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Contact Information

Address: 3 Fuxing Road, Haidian District, Beijing 100038, China.

Email: culturesofscience@cnaiss.org.cn

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Editorial

Culture is a value sphere created by human civilization as well as a structured manifestation of human civilization. It often takes the form of value norms, behavioural designs and road maps of a community or a group of people and is an invisible force directing people's behaviour. Therefore, the initial design of a culture and its practice have a strong directive effect on the culture's subsequent course, until the emergence of a new cultural revolution that leads the culture into a new era.

Due to the social division of labour and differences in occupations, the cultural traditions and communal habits of people in different regions or of different ethnic groups, countries or industries show distinctive attributes. The scientific community, for example, with scientific discovery and the dissemination and application of science and technology as its missions and principal content, generally focuses on scientific exploration and the importation of scientific knowledge and skills. The community forms its code of conduct on the basis of the scientific spirit rooted in shared values, including being rational, seeking truth, questioning and being beneficial to society.

The University of Science and Technology of China (USTC) was founded by the Chinese Academy of Sciences in 1958. One of its core missions was to quickly train top talent versed in both science and engineering to meet the urgent national need to develop atomic bombs, hydrogen bombs and satellites. Its initial design had 'the whole academy running the university and the research institutes being paired with university departments' and 'being both responsible and professional, integrating theory with practice' as its core values and guides to action. This year marks the 60th anniversary of USTC, which has become a leading tertiary education institution known the world over for its pioneering and highly successful academic activities and free academic atmosphere, and has remained as committed as ever to training trailblazing talent in science and technology.

This issue features five research articles dedicated to the scientific and cultural development of USTC over 60 years, by authors with a deep and intimate knowledge of the university. They examine the subject from different perspectives, including cultural design, educational concepts and academic practice, to look at how the cohesive and guiding force underlying the university has led it from success to greater success as it advances its mission to scale the heights of science and technology.

Shukun Tang
University of Science and Technology of China, China

Bei Shizhang and the establishment of the first Department of Biophysics in China

Rui Liu and Qin Yao

University of Science and Technology of China, China

Abstract

Bei Shizhang is known as a biologist in China. After returning from study abroad, he overrode all objections, established the Institute of Biophysics at the Chinese Academy of Sciences in July 1958 and strongly advocated for the establishment of the Department of Biophysics at the University of Science and Technology of China (USTC) in September 1958. He planned and prepared for the establishment of the department from the very beginning. In determining various operational aspects, such as enrolment planning, teacher arrangements, teaching plans and teaching objectives, he endeavoured to change the traditional model of biology education by focusing on the basic knowledge of physics and chemistry and emphasizing the concept that education was in the service of the political and military needs of the country. With these principles, he trained a large number of outstanding talents in the field of biophysics. Using material from the USTC archives and from recorded interviews, this paper describes the process of establishing the Department of Biophysics at USTC and the important role played by Bei Shizhang.

Key words

Bei Shizhang, University of Science and Technology of China (USTC), Department of Biophysics, Chinese Academy of Sciences (CAS)

1. Bei Shizhang in his early years: Education and work experience

Bei Shizhang (1903–2009, Figure 1) was born in Zhenhai, Zhejiang Province, China. He was a biologist who played a major role in the foundation and development of biophysics in China.

Bei graduated from the pre-medical programme of Tongji German Medical School (now Tongji University) in 1921 and received his doctorate in natural sciences from the

University of Tübingen, Germany, in 1928. He was elected as an academician of Academia Sinica in 1948 and of the Chinese Academy of Sciences (CAS) in 1955. From 1958 to 1983, he served as the first director of the Institute of Biophysics at CAS and as the first dean of the Department of Biophysics at the University of Science and Technology of China (USTC).

In his studies abroad, much of his learning was relevant to classical biology, such as cell observation, embryonic development

Corresponding author:

Rui Liu, Department for the History of Science and Scientific Archaeology, University of Science and Technology of China, no. 96 Jinzhai Road, Baohe District, Hefei 230026, Anhui, China.
Email: lr93@ustc.edu.cn.



Figure 1: Bei Shizhang.

Source: School of Life Sciences, University of Science and Technology of China.

observation and research in animal and plant physiology, which had relatively weak connections with mathematics, physics and chemistry. Those subjects experienced rapid development in the 1940s and 1950s. Bei deemed it necessary for biology to be combined with mathematics, physics and chemistry to achieve the best results and believed that biologists must be proficient in those subjects in order to keep pace with the times.

Connections between biology and physics go back to the 18th century, when the Italian scientists Luigi Galvani and Alessandro Volta and the German scientists Emil Heinrich Du Bois-Reymond and others observed by experiment that living tissue could produce an electrical current and cause muscle contraction. Subsequently, Hermann von Helmholtz, a German physicist, made a study of the physical mechanisms of muscle contraction and nerve conduction, connecting biology with physics. Ivan Catton, an American scientist, found a weak electrical current in the human brain, proving that organisms may have physics-related reactions. In 1953, the American scientist James Watson and his British colleague Francis Crick proposed the double-helix structure of DNA based on the results of an X-ray diffraction experiment suggested by Maurice Wilkins and performed by Rosalind Franklin, which opened up the new research

field of molecular biology. These research achievements brought the study of biology from simple theoretical description to quantitative and qualitative research and promoted the emergence of a new interdisciplinary discipline—biophysics. Performing quantitative analysis and research on biological phenomena with the new physical theories and technologies brought previous studies of organisms to a new stage.

In the 1950s, based on his extensive knowledge and years of thinking, Bei Shizhang's academic thought about promoting the intersection of the disciplines became more mature. With the birth of biophysics as an independent discipline, he realized that it was only by carrying out biophysics and biochemistry research that our understanding of biology could significantly develop and the essence of life be revealed.

In 1956, Bei visited the Soviet Union as a member of a delegation from CAS. During the three-month visit, he investigated radiobiological, biophysical and biochemical research conducted by the USSR Academy of Sciences and several colleges and universities. Subsequently, much thought led him to believe that biophysics would develop in two directions: first, to study the physical and physicochemical processes of organisms; second, to examine the impact of external physical factors on organisms under different conditions, as well as the mechanisms of those factors. At the same time, the development of biophysics should be supported by corresponding developments in technology, and biophysical instruments should be replicated, improved and constantly renewed.

Considering contemporary developments in science and technology at home and abroad, as well as the demands of national defence, Bei was eager to change the mode of developing biology in China. He believed that biology should be developed step by step. In the first step, the programme of study involved a number of subjects, such as the peaceful use

of atomic energy (such as to increase plant and animal production and cultivate new varieties); radiation protection; biological problems in aerological measurement (such as the effects of weightlessness, excessive weight and cosmic rays on organisms); and the relationship between the primary substances of organisms (nucleic acid and proteins) and growth and inheritance. The second step included the study of cells and submicrostructures; the structures of molecular groups, biomolecules and macromolecules, and the relationships of those structures to their functions; radiation biology; and the biological effects of temperature, pressure and electromagnetic waves. Subsequently, Bei began to put his ideas into practice.

2. Establishing the Institute of Biophysics at CAS

In the early 1950s, China was suffering a lot in national and international affairs and was eager to strengthen its national defence capabilities and thereby enhance its international status. Consequently, it ranked the development of nuclear weapons as the most pressing strategic objective. To develop nuclear weapons without harming the human body, it was deemed essential to study potential hazards and to prevent them from occurring. It was therefore imperative to set up corresponding disciplines to conduct systematic research on nuclear weapons and to cultivate scientific talent.

At the same time, aerospace engineering was also in full swing. In October 1956, the Fifth Academy of the Ministry of National Defense was officially established. This was China's first rocket research centre and began the continuous development of China's space industry, starting from scratch and moving from small to large. On 16 November 1957, the Second Academy of the Fifth Institute of the Ministry of National Defense, a research centre specializing in missile control systems,

was established. This marked the birth of the predecessor of the Second Institute of China Aerospace Science and Industry. Premier Zhou Enlai appointed Lieutenant General Wang Zheng as the president of the academy (Fu and Ma, 2016). With the development of China's space industry, manned space flight was also covered by the scope of the research programme, and studying the impact of zero gravity on organisms had become a top priority.

In 1958, China launched an experimental rocket that paved the way for military missile and space research. It can be said that the development of the sounding rocket in China started in that year. The T-7 liquid sounding rocket and the improved T-7A sounding rocket were later successfully developed. The T-7A was a biological sounding rocket, demonstrating that biophysics had been incorporated into the strategic needs of the national defence service (Luk, 2015). Establishing the Institute of Biophysics was of great significance in the development of nuclear weapons and aerospace exploration.

Considering the national demand, the models of biophysics and radiobiology studies in the Soviet Union, and his ideas about the subject of biophysics, Bei decided to file an application to establish the Institute of Biophysics at CAS.

In July 1958, he suggested renaming the Institute of Experimental Biology as the Institute of Biophysics. On 29 July 1958, that proposal was passed at the ninth executive meeting of CAS. On 26 September, the change was formally approved by the State Council. At the same time, Bei was appointed as the first director of the Institute of Biophysics. It was one of the few professional biophysics research institutions in the world at that time. Its establishment signalled that biophysics was formally established in China as an independent discipline and laid a solid foundation for its subsequent vigorous development.

In the institute, Chen Qirui was the leader of the party committee and Jiang Pei'ao was the office director. Subsequently, Kang Ziwen, who was appointed as deputy director and secretary of the party committee, continued to work with Bei and became the first deputy director of the Department of Biophysics at USTC.

Wang Guyan, who graduated from the Department of Biophysics at USTC in 1965, wrote in *Biography of Bei Shizhang*:

Bei Shizhang became the founder of China's biophysics for the following reasons: first, he was a respected and well-known biologist; second, he was well prepared for dissent and showed great patience in persuading others; and third, he made a concrete plan for talent cultivation. . . . Bei was one of the foresighted pioneers who promoted the intersection of the disciplines. (Wang, 2010, pp. 162–165)

For Bei, one important idea for managing an institute was 'multidisciplinary intersection'. After the Institute of Biophysics was established, biophysics intersected with physics, chemistry, medicine, electronics, computers, engineering technology and other disciplines of scientific research and was made a priority.

In addition to multidisciplinary intersection, another important idea of Bei was that 'scientific research shall serve national development'. Under unfavourable national and international conditions and in scientific research, how to optimize the use of limited resources to support the work of developing atomic bombs, hydrogen bombs and artificial satellites, and the impact of radiation and microgravity on organisms, became the research focus of the Institute of Biophysics. Guided by that idea, the institute successfully completed 'research on the radiation effects of China's nuclear experiments on animals' and provided valuable data for the formulation of China's radiation safety standards and for an in-depth understanding of the biological effects and risks of radiation.

3. Establishing the Department of Biophysics at USTC

When planning the establishment of USTC, the preparatory committee set up in June 1958 began to think about the principles for setting up departments. Given that USTC was governed by CAS, the founding departments at USTC would refer to CAS institutes. There were many biological research institutes affiliated to CAS, most of which were taken over from the Nationalist government, including the Botany Institute, the Zoology Institute and the Fan Memorial Institute of Biology taken over in 1949.¹ So what kind of biological majors should be included? Should a traditional Department of Biology be established following the previous model of botany, zoology, microbiology and so on? Should a new Department of Biophysics be established?

The preparatory committee made a systematic plan for 13 founding departments and solicited opinions from the directors of CAS institutes. Bei was already preparing to have the Beijing Institute of Experimental Biology renamed as the Institute of Biophysics, so he suggested a pilot programme that would establish the Department of Biophysics at USTC, which would provide research talent for subsequent study at the Institute of Biophysics. Bei believed that we should keep pace with the times, and that, if we continued to set up departments in accordance with traditional biological methods and establish majors such as botany, zoology and microbiology, that would bring no advantages and could not serve the overall national strategy. Therefore, he suggested biophysics as the only major to be offered in the Department of Biophysics, which was in line with China's scientific research on atomic and hydrogen bombs and artificial satellites.

Soon after, Bei's proposal received a response from the preparatory committee. Due to his persistence and efforts, the Department of Biophysics, as the representative of

biology, became one of the 13 founding departments at USTC in September 1958. It could be said that the Department of Biophysics at USTC and the Institute of Biophysics at CAS were established at the same time. Bei's personal influence became an important factor in establishing the department.

