Special Administrative Region (MSAR), and Taiwan. Each region has its governing bodies, education duration, specialization, and educational type as summarized in Table 1.

- ***Education system***
  1. Chinese mainland: Overseen by the Ministry of Education (MoE) [12], programs typically last four years, with some offering three-year options.
  2. HKSAR: Governed by the Education Bureau (EDB) [4], undergraduate CS programs generally last three years.
  3. MSAR: Overseen by the Education and Youth Affairs Bureau (Secretaria para os Assuntos Sociais e Cultura - Direcção dos Serviços de Educação e Juventude, DSEJ) [8], programs typically last four years.
  4. Taiwan region: Regulated by the Ministry of Education, Republic of China (Taiwan) [13], programs usually span four years.

- ***Specialization***
  1. Chinese mainland: Core courses cover data structures, algorithms, operating systems, and database management, with elective courses for diverse interests.



	Computer Science and Technology	Software Engineering	Data science	Internet of Things
2019	85000	73000	29950	30000
2020	83878	71869	39112	30177
2021	85555	74743	43805	28970
2022	97532	83712	50814	32736

Figure 1: Enrollment numbers from 2019-2022

Chinese industries, particularly in technology, e-commerce, artificial intelligence (AI), and fintech, have a strong demand for graduates with strong technical skills in areas such as programming, data analysis, machine/deep learning, and cybersecurity. In the era of big data, industries prefer graduates who are proficient in developing and applying AI methods to analyze large datasets, derive insights, and develop data-driven solutions for businesses. Additionally, there is a growing demand for cybersecurity experts who can protect critical infrastructure and sensitive data.

2. HKSAR, MSAR, Taiwan region: These regions also have similar core courses in their computer science undergraduate programs, but there may be more flexibility, allowing students to choose their specialization earlier. For example, one compulsory course and three elective courses were identified at the beginning of high school in Taiwan region. Students can select any of them by their interests from "Basic Programming," "Advanced Programming," and "Computer Science." [5]

- ***Education type***
  1. Chinese mainland: Emphasis on theoretical teaching.
  2. HKSAR, MSAR, Taiwan region: Emphasis on practical work and project-based learning [10]. For example, Hong Kong Baptist University (HKBU) has collaborated with Google Hong Kong to provide online training programs to their students to cultivate the transdisciplinary problem-solving and analytical skills, including data visualization and analysis or programming [6].

Curriculum settings. CS undergraduates in China typically acquire credits from general courses, professional courses, practical courses, cross courses, and personalized courses. Professional courses often encompass specializations like cybersecurity, network and system, computer graphics and virtual reality, algorithm and software, and artificial intelligence (AI) and big data. Curriculum settings prioritize theoretical study, along with rigorous requirements for engineering practice and scientific innovation.

Graduate expectations. Expectations for graduates align with global goals, focusing on equipping students with technical competence, problem-solving ability, software development skills, mathematical and theoretical analysis ability, critical thinking, creativity, communication, cooperation, ethical and professional conduct, employability, and competency.

Nationwide CS education requirements. Regional demands for undergraduate CS education in China vary significantly across different regions of the country. Tier 1 cities, such as Beijing, Shanghai, Guangzhou, and Shenzhen, which are known for their strong economies and technological hubs, tend to have high demand for CS education. Demand for CS education in Tier 2 and Tier 3 cities is also significant but may not be as competitive as in Tier 1 cities. As these cities develop and attract more industries, the demand for practical CS skills-education increases. Students there prefer to prepare themselves for high salaries depending on skills learned in the undergraduate degree. On the contrary, western, and less economically developed regions, may have a lower demand for CS education compared to the more developed eastern regions. Thus, the Chinese government has been working to promote education and technology development in these regions to bridge the gap, where departments like MoE have launched various initiatives especially targeting less developed areas.

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Table 1: Undergraduate CS education comparison in Chinese mainland, HKSAR, MSAR, and Taiwan region

Regions	Education System		Specialization	Education Type
	Governing bodies	Duration		
Chinese mainland	Ministry of Education	Typical four years, Some three years	Core courses+elective courses	Emphasize theoretical teaching
HKSAR	EDB in HKSAR	Three years	More flexible and earlier to choose specialization	Emphasize practical work and project-based learning
MSAR	DSEJ in MSAR	Four years		
Taiwan region	Ministry of Education, Republic of China (Taiwan)	Four years		

In the era of big data, industries prefer graduates who are proficient in developing and applying AI methods to analyze large datasets, derive insights, and develop data-driven solutions for businesses. Additionally, there is a growing demand for cybersecurity experts who can protect critical infrastructure and sensitive data.