Christine Luk from Arizona State University wrote in a 2015 research paper:

During the anti-Japanese war between 1937 and 1945, Bei was already practicing an integrated biology programme by accommodating zoology and botany and becoming a lifelong supporter of genetics even though it was not his academic territory. Riding upon the postwar coattails of promoting science for national rejuvenation, Bei assumed a position of leadership in the preparatory committee in establishing the Academy of Science. His personal charisma and political capital coincided with the pressing development needs of biophysics of its time which gave rise to a department of biophysics at the newly established USTC. As the only biology-related department among the 13 founding departments at USTC, the department of biophysics administered only one program between 1958 and 1961. (2015, p. 231)

In the 10 years after the foundation of the People's Republic of China, the research content of biology had still been closely linked with traditional biology, so zoology, botany, microbiology, genetics and physiology were the major subjects of biological research, and research on the intersection of biology and physics had not been universally accepted. The Institute of Biophysics founded by Bei became the first specialized institution for studying biophysics at CAS and even in China, when there were no departments of biophysics in universities. Because of the efforts of Bei, the Department of Biophysics, which was established in the same year as the Institute of Biophysics, became the first such department in China.

4. First enrolment and the construction of the faculty for the Department of Biophysics

Once the decision to establish the department was made, the primary issues faced were enrolment and the appointment of faculty.

Enrolment became the top priority once the operational objectives were determined. This was an urgent task, as there were only two months from June 1958, when the decision to establish the department was made, to 1 September 1958, the official opening date. Enrolment became a crucial issue because college enrolment in most provinces had already come to an end, which meant that the department was at a disadvantage, and it was not known whether it would be able to enrol any students, let alone good students.

In June, USTC started an urgent advertising campaign for enrolment and issued a three-page brochure to introduce the purpose of the department, the quota for enrolment, curricula, the duration of study, the enrolment region, registration qualifications and procedures, examination subjects and examination dates (USTC Archives, 1958a).

The enrolment brochure was reported by various mainstream media across the country and was published in *People's Daily*, *Guangming Daily* and *China Youth Daily*. Upon the university's requirement for the deans of each department to write an introduction to their discipline, Bei Shizhang, as the Dean of the Department of Biophysics, wrote (USTC Archives, 1959a):

Biophysics is a subject that uses physical and physicochemical theories and methods to study the phenomenon of life, to clarify the laws of the physical and physicochemical processes of organisms, and to study the influence of external physical factors on organisms under different conditions. Although the issues studied by it are focused particularly on basic theories, the research results are of great significance for agricultural production, health care and national defence.

Biophysics is a new discipline that has recently been established in China with a weak foundation. However, the preliminary success and rapid development of the peaceful use of atomic energy, space rocket launches and human interstellar navigation will certainly raise many important problems for biophysics, and to tackle them all, it is necessary to vigorously promote the development of biophysics.

It can be observed from Bei's description of the elements of biophysics that they differed greatly from those of traditional biology. The programme included radiobiology, energy conversion within organisms, influences of the external environment (such as light energy, thermal energy, electrical energy and physical factors) on organisms, the preparation and application of isotope tracer compounds, and new technologies and instruments for biophysics. The presence of those course components showed that the Department of Biophysics had abandoned traditional biological research streams closely related to botany, zoology, physiology or genetics. It emphasized studying the influence of radioactive substances and ionizing radiation on organisms and seeking methods of protection from it, conducting research into morphology, physiology, biochemistry and genetics. Research on biophysical instruments and technologies was highly valued, reflecting the significant contribution of key technologies and testing methods to biology. Bei and his colleagues hoped to cultivate urgently needed application-oriented scientific and technological talent through such a curriculum.

The first enrolment at USTC was open to nine pilot municipalities and provinces only, including Beijing, Shanghai, Jiangsu, Hebei, Hunan, Hubei, Shandong, Sichuan and Liaoning. The quota for the first enrolment was changed several times. Through the preliminary negotiations between institutes inside the CAS system, the original number was 1,500, but it was reduced to 950 after it was submitted to the Ministry of Education. The

CAS institutes were not satisfied with that decision, thinking that the approved quota was far below the numbers that they needed. However, the quota had been confirmed and was difficult to change, so they had no alternative but to ask each province to recommend some students for enrolment so as to meet the enrolment requirements of each department.

By that time, a new problem had emerged. Because the enrolment process for USTC started so late, many provinces had already finished making recommendations for places. The preparatory committee was not optimistic about enrolling any students using this method. The work had to be done, however. The committee began to contact local education authorities and admissions offices to take advantage of all opportunities for publicity. They also visited the principals who came to Beijing to attend meetings and asked them for their assistance. They received positive responses. For example, the principal of Sichuan Provincial Committee promoted the admissions policy of USTC widely after returning to Sichuan, which increased the number of applicants to USTC by seven times in three days. Additionally, the slogan 'Marching towards science and technology' in the enrolment advertisement of USTC had motivated a great number of young people who dreamed of becoming scientists. The USTC courses were also to be taught by renowned CAS scientists, which met students' wishes for face-to-face communication with first-rate scientists. With the assistance of provinces and cities in the enrolment regions, and by means of in-depth propaganda in schools and classes, various symposiums and other meetings, newspapers and on-air publicity, and even by writing letters to secondary schools, the admissions office was trying to make as many candidates as possible aware of the opportunity. As a result, in some enrolment districts, enthusiasm for applying to USTC even surpassed that for applying to Tsinghua University and Peking University. Figure 2 shows the students enrolled in 1958.



Figure 2: Students enrolled in the Department of Biophysics, 1958.

Source: School of Life Sciences, University of Science and Technology of China.

The selection of teaching staff was initiated under the leadership of Bei after the establishment of the department. The vast majority of teachers were researchers from the Institute of Biophysics at CAS, who were joined by a small number of outstanding teachers who had graduated from Peking University, Tsinghua University, Fudan University, Wuhan University and Beijing University of Technology (Table 1). In the early years of the department, Bei personally taught biochemistry, with the aim of enabling the students to be familiar with the content of their major as soon as possible. A few years later, he handed that work over to Vice Dean Shen Shumin, a researcher at the Institute of Biophysics. Later, as the student source expanded, a large number of outstanding teachers joined the team, including Yang Jike, Xu Fengzao, Jiang Zhensheng, Zhuang Ding, Zheng Ruoxuan, Yao Minren and Xu Haijin. Two of Bei's students—Zheng Zhuying and Wang Yunjiu—also began to teach in the Department of

Biophysics. Hou Huiling, who enrolled as a student in 1959, wrote in an article titled 'In memory of respected teachers and helpful friends' that Zheng and Wang often told stories about Bei and used to show them the biological graphs he had drawn, which had impressed the students profoundly. Professor Shen Shumin played a key transitional role in the early development of the Department of Biophysics. As the vice dean of the department and a close aide to Bei, although with a background in conventional biology, Shen had faithfully implemented Bei's principles. She overrode all objections and adhered to the operational characteristics of the Department of Biophysics at USTC, leaving a deep impression on many graduates.

The excellence of the teaching staff meant that the students in the Department of Biophysics were receiving the best education in China in the field of biology. The teachers for general courses, such as advanced mathematics, general physics and general chemistry,

Table 1: Teachers in the Department of Biophysics, 1958

Teachers	Courses	Employer/graduated from
Bei Shizhang	Introduction to Biophysics	Institute of Biophysics
Shen Shumin	Introduction to Biophysics	Institute of Biophysics
Yang Jike	Mathematical Statistics	Institute of Biophysics
Xu Fengzao	Cytology	Institute of Biophysics
Ma Xiuquan	Radiobiology	Institute of Biophysics
Ye Yufen	Embryology	Institute of Biophysics
Jiang Zhensheng	Anatomy	Institute of Biophysics
Qu Shanle	Biochemistry	Shanghai Institute of Organic Chemistry
Lin Zhihuan	Biochemical Metabolism	Peking University
Cai Zhixu	Genetics	Peking University
Zhuang Ding	Physiology	Peking University
Zheng Ruoxuan	Radiotoxicology	Institute of Biophysics
Yao Minren	Primary Reaction of Radiobiology	Lomonosov Moscow State University
Zhang Zhonglun and Wang Manlin	Radiation Metrology	Tsinghua University
Xia Fasheng and Sun Wenqi	Photobiology and Electron Transport Chains	Fudan University
Gu Fanji	Biocybernetics	Nankai University
Li Gongxiu	Radiobiology	Wuhan University
Wan Qian	Instruments	Yunnan University
Li Xingguo	Cartography	Beijing University of Technology
Jiang Pidong ²	Radiobiology	Peking University

were famous first-class scientists such as Hua Luogeng, Yan Jici, Wu Youxun, Zhang Wenyu, Lu Yuanjiu and Li Zhengwu. The teachers for specialized courses were those with rich experience, such as Bei Shizhang, Shen Shumin, Xu Fengzao and Ma Xiuquan. It was an exceptional advantage and a great blessing for the students to have a chance to be closely associated with these masters and to communicate and discuss with the best teachers at CAS, while being profoundly influenced by the masters' rigorous academic attitude and deep academic knowledge.

Among the students in the department, opinions fluctuated after enrolment. The Department of Biophysics had a lower status among the 13 departments of the university at its establishment, which was closely related to the then current international and national environment and national research priorities.

Many students came to the school with great admiration, ambition, responsibility and love for the country and the science.

However, due to teaching restrictions and enrolment quotas, it was not possible to enrol every student without limiting course numbers, so conflicts were inevitable. USTC was unable to satisfy every student's application for their intended specialty. Allocations were needed, and many students were assigned to specialties that they did not like. It was inevitable that there would be some negative emotions as a result.

Biology was not a popular subject in the 1950s. Although most students considered it acceptable, some were not interested in it. They were dissatisfied after being assigned to the Department of Biophysics, and a few of them began to study passively. The newly enrolled undergraduates were full of passion and hoped to play their part in the construction of the newly established China with their talents. They believed that only by studying subjects such as nuclear physics could they realize their ambition to serve their country. Indisputably, there was a widely held view in

those years that studying biology—a specialty mainly dealing with animals, plants and microscopes—would make it difficult to realize the dream of constructing a rich and powerful country.

In 1959, Professor He Manqiu gave a speech on ‘How to be politically loyal and academically professional’ on behalf of the Department of Biophysics, in which she summarized the problems of the department:

Since the enrolment plan of our department was not satisfied according to the number of students enrolled, we had to transfer some students from other departments for supplements, and quite a few transferred students were unwilling to learn biophysics. They thought that the so-called cutting-edge was merely one step further into the field on the basis of previous achievements. Therefore, after the enrolment, many students, 23 in total, had low professional enthusiasm. Some of them were still unreliable in their professional thinking for a long period of time. (He, 1959)

This figure was staggering, for it was almost half the number of students enrolled in the department. If proper political and ideological guidance were to remain absent, the situation could easily deteriorate, causing serious consequences for both the students and the Department of Biophysics.

5. Course structure in the Department of Biophysics

The first students in the Department of Biophysics were enrolled in 1958 for a programme lasting five years. Bei said of the initial orientation of the department:

Students graduating from this department shall be equipped with general theoretical knowledge in biophysics and certain experimental techniques and, after a certain period of internship, they may be qualified for biophysical research, college teaching, or information work in scientific research. (USTC Archives, 1959b)

Biophysics was an emerging cutting-edge and interdisciplinary subject that covered many topics. It had four aims:

- Master the basic physical structure, performance and movement of the organism.
- Understand the energy metabolism of the organism.
- Understand biological information and control mechanisms.
- Be skilled in using biophysical instruments and technology.

Those four aspects were about professional knowledge training. Since biophysics was an experimental discipline, training in experimental techniques was also necessary. In addition to necessary biological experimental knowledge, the Department of Biophysics also planned to focus on mathematics, physics, electrical engineering, electronics and other subjects so that after graduation the students would be able to work independently in society with a solid foundation in science.

Students majoring in biophysics took specialized courses in radiobiology; the application of isotopes in biology and dosimetrics; biophysics; and biophysical instruments and technologies. The courses were described as follows (USTC Archives, 1959b):

Radiobiology studies the laws of impact of ionizing radiation on the living organism; the damage mechanism of radiation energy to the organism and protective measures; and approaches to the extensive use of radioactive energy in biology, medical science and agricultural science.

The application of isotopes is an important research method in modern scientific research and has been used extensively and effectively in biology. Dosimetrics studies the dosage in radiobiology and isotope applications.

Biophysics consists of the following five aspects. Photobiology: the study of the effect of light on organisms, the transmission and

conversion of light energy, and other issues. Electrobiolgy: the study of the generation and action mechanism of electrical phenomena within organisms; the significance of electricity in vital activities; and the impact of external currents on organisms. Submicrostructure and molecular structure of the organisms: the former uses the electron microscope as the main tool, while the latter uses the diffractometer and suchlike as the main research tool. Cosmobiology: a science that studies the functioning mechanisms and laws of various physical factors and external environments when the organism enters into different layers of the cosmic space. Information control of the organism: the study of the control systems and self-regulating functions of organisms as well as the issue of the unity of organism survival and the environment.

Biophysical instruments and technologies deal with the new technologies and instruments that are closely related to the rapid development of biophysics.

In addition to these specialized courses, students graduating from this department are also required to write a thesis, which gives them training in certain independent work abilities.

The objectives of the Department of Biophysics were embodied clearly in its curriculum, which differed greatly from that of a traditional biology discipline. The classic subdisciplines, such as animal biology, phytobiology, microbiology and genetics, were replaced by courses related to irradiation prevention and control as well as space probing, which resulted from the inextricable link with ongoing research into the 'atomic bomb, hydrogen bomb and artificial satellite' in China, and which also reflected the use of science and technology to meet political and military needs.

The length of study in polytechnic universities was set out in the regulations of the Department of Higher Education, which stipulated that the length of study for all

disciplines in USTC should be five years, the same as for Tsinghua University. This made them the only two universities in China that had a five-year programme of study. All freshmen would take foundation courses in their first three years in the department, and then two years of specialized courses. The foundation courses in the Department of Biophysics were advanced mathematics, general physics, general chemistry and foreign languages, which were further classified into different grades. The periods of study for such courses varied according to the different disciplines (Table 2).

The above data shows that foundation courses in the Department of Biophysics were the same Grade A courses as those in the departments of Nuclear Physics and Nuclear Engineering; Technical Physics; Chemical Physics; and Geophysics. Students majoring in physics-related subjects were required to study Grade A general physics, and those majoring in chemistry-related subjects were required to study Grade A general chemistry. Such strict study requirements for foundation courses in these subjects were beneficial for biological research. Students might feel tired and bored at the beginning, but this wide-ranging programme laid a solid foundation for their subsequent development. Such high requirements also coincided with Bei's teaching philosophy, which held that students majoring in biology must cultivate their knowledge of physics and chemistry.

According to Zhuang Ding, who graduated from Peking University and was the teaching secretary in the Department of Biophysics, the study in the department was 'heavy, tight and in-depth'.

'Heavy' meant more course categories and more class hours. 'Tight' meant a large number of weekly class hours. 'In-depth' meant deep lecture content: that is, the foundation courses were required to link up with the specialized courses as much as possible and specialized courses should include the latest news about the development of the subjects.³

Table 2: Grades of foundation courses for undergraduates at USTC

Departments	Courses		
	Advanced mathematics	General physics	General chemistry
Department of Nuclear Physics and Nuclear Engineering	Grade A	Grade A	Grade A
Department of Technical Physics	Grade A	Grade A	Grade A
Department of Chemical Physics	Grade A	Grade A	Grade A
Department of Thermal Physics	Grade A	Grade B	Grade A
Department of Radioelectronics	Grade A	Grade A	Grade B
Department of Automation	Grade A	Grade B	Grade B
Department of Mechanics	Grade A	Grade B	Grade B
Department of Radiochemistry	Grade B	Grade A	Grade A
Department of Geochemistry and Rare Elements	Grade B	Grade B	Grade A
Department of Polymer Chemistry and Polymer Physics	Grade B	Grade B ^(a)	Grade A
Department of Applied Mathematics and Computing Technology	Grade A	Grade A	Grade B
Department of Biophysics	Grade A	Grade A	Grade A
Department of Geophysics	Grade A	Grade A	Grade A

(a) In the general physics course in the Department of Polymer Chemistry and Polymer Physics, polymer physics is in Grade A, physical chemistry of polymers is in Grade B, and polymer synthesis and natural polymers is in Grade C.

For example, many schools and departments were considering whether to select Grade A, Grade B or Grade C for foundation courses in mathematics, physics, chemistry and other subjects. Grade A courses were characterized by long class hours, so, if every department selected Grade A courses in mathematics, physics and chemistry, then either the time for specialized courses would need to be reduced or the students would face greater pressure. Therefore, many schools and departments decided to mix Grade A, Grade B and Grade C courses. For example, Grade A higher mathematics, Grade B general physics and Grade C general chemistry might be selected; or Grade B higher mathematics, Grade A general physics and Grade B general chemistry; and so on. But the Department of Biophysics selected Grade A for all of these courses. Although the selection increased the pressure on students, the improvement in their abilities was obvious.

Arrangements in the Department of Biophysics were as follows. A total of 400 class hours for the mathematics course was to be completed in two and a half years. The

textbook *General Physics*, published by the Commercial Press, was adopted for the physics course, which also took 400 class hours over two and a half years to complete. The course emphasized hands-on experiments to enrich perceptual cognition. *General Chemistry*, published by the Higher Education Press, was adopted for the chemistry course, which took 150 class hours and one year to complete.

A system of teaching assistants to coach students was implemented, and a teaching assistant was assigned for every 30 to 45 students. Part of the faculty consisted of cadres from Peking University and Nankai University (USTC Archives, 1958b). The proportion of specialized courses in the Department of Biophysics was slightly less than that of the foundation courses in mathematics, physics and chemistry. By drawing lessons from teaching reforms in universities such as Peking University and Tsinghua University, while noting that biophysics was an advanced subject, the department eliminated traditional courses in biology and arranged new courses that closely followed

international scientific developments. In addition to traditional classroom teaching, interactive methods such as analysing reports, studying documents and having discussions were also used in teaching (USTC Archives, 1958c). In the university's schedule, four and a half days per week were assigned to learning and one and a half days were assigned to labour.

In order to provide students with the best education, the instructors of the specialized courses were all well-known scientists from CAS. Higher mathematics courses were mainly taught by 12 instructors, including Hua Luogeng, Guan Zhaozhi⁴ and Wu Wenjun.⁵ The main instructors and teaching assistants were based in the institutes of Mathematics, Mechanics and Computing Technology. The teaching tasks in general physics were mainly performed by 13 instructors, including Wu Youxun,⁶ Yan Jici (Figure 3), Qian Linzhao, Zhang Wenyu,⁷ Lu Yuanjiu,⁸ Li Zhengwu⁹ and Xiang Rensheng. The main instructors and teaching assistants were based in the Institute of Automation, the Institute of Electronics, the Office of Kinetics, the Institute of

Physics and the Institute of Applied Physics and Geophysics. General chemistry was taught by 13 personnel, including Yang Chengzong,¹⁰ Wang Baoren,¹¹ Liang Shuquan¹² and Liu Dafu. The main instructors and teaching assistants were based in the institutes of Applied Chemistry, Petroleum, Chemistry, Physics and Computing Technology.

Inviting first-class masters to teach undergraduates has always been a tradition at USTC. In the teaching of foundation courses, the university has always attached great importance to the role of a handful of scientists with unique expertise. For example, in the early years, in mathematics courses, Hua Luogeng made full use of his expertise in analytic number theory, classical groups and the theory of functions of several complex variables; Wu Wenjun used his expertise in algebraic topology and algebraic geometry; and Guan Zhaozhi used his expertise in the interface between mathematics and physics. Biostatistics in biophysics had a high demand for mathematical knowledge, because only with a strong mathematics background can the experimental data be processed skilfully, which was important in biophysics.



Figure 3: A Lecture by Yan Jici for 500 students.

Source: School of Life Sciences, University of Science and Technology of China.

In addition to mathematics, students in the Department of Biophysics were required to study chemistry because new science and new technologies were closely related with new materials. Systematic knowledge of chemical theory was therefore essential to get a thorough understanding of the properties of those materials. Inviting the best professors to teach foundation courses laid a solid mathematical, physical and chemical foundation for the students in the department and paved the way for their further development.

Table 3 shows the hours allocated to parts of the curriculum of the Department of Biophysics in 1961. The number of hours for physics-related courses totalled 1,798, while those for biology-related courses totalled only 744.

USTC was established under the consensus that priority should be given to the basic sciences, which included mathematics, physics, chemistry and mechanics, so it is not surprising that physics-related courses were allocated

twice as much time as biology-related courses in the Department of Biophysics. Students in the department benefited greatly from this high-intensity training in physics.

Students in the department had a high regard for Bei Shizhang. Shi Yunyu,¹³ who graduated from the department in 1965 and was the first president of the School of Life Sciences at USTC, described Bei's idea of teaching as follows:

First, target scientific frontiers. Second, lay a solid foundation in mathematics. Our specialized courses were drastically reduced, while the foundation courses took up a large proportion. Our courses were jokingly referred to as 'neither fish nor fowl', but we had to learn these foundation courses. We had to attend courses in mathematics, physics and chemistry with those students in the mathematics, physics and chemistry departments. The courses and tasks were heavy and we were pressed for time. The school days were relatively hard.¹⁴

Table 3: Curriculum of the Department of Biophysics in 1961

Courses		Hours	
Foundation courses	Politics	360	
	Physical education	120	
	Foreign language 1 (Russian)	315	
	Foreign language 2 (English)	120	
Subtotal		915	
Specialized courses	Physical science	Applied mathematics	360
		Physics	548
		Electronics	120
		Inorganic chemistry	360
		Isotopes	80
		Organic chemistry	135
		Physical chemistry	195
	Bioscience	Biochemistry	127
		Biology	315
		Radiobiology	120
		General biophysics	112
		Biophysical instruments and technology	50
		Microcosmic and molecular structure	20
		Instruments and apparatus	60
Subtotal		2,602	
Total		3,517	

Source: USTC Archives, file no. 1963-WS-C-67.

Biophysics was an emerging discipline, and it was constantly being updated with developments in science. Bei believed that in any case the development of biophysics had to be based on a solid foundation in mathematics, physics and chemistry. If students mastered knowledge of those subjects at university, they would understand them completely and benefit greatly in their future work. Many graduates of the Department of Biophysics were assigned to the Institute of Biophysics and made important achievements in their respective fields. This testified that Bei's point of view was right. For example, Chen Runsheng,¹⁵ who enrolled in 1959, is now an academic pacesetter in the field of bioinformatics; Chen Lin,¹⁶ who enrolled in 1964, is an academic pacesetter in brain and cognitive science. After graduation, they continued to focus on scientific frontiers and opened up new areas for important disciplines in China. More than 200 students graduated from the Department of Biophysics at USTC in the first three years from 1958 to 1960, and then played a key role in the early development of biophysics in China.

To sum up, biophysics courses were characterized by a tight course schedule; detailed and up-to-date content; increasing difficulty; innovative teaching; little spare time; and a heavy academic burden.

6. Specialty adjustments in the Department of Biophysics

Immediately upon the establishment of the Department of Biophysics, leaders of the Institute of Biophysics, such as Bei and Shen, had considered setting up a bioinformatics programme. As an important branch of informatics, bioinformatics was a cross between natural sciences (such as life science), social sciences (such as informatics, library science and archival science) and technical sciences (such as information science and computer science). It focused on how to meet the needs

of humans and society for biological data and knowledge processing in the information age. The motivation for establishing a bioinformatics programme was based on the molecular biology established by Watson and Crick's discovery of the DNA double helix in 1953.

Establishing a bioinformatics programme was not easy. According to Shou Tiande, shortly after establishment of the university, CAS merged the University of Scientific Information of China with USTC to form the new Department of Scientific Information. The department recruited few students, and enrolment lasted only for several sessions. It aimed at cultivating talent with the ability to systematically collect scientific and technological information for CAS and producing professionals in scientific and technical information who had knowledge of mathematics, astronomy, geography and biology to serve the libraries in CAS branches. This subject was not at all popular, and the demand for such professionals within the CAS system was not great, so the scale of enrolment in this specialty was limited. The enrolment was, after all, designed to serve a practical end.

Students in the informatics specialty were required to study specialized courses in various disciplines, including mathematics, physics, chemistry and biology. Since only students in the Department of Biophysics studied all the science and engineering courses, informatics was incorporated into the department and became a subordinate specialty, in line with the principle of 'merging similar items'. Later, because of the policy of institutional simplification and the scarcity in demand for informatics graduates, the enrolment was stopped. Thus, this 'peculiar' specialty in the department existed only for a short period.