In addition to technical skills, Chinese industries also value soft skills such as communication, teamwork, problem-solving, and adaptability [2]. These soft skills can be summarized as competency, that is, the integration of knowledge (i.e., know-what), skills (i.e., know-how), and professional dispositions (i.e., know-why) [1].

2. TWO REPRESENTATIVE CS EDUCATION REFORM INITIATIVES IN CHINA

The most representative explorations of computer science education in China are the "Talent Training Plan" and the "101 Plan." This section will first describe how these two plans were implemented. Two top-tier universities in China are selected as case studies to show what results were achieved. Shanghai Jiao Tong University (referred to as "SJTU" in the herein) participates both in the "Talent Training Plan" and the "101 Plan." Another selection, Xiamen University, did not participate in either plan but has explored its unique education scheme as an active follower.

2.1 THE "TALENT TRAINING PLAN" AND "101 PLAN"

In 2009, the Ministry of Education launched the "Talent Training Plan" 1.0. Computer science is one of the first five top-notch disciplines selected. Along with the ten-year plan, 98% of the 6,647 graduates continued postgraduate study, showing the potential to become future scientific leaders. In 2020, the second version of this plan was launched, which plans to train tens of thousands of top students in basic disciplines from 60 colleges and universities in the next 10 years [10]. The development of the talent training plan 1.0 to 2.0 is to expand the scope of disciplines horizontally, from pure science to comprehensive arts and sciences.

This plan does not regard students' grades during schooling as the only standard but pays attention to the combination of written examinations, interviews, and expert recommendations. Thus, it can provide opportunities to some "partial talents," "weird talents," and students from non-famous schools to have a better education. In addition, this plan encourages the establishment of high-level tutor groups to jointly guide students. Experts are frequently invited to give talks to students as shown in Figure 2. According to the characteristics of different disciplines, this plan proposes to formulate corresponding support policies to get rid of the evaluation system of "only papers." For the training of top-notch innovative students in engineering, it is recommended to unite scientific research intuitions and enterprises by the sharing of guidance and equipment resources to cultivate world-class scientific and technological talents.

In December 2021, based on the proposal of Professor John Hopcroft and the overall deployment of Minister Huai Jinpeng, the Ministry of Education in China decided to implement a pilot work plan for undergraduate education and teaching reform in the computer field (referred to as "101 Plan"). The goal of the "101 Plan" is to launch a batch of famous courses, teachers, and textbooks in the computer field within two years, driving the overall improvement of the quality of personnel training in colleges and universities. To be specific, the main tasks of this plan include the following.

- **Core curriculum system construction:** 12 excellent courses are selected and concentrated to be built in this plan. They will form a complete core computer course system, including the construction of the course knowledge points, online resources, and practice platforms.
- **Core teaching material system construction:** A batch of world-class, Chinese characteristics, and 101-style excellent core textbooks are expected to be built to form a computer core textbook system.
- **Classroom teaching effect improvement:** Through on-site lectures and seminars, a measurable and visible improvement in the quality of classroom teaching is expected. A group of excellent teachers is trained.

The "101 Plan" working group is mainly led by 33 domestic colleges and universities under the leadership of Peking University. Three hundred excellent teachers are selected to form the secretariat, curriculum construction group, and classroom improvement group. And 12 core courses in CS are the objects of such initiative. The 12 core courses are algorithm design and analysis, discrete mathematics, introduction to artificial intelligence, data structure, introduction to computer systems, introduction to computer science, software engineering, operating system, fundamentals of compiling, computer networks, database systems, and computer organization.

2.2 PRACTICE EXPERIENCES OF UNIVERSITIES

SJTU launched the "Zhiyuan Honor Plan" in 2017. This plan is consistent with the "Talent Training Plan." The "Zhiyuan Honor Plan" selected the top 10% outstanding students in basic disciplines to create a growth system of "future academic masters" that is in line with the world, where CS is also selected as one of the disciplines. It has won the first national excellent in the ten-year evaluation of the Ministry of Education's "Top-level Student Training Program for Basic Subjects."