The existence of bioinformatics has a certain historical significance. Internal and external problems coexisted in the 10 years that followed the foundation of the People's Republic of China. Internationally, China was not recognized by countries in Europe and

North America, which continued to implement not only an economic blockade but also strict controls over technology, which prevented China from obtaining the latest scientific information. However, in the development of science and technology, countries need to exchange information with each other in order to understand the latest research trends and directions. Bioinformatics played an important role in collecting various kinds of scientific research information. Graduates in this specialty were assigned to information research institutes and libraries in a number of CAS branches. Given the historical circumstances, searching for various kinds of scientific research information became the primary task of informatics.

Following the establishment of the Department of Biophysics, and with a deeper understanding of the relationships between the specialties, there came a need for adjustments as part of departmental optimization. In order to meet the country's requirements for radiobiology, that subject was added to the Department of Biophysics as a specialized discipline.

A report about issues in the adjustment of departments, specialties and specialization at USTC recorded the following changes in departments (USTC Archives, 1961a):

According to the directives of the Ministry of Education and the Chinese Academy of Sciences, we should set up 30 specialties in our university, and a proposal has been made in December 1960 after soliciting opinions from various institutes. . . Our opinion on department adjustment is that we shall reduce several departments. The adjustment should be based on the needs of students, considering the common features of different courses, and the combination of institutes and departments.

Before these adjustments, the only specialty in the Department of Biophysics was biophysics; after the adjustments, radiobiology was added.

Radiochemistry is a branch of chemistry that studies radioactive substances and

chemical problems associated with nuclear processes. It is associated and intertwined with nuclear physics, and the two subjects are sister disciplines in nuclear science and technology.

In comparison with radiochemistry, radiobiology in the Department of Biophysics focused primarily on the effect of radiochemistry on biological tissues, especially the human body. Its main aim was to examine the body's response and the biological consequences of radiation damage and to develop corresponding mechanisms for regulation. Radiobiology had been developing worldwide for more than 60 years. With the use of radioactive substances, cells undergo a radiation effect that triggers a series of cytological reactions, such as chromosomal mutation and remodelling, DNA impairment and cell death. Therefore, explaining the hazards of radioactive radiation and proposing corresponding counter measures had become the main research aim.

The addition of radiobiology to the Department of Biophysics at USTC was closely related to the international environment. Faced with the complicated relationship between China and the Soviet Union and between China and the rest of the world, China was making intensive preparations for research into atomic and hydrogen bombs in order to develop its own nuclear weapons and compete with the world's nuclear powers. In another sense, research on human protection under the nuclear deterrent had become an urgent priority. As the international community was maintaining a strategic blockade against China, it had been trying to develop its own nuclear strike force. This background provided a well-reasoned argument for setting up the radiobiology specialization.

In addition to informatics and radiobiology, the Department of Biophysics also attempted to add biochemistry to its specialties. On 23 January 1960, a number of planned changes were proposed to the USTC Party Committee, including the department's proposal to add

biochemistry. However, those proposals were not approved by CAS.

On 15 March 1960, the Institute of Mechanics at CAS suggested that biomechanics be added to the Department of Biophysics (USTC Archives, 1960). However, a meeting of the University Council on 3 April decided against that suggestion because of the low enrolment ratio and small number of students. The council also rejected a proposal to add biomechanics to the department because that subject was included in biophysics.

A 1962 file mentions some specialties that were planned to be added at USTC, including plasma physics; hydroacoustics and hydroacoustic equipment; hydrodynamics; inorganic polymers; operations research; and biochemistry. Only biochemistry was related to biology.

The biochemistry specialty was described in detail in the file as follows (USTC Archives, 1962):

A biochemistry specialty is to be set up within the Department of Biophysics. Biochemistry studies the chemical composition of the tissues and organs of organisms and the chemical processes of vital activities. With the development of biology and chemistry, especially organic chemistry, the discipline has already achieved a lot. In recent years, because of the establishment and rapid development of biophysics, chemical theories and methods are often essential in the application of physical theories and methods to the study of biological and vital activities and the study of physical problems in the physiological processes of organisms. It requires the application of theories and methods of both biophysics and biochemistry, and only in this way can we have a deep understanding about the processes of vital activities. Therefore, biochemistry, which has complemented biophysics and has already been developed, is a discipline that has gained a new content and life in the present day. After applying the theories and methods of biophysics, biochemistry is still essential for some of the typical objects that biochemistry deals with,

such as pharmaceuticals, fermentation and other industrial-related disciplines, as well as radiobiology, radiation medicine and other disciplines developed recently. In conclusion, on the one hand, biochemistry is a discipline that complements biophysics; on the other hand, after being linked up with biophysics, it has a new content and becomes an emerging, cutting-edge discipline that incorporates completely new content in its old form.

Although there was a clear understanding of biochemistry, there were still many doubts about whether it was to be added to the Department of Biophysics, so the specialty was still in a 'pending approval' state.

The failure of the attempts to add new subjects to the department reflected the following situation. In general, members of the University Affairs Committee believed that biophysics was a unique and normative discipline, but it was the smallest in the almost vertical management structure. Many who supported the addition of biophysics as a specialty believed that this was an exceptional opportunity to expand the research field.

At that time, the Institute of Mechanics at CAS suggested that USTC should add fluid dynamics and high-speed and high-pressure mechanics to the Department of Mechanics and Mechanical Engineering, and add operational research to the Department of Applied Mathematics and Computer Technology. Those proposals were successful. The institutes' only failure was the proposal to establish a biomechanics specialty, which was rejected because the Department of Biophysics was regarded as a unified discipline that included biomechanics (Luk, 2015).

Bei supported the idea of adding a biochemistry specialty, but the decision to reject the proposal was made by CAS from a macroscopic perspective and was thus beyond his jurisdiction. Ultimately, even though biochemistry did not become a part of the Department of Biophysics, it was set up as an independent course in the department in 1961.

In 1961, the syllabus for biochemistry was set out. The main learning content was an introduction to biochemistry; protein chemistry; nucleic acid chemistry; vitamins; enzymes; hormones; glucose metabolism; fatty acid metabolism; protein metabolism; nucleic acid metabolism; bio-oxidation; energy metabolism; water and inorganic salt metabolism; respiration and neutralization (USTC Archives, 1961b).

From the beginning of the 20th century, the research content of biochemistry was gradually enriched and improved, and it became an independent discipline with the main aim of studying the chemical composition and structure of the organism and the chemical changes in the life process. The development of biochemistry played an important role in immunology, cell communication, the metabolism of biomacromolecules, and the exploration of genetic information transmission.

Objectively, the failure to add a biochemistry specialty was detrimental to the development of the Department of Biophysics. If a biochemistry specialty had been established, instead of a biochemistry course, that may have created another pattern in the development of the department.

7. Conclusion

The establishment of the Department of Biophysics at USTC was due partly to the unique social and historical background and partly to the personal influence and persistence of Bei Shizhang. After the establishment of the department, Bei and his assistant Shen Shumin adhered to a unique training scheme, which was different from traditional biology in its content and educational concepts. They attached great importance to the principle of open-door enrolment, consolidating mathematical and physical foundations, and promoting the importance of experimental methods and techniques and the application

of physics research methods to biological research. Subsequently, they both achieved creative breakthroughs in a number of fields, including cytobiology, radiobiology, cosmobiology, structural biology and enzymology.

The mode of operation proved to be successful. Among the 200 students who graduated in the first five years from the Department of Biophysics, five were appointed as academicians of CAS, many participated in the development of the ‘atomic bomb, hydrogen bomb and artificial satellite’ and manned space flight programme of China, and nine received recognition for that work, including Jia Kepu from Class 5812; Xu Guolin, Yan Gongdong and Chen Mei¹⁷ from Class 5921; and Yang Tiande, Ma Zhijia, Pei Jingchen, Xue Yueying and Teng Yuying from Class 6012. Their achievements were closely related to the education they had received from the Department of Biophysics, USTC—the first Department of Biophysics in China.

The year 2018 marks the 60th anniversary of the establishment of both USTC and the Department of Biophysics. Although biophysics is now part of the School of Life Sciences at USTC, it is still the most prestigious specialty in the school owing to the academic accumulation and advanced thinking of the scientists of the older generation, and also provides us with a benchmark for setting up future specialties.

Notes

- ¹ The Fan Memorial Institute of Biology was established in 1932. The principal founders were the famous Chinese zoologist Bing Zhi and the botanist Hu Xiansu. It was named after the sponsor, Fan Jingsheng, and was one of the early and successful biological research institutes in modern China. It was the precursor of the Institute of Zoology and the Institute of Botany of CAS.
- ² Jiang Pidong was born in Jiang Cun, Jingde County, Anhui Province. He is a biophysicist who graduated from the Department of Physics at Peking University in 1958 and served the Institute of Biophysics at CAS as a researcher; concurrently

- served as deputy chief designer of the Space Life Science system of the Manned Space Flight Project; and is a member of the American Society for Gravitational and Space Biology.
- ³ The comment is from an unpublished recording of an interview with Zhuang Ding. The material was collated by Liu Rui and Yao Qin.
 - ⁴ Guan Zhaozhi (1919–1982) was from Nanhai County, Guangdong Province. He was a mathematician, an expert in systems and control, a CAS academician, a pioneer and disseminator of China's modern control theory, and the first director of the Institute of Systems Science at CAS.
 - ⁵ Wu Wenjun (1919–2017) was born in Shanghai. His family was originally located in Jiaxing, Zhejiang Province. He was a mathematician, a CAS academician, a researcher at the Academy of Mathematics and Systems Science, CAS, and an honorary director of the Institute of Systems Science.
 - ⁶ Wu Youxun (1897–1977), with the literary name of Zhengzhi, was from Gaoan, Jiangxi Province. He was a world-renowned physicist and the founder of modern physics in China, a scientist and an educator, vice president of the China Association for Science and Technology (CAST), and vice president and a researcher of CAS.
 - ⁷ Zhang Wenyu (1910–1992) was a physicist and a CAS academician who was dedicated to nuclear science research and teaching throughout his life. He made a number of important inventions and discoveries. His most outstanding achievement in the academic field was the discovery of μ -mediated atoms, which gave rise to an in-depth study of exotic atom physics.
 - ⁸ Lu Yuanjiu (1920–) is an expert on gyroscopes, inertial navigation and automatic control. He is an academician of CAS, the Chinese Academy of Engineering and the International Academy of Astronautics. He was born in January 1920 in Chu County, Anhui Province. In 1941, he graduated from the Department of Aeronautical Engineering at National Central University (now Nanjing University) with a bachelor's degree. In 1949, he received a doctorate from the Massachusetts Institute of Technology (MIT). He served as an associate researcher and research engineer at MIT, and as a chief engineer at Ford Motor Company. He returned to China in 1956 and worked at the Institute of Automation, CAS. In 1968, he worked in the Ministry of Aerospace Industry and served as a researcher, director, chief engineer, and member of the Standing Committee of the Science and Technology Commission.
 - ⁹ Li Zhengwu (1916–2013) was born in Dongyang, Zhejiang Province. He was a famous nuclear physicist, one of the founders of magnetic confinement fusion in China, the founder of the Institute of Plasma Fusion and Plasma Science, a member of the Fourth, Fifth, Sixth and Seventh National Committees of the Chinese People's Political Consultative Conference, a CAS academician, and an honorary dean of the Southwestern Institute of Physics.
 - ¹⁰ Yang Chengzong (1911–2011) was born in Wujiang County, Jiangsu Province. He was the founder of radiochemistry in the People's Republic of China, a founding father and former vice president of USTC and the first dean of the Department of Radiochemistry at USTC.
 - ¹¹ Wang Baoren (1907–1986) was born in Jiangdu County, Yangzhou City, Jiangsu Province. He was a chemist. In 1935, he received a doctorate from Imperial College London. In 1936, he returned to China and established the School of Science and the Department of Chemistry at Tongji University. From 1951 to 1956, he served as a researcher and deputy director of the Shanghai Institute of Organic Chemistry, CAS. From 1956, he was a researcher and deputy director of the Institute of Chemistry, CAS. In 1958, he established the Department of Polymer Chemistry and Physics at USTC.
 - ¹² Liang Shuquan is an analytical chemist and an educator. In 1955, he was elected to CAS as an academician of the Department of Mathematical and Chemical Sciences. He served as an adjunct professor successively in Peking University (1950s), USTC (1958–1965), the CAS Graduate School (1970s), Shanghai University of Technology (1980s), National University of Defense Technology (1980s) and Northwest University (1991–present).
 - ¹³ Shi Yunyu was born on 21 April 1942 in Chongqing but is a citizen of Nanjing, Jiangsu Province, and is originally from Chongming, Shanghai. She graduated from the Department of Physics at USTC in 1965, majoring in biophysics. At present, she serves as a professor and doctoral adviser at USTC. She was elected as a member of CAS in 1997 and was elected as a member of the World Academy of Sciences in 2009.
 - ¹⁴ This description is from an unpublished interview record made by Xiong Weimin and Yao Qin: 'From the Department of Biophysics to the School of Life Sciences at USTC: Self-reliance in hard times'.
 - ¹⁵ Chen Runsheng was born in June 1941 in Tianjin. He graduated from the Department of Biophysics at USTC in 1964 and currently serves as a researcher at the Key Laboratory of Non-Coding Nucleic Acids, Institute of Biophysics, CAS. He is a CAS academician, a doctoral adviser, a member

of the Human Genome Organization, a member of the CODATA Bio-macromolecular Panel and a member of the International Union of Pure and Applied Physics Bioinformatics Committee. Chen was one of the earliest researchers in China to engage in theoretical biology and bioinformatics research.