The program starts with cutting-edge experimental courses. It can help to initiate academic interest and build scholarly awareness among students. So far, this plan has made excellent achievements. In 2018, the project "Efficient Interface Evaporation Device and Seawater Desalination" led by students of grade 2014 won the highest award in the U21 Global Innovation Challenge for the first time on behalf of SJTU. In 2021, the question "Will the periodic table of elements be complete?" proposed by students of grade 2018 was selected in 125 Scientific Questions of Science (version 2.0) from scholars around the world [15].

Figure 2: Professor Frank Wilczek, winner of the 2004 Nobel Prize in Physics, met with students in "Zhiyuan Honor Plan" [20].

The IEEE pilot class is set up as another exploration of the "Talent Training Plan." This class covers four professional directions in the electronic information area: computer science and technology, information engineering, automation, and information security. The college provides a wealth of overseas study opportunities for the students of the IEEE pilot class. It regularly invites Turing Award winners, Nobel Prize winners, Fields Medal winners, and so on to the school to conduct in-depth exchanges with students. That will greatly help to broaden students' international horizons, improve professional quality, and cultivate academic pursuits. According to the statistics of the past three years, 85% of the students in the IEEE pilot class went to Yale University, Columbia University, Cornell University, and other top-tier universities to continue their studies after graduation, and the rest of them went to well-known companies to work [7].

The ACM class established in 2002 is a typical CS education exploration of the "Talent Training Plan". The name comes from the Association of Computing Machinery, an international computer organization for science education. This also means that the goal set up by the ACM class at the beginning is to train computer scientists. Within ten years, the students in the ACM class won the "Triple Crown" of the Global ACM Contest (an International Collegiate Programming Contest).

Under the elite education in an ACM class, some outstanding graduates have founded well-known enterprises, such as 4Paradigm, Liulishuo, Senyi Intelligence, Yitu Technology, etc.

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These enterprises are distributed in multiple directions of artificial intelligence and blockchain and thus have penetrated all aspects of social services. At present, the overall valuation of these companies has reached tens of billions of yuan [9].

For another initiative, SJTU specifically participated in the construction of 9 core courses in the "101 Plan". At present, SJTU has completed the course system and knowledge map arrangement, white paper writing, and platform construction in the "101 Plan" [11]. Six courses have been participating in classroom teaching effect evaluations, while seven experts have been actively participating in course observation and guidance work for other schools. Meanwhile, driven by the curriculum construction team, SJTU has already formulated a "101 Plan" textbook publishing plan with multiple publication houses. Textbooks on topics such as Data Structures, Operating Systems, Discrete Mathematics, and Programming Language Design have been completed in 2023, and are expected to be published in 2024.

Xiamen University also takes active steps to explore different ways to improve the quality of computer science education to better prepare students for their future career. For example, the school of informatics, in which all computer science-related majors were hosted, started a pilot initiative called the "strong informatics plan." This initiative selects top students from these majors at the end of the freshman year, and offers them extracurricular training and independent research opportunities in different areas of computer science, such as algorithms, artificial intelligence, and network security. This initiative has been running for several years. Career statistics, such as the percentage of students going to high-rank graduate schools and the percentage of students whose starting position and salary are higher, of graduates participating in this initiative demonstrate its efficacy. In addition, faculties are also introducing competency-building exercises to their courses, including data structure and algorithms, operating systems, and computer networks.

3. CHALLENGES AND OPPORTUNITIES

The challenges facing computer science education in China are multi-faceted and addressing them is crucial for the continued advancement of the discipline. These challenges include the following.

1. **Regional Disparities:** Bridging the educational gap between more developed eastern regions and less economically developed western regions remains a significant challenge. Despite government initiatives, experienced professors tend to favor the eastern regions, creating an imbalance in educational resources. This is particularly challenging for undergraduate CS education, which often requires substantial support in terms of hardware and teaching resources.
2. **Theoretical vs Practical Emphasis:** Striking the right balance between theoretical and practical teaching is a persistent challenge. Mainland China emphasizes theoretical teaching, while HKSAR, MSAR, and Taiwan region focus on practical work and project-based learning, aligning with industry demands. However, research-oriented roles necessitate students with strong theoretical foundations, highlighting the challenge of maintaining equilibrium within limited class hours.
3. **Fundamentals vs Emerging Technologies:** A contentious issue revolves around deciding the emphasis on fundamental computer science knowledge (e.g., data structures, algorithms, and computer architecture) versus emerging technologies like artificial intelligence, computer vision, and natural language processing. The debate over allocating credit hours to each area underscores the difficulty in achieving a balanced CS curriculum.