- ¹⁶ Chen Lin was born in Chengdu, Sichuan Province, in 1945 and was originally from Fuzhou, Fujian Province. He graduated from USTC in 1970 and is a CAS academician. He serves as a professor at the Institute of Biophysics, CAS, the director of the Beijing Center for Magnetic Resonance Imaging, a chief scientist for the 973 Project (Basic Units of Cognition), and the chairman of the Chinese Society of Cognitive Science.
- ¹⁷ Chen Mei was held back for one year due to illness, so she was enrolled in 1959 and graduated with Class 6012 in 1965.

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Author biographies

Rui Liu is an associate researcher in the Department for the History of Science and Scientific Archaeology, University of Science and Technology of China. His expertise covers the history of biology and the history of modern science and technology.

Qin Yao is a PhD student in the Department for the History of Science and Scientific Archaeology, University of Science and Technology of China.

Yang Chengzong and the University of Science and Technology of China

Pei Liu and Zhihui Zhang

University of Science and Technology of China, China

Abstract

Yang Chengzong was a famous radiochemist and is considered the founding father of radiochemistry in China. He was also a pioneer in the field of natural uranium technology and was one of the founders of the University of Science and Technology of China (USTC). Professor Yang planned and participated in the establishment of the university and its relocation to Hefei, Anhui Province, making indispensable contributions to the development of USTC. This article describes his more than 30 years of experience in scientific and educational endeavours at USTC and explores the important roles he played in the development of the university.

Key words

Yang Chengzong, University of Science and Technology of China, radiochemistry

Yang Chengzong (1911–2011) was a famous radiochemist and educator who is considered to have been the founding father of radiochemistry in China. In addition, he was also a pioneer in the field of natural uranium technology. In 1932, he graduated from Utopia University (1912–1952, located in Shanghai), and in 1934 he joined the Institute of Radium at Peiping Academy (established in 1929 and taken over by the Chinese Academy of Sciences in 1949), starting a productive career in radiochemistry. He went to France and studied at the Curie Institute in 1947 with Irène Joliot-Curie, the discoverer of artificial radioactivity, as his adviser. He earned his PhD degree from the College of Science at the University of Paris (now the Paris-Sud University) in 1951. He returned to China in October of that year and became engaged in

radiochemistry research, first at the Institute of Modern Physics (later renamed as the Institute of Atomic Energy, and currently known as the China Institute of Atomic Energy) of the Chinese Academy of Sciences (CAS), and later at the Fifth Institute of the Second Ministry of Machine Industry (currently known as the Beijing Research Institute of Chemical Engineering and Metallurgy), greatly contributing to the development of nuclear science in China.

Professor Yang participated in the establishment of USTC in 1958 and founded the Department of Radiochemistry and Radiation Chemistry. During the ‘Cultural Revolution’ (1966–1976), he shared weal and woe with USTC and lived through a hard year after the university was moved south. After China’s reform and opening-up, he assumed the

Corresponding author:

Zhihui Zhang, Department for the History of Science and Scientific Archaeology, University of Science and Technology of China, no. 96 Jinzhai Road, Baohe District, Hefei 230026, Anhui, China.
Email: zzh@ustc.edu.cn

position of Vice President of USTC and continued to work hard in developing the university. In his later years, looking back upon his life, Yang once said: 'I have only done two things of note in my life; namely, refining the uranium required for nuclear weapons and founding the specialty of radiochemistry at USTC.'¹ These words show how important the university was to him.

1. Outstanding achievements during early years at USTC

In the beginning of 1955, after the Communist Party of China (CPC) Central Committee decided to create a nuclear industry, the cultivation of nuclear science talent became an urgent national need. In 1955, Liu Jie, the Deputy Director of the Third Office of the State Council (later known as the Second Ministry of Machine Industry) made a report on the nuclear industry. As a reply to his report, the CPC Central Committee stated on 4 July that 'the development of nuclear physics and professional talent in this field is important', 'the Leading Party Group of the Department of Higher Education should make a general plan', and 'we must overcome the difficulties and strive to cultivate large quantities of cadres in the next few years.' The Department of Higher Education subsequently organized physical science research centres at Peking University and Lanzhou University. Relevant specialties were also designed at Peking University and Tsinghua University so as to cultivate scientific researchers and engineers specializing in atomic energy (Zheng, 2003). The specialty of radiochemistry at the Physical Science Research Centre of Peking University began to enrol students in the summer of 1956. In October of that year, Tsinghua University established the Department of Engineering Physics, including four specialties related to nuclear science, such as the technology of radioactive substances. These were the two earliest examples of radiochemistry in China.

Unlike Tsinghua and Peking universities, which added or altered curricula, USTC, set up in September 1958, clung to its original mission of 'developing state-of-the-art science and technology, filling up vacancies and eliminating weak disciplines' and organized the Department of Radiochemistry and Radiation Chemistry (originally called the 'Eighth Department' of the university) when the university was founded. The urgent need for domestic nuclear fuel chemical talent was thus met to the fullest.

At the founding of USTC, 13 departments were organized. The departments cooperated with corresponding research institutes of CAS, leaders of each institute and famous scientists doubled as deans of the departments, and scientists of the institutes served as teachers at the university, thus forming the 'department-institute cooperation' model. The Eighth Department's teaching and logistic work were strongly supported by the Radiochemistry Research Centre of the Institute of Atomic Energy as Professor Yang assumed its directorship.

On 28 July 1958, Yang was appointed as the first director of the Eighth Department at the first meeting of deans held by the preparatory committee of the university. He set out the syllabus and curriculum and organized the teaching team. Three specialties (radiochemistry, radiation chemistry and isotope chemistry) were first designed within the Eighth Department (Figure 1). Students were able to study either theoretical or practical radiochemistry,² and the curriculum lasted five and a half years. Unlike other universities, which offered only five-year curricula, USTC mandated an extra half-year for graduation project design. The theoretical and practical radiochemistry courses mandated 4,080 and 4,176 class hours, respectively. According to the teaching plan made by Yang in August 1959 (Figure 2), the first three and a half years of study provided systematic theoretical, technical and professional foundation courses. Specialized courses would be

用的填充层)的流动,热传导问题,都是化学流体力学研究的对象。可以肯定,随着地下煤的气化,原子能动力等新技术的日益发展,

在化学流体力学这门年青的力学分支中将出现更多更新的研究成果。

放射化学与辐射化学

中国科学院原子能研究所研究员 楊承宗
兼本校放射化学和辐射化学系主任

放射化学与辐射化学都是研究有关原子能方面的化学;它们既以化学为工具服务于原子能工作中提出的要求,同时也利用原子能科学的成就以服务于化学。通过这两门化学,使得原子能科学与化学之间互相帮助,互相提高。

放射化学这门科学是在十九世纪末叶由居里夫人创始的。她首先用化学的方法,分离出第一个放射性元素钋。不久以后,用相似的方法,又发现第二个放射性元素镭,守旧的人们因为钋与镭太少,目不能见,不相信她;居里夫人为了证实她的真理,花了四年时间,终于在几千公斤的矿石里,用化学方法分离出几十毫克在夜晚可以看得见放射出光辉的镭。这些重要的发现,当时不单完全打破了原子不能改变的错误概念,并且也揭露了原子内隐藏着惊人能量的事实。

人们应用居里夫人的放射化学方法,接着也发现了许多放射性元素;在不到二三十年的时间内,把周期表中84号以上的元素大部找到了,但是只局限在自然界本来存在的放射物方面。

1935年,约里奥·居里夫妇在用 α 粒子轰击铝以后,采用化学方法发现了一簇新的放射性磷同位素,这是人造放射性物质的发现,也是人造物质的第一次成功,自古以来历代炼金术士们所追求的点铁成金的美丽梦想,从此变成了现实。

那时中子发现不久,人们用中子轰击铀,在铀中发现了许多放射性同位素;当时由于

分不清它们是什么,科学界就议论纷纷,不图真相,大家称作“铀谜”。这个谜引起了1939年裂变现象的发现,说明铀原子核经过中子轰击以后,可以分裂成为一系列放射性碎片元素的事实,但是这个裂变现象还是通过放射化学方法才得以最后确定的。

下一年,有人又在中子轰击过的铀中,分离出原子量超过铀的元素镅与钷。这些超铀元素的获得,是人工制造物质的更进一步。由于第二次世界大战的需要,1942年开始了在实验室中大量制造钚的工作。在四个月的时间内,首次从几百公斤用中子轰击过的铀中分离出五分之一毫克的钚,钚的数量确实不多,然而这个提取钚的化学过程,却可以立即被用来设计与建造提取钚达数十公斤的原子能化学大工厂,一次扩大到1亿倍而无需经过中间工厂的试验,由此也可见放射化学研究工作进步之快与准确程度之高了。

这一系列的成就是人们对原子能时代的贡献,是整个放射化学工作的光荣。但是在帝国主义者手中,却变成了杀人的武器。

虽然如此,由于和平利用原子能的力量日益高涨,十几年以来,人们已经更进一步以原子能为人类造福。1954年世界上第一个原子能发电站在莫斯科建成了。利用原子能推动轮船航行已经成为事实。时至今日,一个近代国家的国力,已经不以金银计,也不单以钢铁计,而开始以铀与钚的储量来衡量了。

在这个原子能时代里,我国对放射化学方面的要求自然是很多而且也很高的。

Figure 1: Specialty introduction written by Yang for an admission brochure of USTC in 1958.

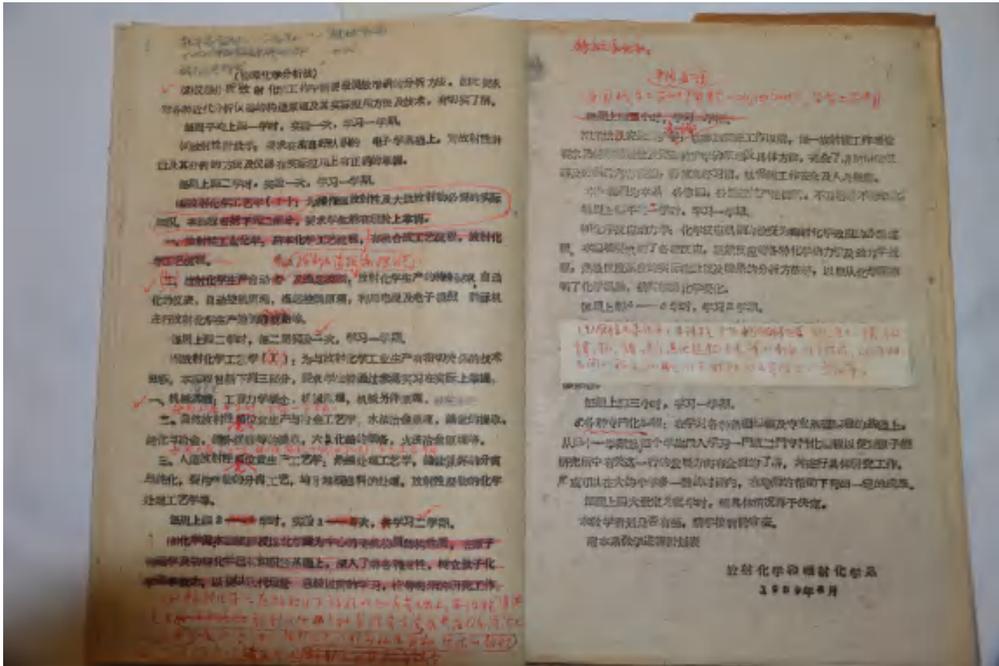


Figure 2: Teaching plan modified by Yang.

conducted from the second term of the fourth year of study, and more time would be dedicated to scientific research or discussion in the second term of the fifth year. The last half year of university study was dedicated to research at the Institute of Atomic Energy, graduation thesis writing and determining career prospects.