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During these challenges, there are promising opportunities for the ongoing evolution of computer science education in China, including the following.

1. **Interdisciplinary Learning:** Introducing interdisciplinary programs like Computer Science + X (e.g., economics, law, mathematics, physics) can enrich students' educational experiences, fostering a holistic understanding of the applications of computer science in various domains.
2. **Leveraging Large Language Models (LLMs):** Building students' programming skills and system design thinking through LLMs presents a unique opportunity. Integrating these advanced models into the curriculum can enhance students' capabilities and keep them abreast of industry trends.
3. **International Collaboration:** Establishing collaborative ties for computer science education between China and other countries opens new avenues for knowledge exchange. International partnerships can bring diverse perspectives, enhancing the overall quality of education.
4. **Virtual Teaching via Online Technology**: Embracing virtual teaching methods based on online technology has the potential to democratize access to educational resources. This approach can reach a broader student population, providing them with valuable learning materials and experiences.

As China navigates these challenges and embraces these opportunities, the continuous evolution of computer science education will be pivotal in preparing students for the dynamic landscape of the tech industry.

As part of the ongoing efforts to enhance computer science undergraduate education, Chinese educators are proactively establishing stronger connections globally. An illustrative example of this commitment is their active participation in international projects focused on computer science curriculum development, notably CC2020 and CS2023.

4. LOOKING AHEAD

As part of the ongoing efforts to enhance computer science undergraduate education, Chinese educators are proactively establishing stronger connections globally. An illustrative example of this commitment is their active participation in international projects focused on computer science curriculum development, notably CC2020 and CS2023 [16].

The Computing Curriculum 2020 (CC2020) [1] project, jointly initiated by ACM and IEEE-CS, aims to provide contemporary, worldwide guidance for undergraduate computing programs. Encompassing fields like computer engineering, computer science, information systems, information technology, and software engineering with data science, CC2020 proposes a shift from a knowledge-based to a competency-based learning model. Chinese educators contribute significantly to the CC2020 task force, with formal membership from five educators, including one steering committee member and four regular members, two of whom are co-authors of this article. After the CC2020 report's publication, Chinese educators actively disseminate and implement its guidelines in China, translating the report into Chinese and organizing forums at prominent national computer science conferences.

In contrast, CS2023 focuses on crafting specific curricula for global undergraduate computer science education over the next decade. Building on the success of CC2020, Chinese computer science educators continue their active engagement in the CS2023 project. A Chinese educator assumed a role in the steering committee and chairs the System Fundamentals (SF) subcommittee, with additional educators serving as task force members. Their contributions involve designing and refining the curriculum, offering feedback and experiences on the knowledge and competency model, and promoting CS2023 at national computer science conferences and in journal publications.

As Chinese educators have become prominent voices on the global CS education stage, the potential for further strengthening these connections is evident. The wealth of experience in Chinese CS education can be shared with the world, while concurrently learning from global best practices. For instance, the competency model highlights the potential addition of an emphasis on practical problem-solving abilities to augment the foundational theoretical teachings. This two-way exchange positions Chinese CS education as a valuable contributor to and beneficiary of the global landscape.

5. CONCLUSION

The trajectory of undergraduate CS education, both on a global scale and within China, has been marked by exponential growth and heightened prominence as we approached the year 2024. This paper provided an overview, delving into the historical roots, current status, and developmental trends of undergraduate CS education in China.

The concerted efforts of Chinese CS educators over the past decade have played a pivotal role in elevating CS education to a position of global significance. Through innovative initiatives and meticulously designed curricula, these educators have demonstrated a commitment to shaping a robust educational foundation for future generations. Noteworthy contributions include active participation in international education initiatives, indicative of China's dedication to fostering a global perspective within its CS education landscape.

Looking ahead, the imperative to fortify connections between Chinese CS education and the broader global community becomes evident. The experiences chronicled in this paper serve as a source of inspiration and a fount of insights for the ongoing reform of undergraduate CS education on an international scale. As China continues to navigate the ever-evolving landscape of technology and education, the shared experiences and lessons articulated herein are poised to stimulate meaningful dialogue and catalyze positive transformations in CS education worldwide. This paper stands as a testament to the collaborative spirit propelling the field forward and underscores the potential for cross-cultural synergies in shaping the future of undergraduate computer science education. ❖

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DOI: 10.1145/3638563