When radiochemistry was initially founded as a specialty of study, a lack of experienced instructors was a major difficulty for universities in China. Prior to joining USTC, Yang was engaged first by Peking University and then by Tsinghua University as an adjunct professor in 1957. During this time, he taught specialized courses for radiochemistry students. Upon joining USTC, Yang built a teaching team with many notable professors of the time: Yang mainly taught theoretical radiochemistry; Liu Yunbin mainly taught practical radiochemistry; Xiao Lun taught isotope chemistry; Feng Xizhang taught nuclear chemistry; and Lin Nianyun taught radiation

chemistry (Xu, 2000). Most of these teachers were experts in radiochemistry. They not only possessed a comprehensive theoretical knowledge of their field, but were also at the forefront of nuclear fuel research and development and knew the latest discoveries about the application and development of radiochemistry. Such advantages were embodied in the curriculum at the Eighth Department. For example, Liu Yunbin classified practical radiochemistry into four courses: ordinary chemical industry theory and equipment; natural isotopic production and smelting; artificial radioactivity production; and automatic production and control of radiochemistry. Teaching was carried out across two semesters, and two of the four courses were taught in each semester. At the end of one semester, at least one month was set aside for plant internship. Liu was then the director of the Tenth Research Division of the Institute of Atomic Energy and played a leading role in nuclear fuel research

conducted by the Second Ministry of Machine Industry. This arrangement of courses was complete and systematic. For example, the course on artificial radioactivity production included various nuclear fuel reprocessing techniques, such as precipitation, ion exchange, extraction and high-temperature fluorination. Uranium recovery, plutonium refining and comprehensive utilization and separation techniques for fission products were covered as well (Figure 3).³ Much of this content remains relevant even by current standards. Although Liu Yunbin, Xiao Lun and other instructors did not teach lessons to undergraduates due to their heavy research workloads, they proposed content for professional foundation courses for which they were separately responsible. Almost all of their proposals were eventually absorbed into the formal curriculum of the Eighth Department.

To build a teaching team, Yang recruited Zhang Manwei, Sun Pengnian, Lv Weichun, Li Huhou and other early-career core research personnel from the Institute of Atomic Energy, and subsequently recruited Xu Liruan, Zhang Jixiang and Fan Longxiang, who returned to China after study in the Soviet Union. The Radiochemistry Teaching and Research Office was thus founded. The office was classified into three groups (basic radiochemistry, professional radiochemistry and radiation chemistry), which undertook teaching and experimental work on radiochemistry, nuclear chemistry, practical radiochemistry, isotope chemistry and radiation chemistry.

As the Dean of the Eighth Department, Yang also assumed responsibility for teaching chemistry courses to USTC undergraduates. Foundation courses were considered to be of great importance at USTC. Hence, courses in mathematics, general physics and general chemistry were not organized according to department; instead, all undergraduates were organized into 10 classes. Chemistry courses were taught by 13 teachers, including Yang

Chengzong, Wang Baoren, Liang Shuquan and Liu Dafu. Yang taught courses on inorganic chemistry for five class hours each week.

After 1960, the Eighth Department was reorganized numerous times. Its name was initially changed to the Department of Atomic Energy and Chemistry, as adopted by many universities at the time, and was then changed to the Department of Modern Chemistry in 1961. In April 1964, the Leading Party Group of CAS agreed with USTC leadership on academic and administrative reshuffling, combining the original 13 departments into six. The Department of Chemical Physics, the Department of Modern Chemistry, the Department of Geochemistry, the Department of Polymer Chemistry and Polymer Physics as well as the Chemistry Teaching and Research Office were combined into one department bearing the name of the Department of Modern Chemistry. After the rearrangement, the original radiochemistry specialty was brought under the direction of the Radiochemistry Teaching and Research Office (the name of which was later changed to the Radiation Chemistry Teaching and Research Office) (Xin, 2008, p. 8).

From the above description, we can see that the radiochemistry specialty at USTC was reorganized many times, with course names and teaching settings changing according to the needs of the school's tasks and academic programmes. However, because Yang set up a relatively systematic and integral syllabus and organized an experienced teaching team when the department was established, USTC was able to produce scholarly talent for years during the reorganizations. Before the 'Cultural Revolution', students who graduated from the USTC radiochemistry specialty from 1963 to 1965 were capable of serving the needs of national development (Table 1).⁴

In March 1961, Zheng Lin, the Secretary of the Party Committee of the Institute of Atomic Energy, asked Yang whether he was willing

敬爱的杨先生：

请您考虑一下关于科技大学工艺学课程的
 学习计划问题。由于您的很急，因此没有很多时间
 去翻翻一翻教材资料。同时由于我的水平很差，
 对本门课程一无所知。祇靠个人的一些主观
 的想法，写一下工艺学的大至内容。是否适当，请
 您指教修正。

可能您所需要更详细更具体一点的学习计划，
 甚至翻书大綱。目前根据我的水平是很困难订出
 来。暂时祇把我的想法写出来。如果您认为
 稍有参考价值，那我就非常满意了。

倘若您还需要更具体的计划。通过您对我
 初步意见提出您的指教^{批评}，我尽我的一切努力
 来修改本草稿。竭力能达到能^能满足您的
 要求和期望。

此致
 敬礼。

请接受我对您的诚恳的敬意。
 请原谅我文字上的草率。

刘云斌

1959. 3. 23日

Figure 3: Letter written by Liu Yunbin to Yang Chengzong detailing the curriculum in practical radiochemistry.

Table 1: Career statistics of graduates of radiochemistry from USTC, 1963 to 1965

Years	Students serving the Second Ministry of Machine Industry	Students serving CAS	Students serving USTC	Students serving other (mainly military) organizations	In total
1963	32	36	12	5	85
1964	45	24	10	21	100
1965	57	14	1	28	100
In total	134	74	23	54	285

to join USTC to support its development.⁵ Although Professor Yang had previously taught courses at USTC for three years, had been the dean of the Eighth Department for three years and had spent more time on teaching than he did at the Institute of Atomic Energy, those duties had been part time. In order to run the school better and play a greater role in the cultivation of radiochemistry talent, Yang accepted the transfer without consideration. On 27 March, he was formally transferred to USTC.

2. Hard years at USTC

In 1970, the CPC Central Committee issued a 'university evacuation' order, and USTC was relocated to Hefei, Anhui Province. Yang travelled to Hefei along with the university. After the relocation, all personnel of the school were sent to factories, mines and farms in Huainan, Ma'anshan, Tongling and Hefei for 'criticism and education'. Yang and the students (enrolled in 1964) of the radiochemistry specialty (Class 6432, Figure 4) were sent to the Nanshan Iron Mine in Ma'anshan to participate in physical labour and be re-educated.

On 21 July 1970, the Mao Zedong Thought propaganda teams of workers and of the PLA of Tsinghua University published the article 'Struggle for founding Socialist University of Science and Technology' in the magazine *Red Flag*, promoting the so-called 'Six Basic Rules', including 'the working class must

firmly grasp the leadership of the Education Revolution in its struggle.' This rule was promoted as a guiding thought in running colleges and universities throughout the country during the 'Education Revolution'. Those rules go against objective laws for running schools and have since been eliminated from Chinese academia. However, under the special conditions at that time, the rule on 'combining theory with practice, combining factory work with school, and establishing a new unified system of education, scientific research and production' effectively increased relations between universities, research institutes and factories, and universities benefited somewhat from these measures. As university professors were academically idle during the 'Cultural Revolution', they saw a glimmer of hope that they might resume scientific research by running factories.

When all USTC professors were required to learn from Tsinghua University's experience in order to face the 'Education Revolution', Yang had just returned to Hefei from the Ma'anshan mining site. Although he was nearly 60 years old, he had no time to rest and did not resent his status as only an ordinary 'soldier'. All he thought and talked about was how to continue developing radiochemistry at USTC by utilizing prevailing conditions in Anhui. Yang initially selected the 'front end' of the nuclear fuel cycle as the main direction for radiochemistry study at USTC. According to his nine-year working experience at the Fifth Institute of the Second Ministry of



Figure 4: Photo of Class 6432 at Nanshan Iron Mine in Ma'anshan in 1970 (Yang is in the third row, fourth from the right).

Machine Industry, the major limiting factors hindering the development of nuclear weapons were difficulties in acquiring uranium, low factory labour productivity and high mining costs. He saw a bright future in cultivating uranium mining talent and worker-students for the Second Ministry of Machine Industry. Moreover, observing other radiochemistry departments all over the country, Yang found that Tsinghua University focused on reprocessing; Peking University had many directions of radiochemistry study, but did not research uranium mining techniques; and Lanzhou University focused on radioactive waste disposal. It was therefore necessary and feasible to develop the study of uranium mining as a breakthrough subspecialty of radiochemistry at USTC.

In the autumn of 1970, under the leadership of Professor Yang, Li Huhou and Wang Gengchen, who studied radiochemistry, and several other instructors who studied geochemistry made a preliminary survey of mining sites in Anhui Province. Survey results revealed at least five or six potential uranium mining sites.⁶

In Yang's opinion, as there was ample uranium in the province, setting up uranium refining sites according to Tsinghua University's model was a viable option. He modified his proposal several times and finally finished the 37-page draft titled 'Proposal for USTC's Education Revolution' (Figure 5), which systematically explained the concept of 'combining factory work with specialty research'.

Yang noted that uranium was the most basic raw material used by the nuclear industry and that products from the uranium factory run by the school could be used as raw material for the future construction of a reactor or be directly supplied to the Second Ministry of Machine Industry. Yancun village or Dalong Mountain could be potential sites for a uranium processing factory with a capacity of 2–3 tonnes/year. If useful ore content was considered to be 0.1%, 10 tonnes of ore would be processed daily. Procedures such as ore crushing and sieving would be carried out over one daily shift, while chemical extraction (dissolving and filtering) would be carried out over four shifts daily (six hours per shift).

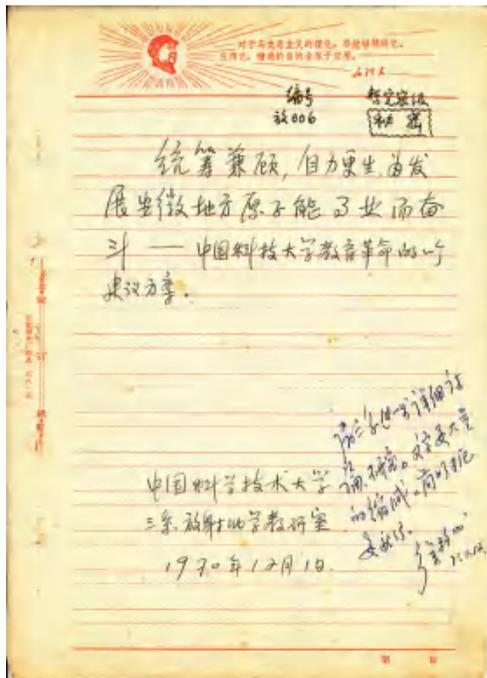


Figure 5: Cover page of the proposal transcribed by personnel invited by Yang (the file number and the confidential level at the top right were added by Yang himself).

Yang thus analysed how factory work drove progress in the specialty. First, chemical exploration was the most effective method to explore a uranium mine, and the geochemistry courses of USTC's Department of Modern Chemistry (the Third Department) could be partly connected to uranium mine exploration by geological teams in the province. The geological teams could provide classes in 'isotope geochemistry'. Second, various ion exchange resins and extracting agents were widely used in the uranium extraction and purification process. Professors of the Third Department researching organic synthesis and resins could play a role in the development of a new exchange resin and extracting agent. Third, USTC's Department of Modern Physics should develop radioactive measurement and metrological work and effectively ensure safety in

uranium mining. Fourth, the development of radioactive measurement equipment as well as portable and automated instruments was to be carried out by USTC's Department of Physics and Department of Radio-electronics.

At that time, there were three types of enrolled students: worker-students of the uranium mining factory of the Second Ministry of Machine Industry; local (province, county and army) workers and PLA soldier-students of existing uranium factories (mines); and worker-peasant-soldier students of minor uranium sites throughout the province.⁷

Detailed planning was just a first step. After a suitable amount of uranium was collected by the radiochemistry faculty over the course of two to three years, isotope separation research would be carried out to produce a certain amount of low-enriched uranium. It would then be possible to build one or two reactors, so as to create conditions for a second nuclear science base encompassing both education and nuclear production. After the reactor was built, further research on reprocessing chemical techniques and the production of new radioactive isotopes would be possible. According to Yang's expectations, USTC radiochemistry studies would be involved in every aspect of the nuclear fuel cycle. His zeal for radiochemistry was perfectly embodied in his ambition to develop the subject even in the face of great adversity.

At that time, in the Teaching and Research Office of Radiochemistry, some teachers were stationed outside of academia, some wanted to return to Beijing, and others were disappointed at the bleak specialty prospects due to a lack of necessary drainage conditions in Hefei. There were therefore few positive responses to Yang's proposal. Yang proceeded to send a letter to the Fifth Institute under his own name in October 1971, making three preliminary proposals:

- USTC could cooperate with the Fifth Institute, taking uranium mining as a main direction for radiochemistry studies.

- The Fifth Institute could invest in the construction of infrastructure at USTC as a base for scientific research and coordinated production, and it could be used as a rear base of the institute in emergencies.
- The radiochemistry faculty would be responsible for small mines and comprehensive utilization⁸ under the direction of the Fifth Institute, both serving the province and increasing national production.⁹

After receiving a positive response from the Fifth Institute, Yang reported to the school leader, indicating that, if the school approved his proposal, he would further propose specific courses of action.

Yang made such a proposal because CAS and USTC were not so closely related during the ‘Cultural Revolution’ as in previous years. In October 1967, Mao Zedong approved the ‘Report on the adjustment and reorganization scheme in relation to national defence scientific research system’ proposed by Nie Rongzhen. Thus, the New Technology Committee of CAS and the units under its jurisdiction were all governed by the Commission of Science, Technology and Industry for National Defense of the People’s Republic of China. As most of the departments and specialties organized when USTC was established were related to the development of ‘two bombs and one satellite’, many departments that had cooperated with corresponding institutes at CAS had since departed from CAS. Because of the interruption to education and scientific research, CAS and USTC had only relationships between superiors and subordinates, and the combination of institutes with departments existed in name only.

Professor Yang intended to develop the specialty of radiochemistry under the jurisdiction of the Fifth Institute, which was governed by the Second Ministry of Machine Industry. This ensured the long-term development of the specialty. Subsequently, Wu Ruyang, Qian Zhidao and other USTC

leaders negotiated with the Second Ministry of Machine Industry many times; however, relevant individuals responsible for the final decision considered USTC to be minimally effective after its relocation and would not support the development of radiochemistry at the university.

On 4 May 1973, the USTC Party Committee finally announced that the radiochemistry specialty was to be cancelled; early-career employees would be rearranged within the university, middle-career teachers meeting relevant requirements would be transferred from USTC, while older professors would retire.⁴ The radiochemistry specialty had emerged in Beijing but was closed down after its relocation in Anhui Province. Yang was saddened to see the closure of the specialty and wrote an article titled ‘Annihilation of the radiochemistry specialty’, which contained many indignant words.¹⁰ In his view, radiochemistry could have been organized effectively had school leaders avoided errors.

Objectively, there was no choice but to close down the radiochemistry specialty of USTC under great adversity. In fact, the entire university was at a breaking point. By the end of 1971, USTC was under the jurisdiction of the Third Ministry of Machine Industry—the leading department responsible for national aviation industrial systems—but the foundational principle of USTC was ‘combining science and engineering, with science as the primary goal’. Among all 37 specialties in the school, 17 were not relevant to the Third Ministry of Machine Industry, especially the radiochemistry specialty and the four specialties of the Department of Modern Physics. Relevant leaders of the ministry declared that specialties not relevant to their bureau would be deprived of funds for scientific research. In order to solve the problem concerning those specialties, the university successively submitted the ‘Request report on early determination of jurisdiction over the atomic energy specialty’ and the ‘Request report on the jurisdiction over and system and specialties of USTC’ in 1972.

After many efforts, USTC was finally reconnected into the CAS system on 7 May 1973. After a great adjustment of study specialties, the vast majority were placed under the jurisdiction of CAS. Thirteen specialties deemed relevant to national ministries and commissions, such as space physics, semiconductor physics and structural aircraft mechanics, remained unaltered (Ding and Ke, 2015).

If the Second Ministry of Machine Industry had provided its backing, radiochemistry could have been continued as a field of study at USTC. However, the specialty was ultimately closed down. As one of the most prestigious experts in radiochemistry in China, Yang departed the front lines of teaching and scientific research. His departure from academia was a great blow not only to the university but also to the discipline of radiochemistry in China.

3. A new start for Yang's scientific career

In November 1978, Yang was appointed as the Vice President of USTC and took charge of scientific research. Therefore, after several years outside academic life, he engaged once again in the development of the university.

Yang's excellent administrative skills had been fully demonstrated as early as during his time as the Deputy Director of the Fifth Institute. After taking the position of Vice President of USTC, he quickly adapted to his new role. The first thing that he focused on was solving a problem that some faculty encountered concerning household registration. After the school was relocated to Hefei, many instructors wanted to return to Beijing and could not properly dedicate themselves to academic activities. In early November 1978, with the help of journalists from Xinhua News Agency, students (enrolled in 1977) of Class 1 at the Department of Modern Physics of USTC sent a letter signed by the whole

class to Fang Yi, who was then the Vice Prime Minister of the State Council. In the letter, they expressed their concerns about the problem among faculty. At that time, Yang considered the 'Five Zis'¹¹ method, which was proposed by Hu Yaobang to allow researchers to work easily while he acted as leader of CAS in 1975. Yang believed that for USTC faculty who came from Beijing household registration was another important event besides the 'Five Zis'. In the early spring of 1979, during the National People's Congress, Yang communicated this matter to Gu Zhuoxin, the Deputy Secretary of the Anhui Provincial Party Committee, and expressed his wish for USTC faculty to retain Beijing household registration. Gu was very supportive of this and suggested that Yang pay an official visit to responsible comrades of the Beijing Municipal Committee. Shortly afterwards, the policy of retaining Beijing household registration for USTC faculty was implemented, allowing faculty to settle down satisfactorily in Hefei.

In addition to being in charge of scientific research and the construction of some laboratories, Yang also served as the Director of the Foreign Language Teaching and Research Office. Due to problems caused by the 'Cultural Revolution', the office was unstable at that time, and there were many disputes concerning various languages. In addition, the learning of foreign modern science and culture had not been promoted for a long time, and this resulted in a general lack of emphasis on foreign language learning apart from students of foreign language specialties. Yang proposed that foreign language education would give priority to English while considering other languages as well. USTC changed its focus of foreign language education from Russian to English quickly and became a top school with the most effective foreign language education. Throughout the 1980s, studying abroad became a trend among USTC students. Afterwards, at a meeting held by the Ministry of Education to discuss the

CUSPEA¹² programme, Huang Xinbai, the Deputy Director of the Ministry of Education, consulted Qian Linzhao, another Vice President of USTC, asking, 'Why does your university have the largest number of students enrolled in the programme?' Qian replied, 'There is nothing special. What is unique to us is that Professor Yang, as Vice President of USTC, engages himself in the work of the Foreign Language Teaching and Research Office.'¹³

Fortunately, although the radiochemistry specialty of USTC was discontinued during the 'Cultural Revolution', the specialty of radiation chemistry was able to continue to develop. To carry out teaching and research work in radiation chemistry, cobalt-60 was essential. Considering that USTC was underfunded at that time, Yang proposed to relevant organizations in Anhui Province to borrow cobalt-60. Since accidental deaths had been caused by cobalt during attempts at radiation breeding during the 'Great Leap Forward' (1958–1960), many organizations considered cobalt to be a burden and were willing to offer it for free. Unfortunately, the amount of all the cobalt combined was still too small to meet the demands of research in radiation chemistry. Yang's application to acquire cobalt from abroad and to establish a cobalt source laboratory was quickly approved. The laboratory was constructed so as to ensure maximal radiological protection, and safety was repeatedly tested. Yang recommended Zhang Jixiang and Chen Wenming, both from the Radiation Chemistry Teaching and Research Office, to take responsibility of various matters. On the afternoon of 10 April 1984, a lead box containing cobalt-60 imported from the United Kingdom arrived in Hefei; USTC successfully completed the placement of cobalt by the evening of the same day. On 5 May, 60,000 curies of cobalt-60 source was installed and passed inspections. With this advantage, the Radiation Chemistry Teaching and Research Office made many achievements in basic theory and applied research, such as the synthesis of

polymer materials, the treatment of 'three wastes' (waste gas, waste water and solid wastes from industrial production) by radiation, and radiation processing of industrial and agricultural products. While cultivating a large number of scholars, the office also created considerable economic benefits for USTC.

Yang also did a lot of work on the construction of chemical disciplines at USTC. In 1984, after approval from the Academic Degrees Office of the State Council, USTC became one of three universities to offer a doctoral programme in radiochemistry in China (the other two were Peking University and Beijing Normal University),¹⁴ due in no small part to Professor Yang's extraordinary seniority and prestigious reputation in academic circles. In fact, the doctoral programme in radiochemistry was the first doctoral programme offered in chemistry at USTC and was also one of the two doctoral programmes in chemistry in the university throughout the 1980s (the other was analytical chemistry). For quite a long time, the cultivation of doctoral candidates in other subdisciplines of chemistry at USTC was affiliated with the radiochemistry doctoral programme. For example, excellent graduates with bachelor's or master's degrees in physical chemistry, inorganic chemistry and polymer chemistry/physics were all willing to apply for the radiochemistry programme at USTC. Yang provided enthusiastic guidance when they required it (Figure 6). A large number of people among them served as USTC teachers after gaining PhD degrees and returned to work in their original disciplines, and most of them later advanced as core researchers at USTC (Yu, 2000, p. 60).

Yang officially retired from USTC in March 1994 at 84 years old and returned to Beijing to spend his remaining years. On 16 September 2010, the 'Celebration of the 100th birthday of Professor Yang and symposium on his engaging in academic activities for 80 years' was held. Many notable individuals attended the event. Nearly 400



Figure 6: Yang is instructing young teachers (the person sits in the middle is Chen Zuyao, and the person stands on the right is Liu Qingliang, both became professors and advisers for PhD students).

experts and scholars from various fields of science and education gathered, including He Zehui, Wu Wenjun, Xu Guangxian, Guo Musun, Wang Fangding and other senior academicians. During his address of thanks, the centenarian commented on the indissoluble bond between USTC and him for over half a century, saying with deep affection: ‘From the establishment of USTC in 1958 to the present, I have always been a part of USTC and I am proud of the university.’ (USTC News Center, 2010) Indeed, from the school’s founding and relocation to Hefei, Yang actively planned and participated in all aspects of university development. As pointed out by Academician Hou Jianguo, the former President of USTC:

Professor Yang was the founding father of the rebirth of USTC. He stayed with the university through thick and thin and made outstanding contributions to its re-emergence. Professor Yang is forever to be a model person for us to

learn from in terms of his loyalty to his country, his dedication to scientific research, his love for education, his indifference to fame and fortune, and, finally, his broad mind and optimism and open-mindedness. (USTC News Center, 2010)

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We are thankful to Professor Yang Chengzong’s relatives for contributing pictures so as to enrich the content and increase readability of this article.

Notes

- ¹ This statement was published in *Science Times* on 20 September 2010, p. A1.
- ² In the 1950s, the higher education system in China, after adjustments of departments and specialties, generally followed the Soviet model; different subspecialties, which were similar to research directions, were set out under each specialty.

- ³ From a letter to Yang Chengzong written by Liu Yunbin on 23 March 1959.
- ⁴ From a copy of Yang's 'Proposal for recovering the radiochemistry specialty at USTC', 23 August 1978.
- ⁵ From a copy of Yang's 'Report' (Autobiography), 17 December 1968, p. 15.
- ⁶ From a copy of Yang's 'Suggestion on the preparation of a small-sized uranium factory by the radiochemistry department', 14 September 1970.
- ⁷ From a copy of Yang's 'Proposal for USTC's education revolution', 1 December 1970.
- ⁸ The task of comprehensive utilization was proposed by the National Development and Reform Commission to the Fifth Institute in 1968, but the institute could not finish the task due to other preoccupations.
- ⁹ From a copy of Yang's 'Proposal in relation to the long-term development of the radiochemistry specialty', November 1971.
- ¹⁰ See the copy of Yang's article, 'Annihilation of the radiochemistry specialty', 20 November, 1973.
- ¹¹ The so-called 'Five Zis' refer to 'piaozi (money), fangzi (house), qizi (wife), haizi (kid) and luzi (stove)'. Hu Yaobang learned that the general difficulties faced by scientists were worries caused by low wages; crowded housing; long-term separation of husbands and wives; difficulty in getting children into nursery schools; and lack of domestic gas containers, which made cooking difficult. Hu personally consulted leaders of relevant departments and requested support. Eventually, most of the problems were solved. The 'Five Zis' method later became an excellent example at CAS.
- ¹² CUSPEA (China-US Physics Examination and Application) was a joint Sino-US programme to cultivate postgraduates in physics. Promoted by Professor Tsung-Dao Lee and established in 1981, this programme aimed to further open the doors to overseas education for Chinese students. The programme was cancelled in 1989. During the years when it ran, nearly a thousand Chinese students passed the examination and thus were able to pursue degrees at public expense in the United States.
- ¹³ From an interview with Yang by Zhang Zhihui on 2 September 2007 in Beijing.
- ¹⁴ In the 'Catalogue of disciplines and specialties with the qualification of awarding Doctor's and Master's degrees and postgraduate cultivation' issued by the Ministry of Education in 1990, radiochemistry (specialty code 070306) is a secondary discipline of chemistry, and radiation chemistry is a subdiscipline of radiochemistry.

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Author biographies

Pei Liu is an associate research fellow in the Department for the History of Science and Scientific Archaeology at USTC.

Zhihui Zhang, PhD, is a professor in the Department for the History of Science and Scientific Archaeology at USTC. His expertise covers the history of science and technology in modern China, scientific policy and oral history. He has been in charge of many research programmes and has published more than 30 research articles and four books.

The process of establishing a Special Class for the Gifted Young at the University of Science and Technology of China

Haohua He and Zhihui Zhang

University of Science and Technology of China, China

Abstract

The Special Class for the Gifted Young (SCGY) is an educational model created by the University of Science and Technology of China (USTC) during a special historical period. It aims at selecting and cultivating young talent in the natural sciences. Significantly, the establishment of the SCGY in 1978 marked the beginning of higher education reform in China after the ‘Cultural Revolution’ (1966–1976) and promoted the development of education. Currently, there are only a few general descriptions of how the SCGY was established. In research for this paper, we used many sources, including archives, personal diaries and interview records, to uncover the process leading to the establishment of the SCGY. We also investigated the reason why the SCGY was first established at USTC.

Key words

Special Class for the Gifted Young, University of Science and Technology of China, establishment, Fang Yi, Ning Bo, Tsung-Dao Lee, higher education reform

The Special Class for the Gifted Young (SCGY) at the University of Science and Technology of China (USTC) is a special form of undergraduate education for gifted younger students who do not complete senior middle school courses according to the normal pattern. The first SCGY at USTC commenced on 8 March 1978, marking the beginning of innovation in contemporary higher education in China. At the beginning, the SCGY was a preparatory class. After nearly six months of exploration, discussion and research, it evolved to become an undergraduate class by the time of the

second enrolment and formed the basis of the current USTC SCGY.

This year marks the 40th anniversary of the SCGY, which remains an innovative and far-reaching education reform in China. The special class has been constantly reviewed and discussed by the academic community. In 2008, USTC published *The Thirty Years of the SCGY*, which reviewed and summarized the 30-year developmental process. However, the existing records of the SCGY’s establishment are too general or use a narrative structure; they lack in-depth discussion and details

Corresponding author:

Haohua He, Department for the History of Science and Scientific Archaeology, University of Science and Technology of China, No. 96 Jinzhai Road, Baohe District, Hefei 230026, Anhui, China.

Email: howe@ustc.edu.cn.

of the evolution of the nature of the SCGY. Based on relevant files and data, such as diaries, autobiographies and interview records, we identified and analysed particular details of the program's history in an attempt to more comprehensively record the historical process of the SCGY's establishment and to determine the reason why the SCGY was first established at USTC.

1. Background: the need for talent after the 'Cultural Revolution'

The 'Cultural Revolution' included a proletarian 'Education Revolution' in the education field. Colleges and universities suspended enrolment for four years from 1966 to 1970. From June 1970, following a process of public recommendation, leadership approval and university review, universities started to recruit students from among workers, poor peasants, ex-servicemen, and young cadres holding diplomas above junior middle school level and with more than three years of working experience (Zhou, 1997, p. 85).

The 'Education Revolution' was intended to realize 'education for proletarian politics' and educational equity by means of education reform. However, the model of test-free admission to study programs was not considered fair and equitable in practice. Academic requirements were overlooked and political and practical criteria were emphasized, resulting in irregularities in learning levels among students and a generally low level of educational quality (Zhu et al., 2006). While practical knowledge was highlighted, the development of talent in basic subjects was given less importance. The suppression of intellectual education and the neglect of elementary education over the decade of the 'Cultural Revolution' led to a severe talent shortage and discontinuity across the country.

In October 1976, after the 'Gang of Four' (a political team during the 'Cultural Revolution'

led by Wang Hongwen, Yao Wenyuan, Zhang Chunqiao and Jiang Qing) was dismantled, Hua Guofeng, on behalf of the Communist Party of China (CPC) Central Committee, proposed the building of a powerful modernized socialist country and coined the slogan of 'Advance towards modernization of science and technology' (S&T). In July 1977, Deng Xiaoping officially resumed his senior political and military roles. He shared ideas with Hua on several issues, including 'S&T work is the leading part of the four modernizations (modernization of industry, agriculture, national defence and science)' and 'Respect knowledge and respect talent.' Hua empowered Deng to take charge of the development of S&T and education (Wang, 2018). With the efforts of Hua and Deng, the central government decided to convene a national science meeting in the spring of 1978 and resume the National College Entrance Examination (NCEE). The development of S&T and education was brought back on track from then on. With many things to be done, talent became the key to national development. Throughout the country, it became a common aspiration to 'develop talents faster and gain achievements earlier'.

On 18 September 1977, the CPC Central Committee issued a 'Notice on convening the national science meeting'. Within several months, numerous people throughout the country wrote to the State Scientific and Technological Commission (SSTC), the Chinese Academy of Sciences (CAS) and local leading S&T departments to make proposals and recommendations and to contribute their personal achievements to the country. At that time, CAS received 200–300 letters every day (Xinhua News Agency, 1978a, p. 1).

Fang Yi, a member of the Political Bureau of the CPC Central Committee, director of SSTC and Vice President of CAS, was the chief assistant of Deng Xiaoping in developing science and education. He worked carefully

and attached great importance to letters from and visits by the general public. Deng once said that talents are the key to the development of science and education. Fang resolutely implemented Deng's instructions and attached great importance to talent selection (Editorial team of Fang Yi's biography, 2008, p. 532).

With Fang's efforts, CAS regarded 'exceptional selection' of talent as an important measure for implementing the central government's ambition to 'develop talent rapidly, earlier, and more'. Following the introduction of the measure, affiliates of CAS enrolled some 'exceptionally admitted' scholars. For example, Beijing Observatory and the Institute of Botany admitted, respectively, Duan Yuanxing, who discovered a new star through astronomical research, and Li Zhenyu, who was knowledgeable in plant taxonomy, as postgraduates (Zhou, 1978). USTC, which was directly subordinate to CAS, also followed Fang's instruction that 'colleges and universities may exceptionally admit excellent teenagers' (USTC Achieves, 1977a). In July 1977, Xiao Gang, a 25-year-old worker-peasant-soldier undergraduate of Jiangsu Normal University, wrote to CAS, recommending himself. He was then examined and became the first student exceptionally admitted by USTC, as a postgraduate student in mathematics. During the enrolment of postgraduates and undergraduates in 1977, USTC successively admitted Li Kezheng (as a postgraduate in mathematics), Liu Gang (as an undergraduate in modern physics), and Zheng Zhongwang, Yang Zili, Zhang Shangyou, Shi Fengshou, Sha Jiping and Zuo Kang (as undergraduates in mathematics) (USTC Achieves, 1977a, 1977b). After the NCEE in 1978, Li Weidu was exceptionally admitted as an undergraduate of earth and space science (Zhu, 2008, p. 190). It was during this period that the SCGY of USTC was established.

2. Germination: the conception of a trial middle school of science

USTC's idea of enrolling middle school students to prepare them for S&T study can be traced to a proposal for a trial middle school of science in October 1975.

The '9/13 Incident' in 1971, in which Marshal Lin Biao died in an aircraft crash, made Chairman Mao Zedong rethink the 'Cultural Revolution'. Between 1972 and 1973, Premier Zhou Enlai seized this opportunity arising from the transitioning of Mao's thought. He endeavoured to correct ultra-left (politically radical and impractical) errors during the 'Cultural Revolution' and implemented several important education initiatives in an attempt to break through the 'Two Estimations' line (Gao and Yao, 2009, p. 162).¹ During this period, Yang Zhenning and Tsung-Dao Lee (two famous Chinese physicists and winners of the Nobel Prize in Physics) returned from overseas on several occasions and were received by Mao and Zhou. Respectively, they suggested enhancing basic science research and cultivating basic science talent, and both recommendations were endorsed by Mao and Zhou (Gao and Yao, 2009, pp. 163–166). However, from the end of 1972, Zhou's correction of ultra-left errors increasingly displeased Mao. In the second half of 1973, a student's submission of a blank answer sheet during the NCEE² triggered a counter-attack on the 'resurgence of a revisionist education route' and generated a counter-resurgence movement in the education field, which promptly extended to other fields (Zhou, 1997, p. 127), resulting in Zhou being criticized (Gao and Yao, 2009, p. 170).

After October 1973, Mao made successive efforts to prevent Jiang Qing and others from developing their political power, indicating a change in the situation. At the beginning of 1975, Zhou became seriously ill and Deng Xiaoping, supported by Mao, was appointed Vice Chairman of the CPC Central Committee,

Vice Premier of the State Council and Vice Chairman of the Central Military Commission, enabling him to preside over the routine work of the CPC and the country and to comprehensively rectify the disorder caused by the 'Cultural Revolution' (Zhou, 1997, p. 143).

In response to Deng's instruction to 'reorganize the Chinese Academy of Sciences and enhance leadership', CAS drafted the 'Work report outline of CAS' and required its affiliates to report progress in their work. On 15 August 1975, Liu Da, the then secretary of the Party Committee of USTC; Wu Ruyang, the deputy secretary; Qian Zhidao, the vice president; and other officials reported USTC's situation to Li Chang and Wang Guangwei, the then deputy leaders of the CAS caucus, and made recommendations for the further development of USTC (Zhu, 2008, p. 152–155). During their discussion, Li recommended that USTC establish a middle school of science, saying:

Science can be classified into basic and applied science. Chairman Mao and Premier Zhou have discussed the cultivation of basic science talent with Tsung-Dao Lee and Yang Zhenning, respectively. The concept of a middle school of science is well grounded, because students of such a school can go directly to USTC when they graduate. To establish a trial middle school at USTC, the students must be carefully selected from throughout the country. (USTC Archives, 1975a)

On 26 September 1975, when discussing the work report outline with Hu Yaobang, the then chief deputy leader of the CAS caucus, Li and Wang, Deng issued the following instruction:

To run USTC well, CAS should admit students skilled at mathematics, physics and chemistry, and no cadres' children shall be privileged. If there should be something wrong in doing this, I would be the first to apportion blame. There cannot be a relapse! There will be no way of reaching the summit of education without an

adequate knowledge of foreign languages, mathematics, physics and chemistry. (Zhu, 2008, p. 155)

Before and after Deng's instruction, CAS successively convened three symposia on the development of USTC on 11 September, 26 September and 5 October, asking USTC to develop, as soon as possible, a draft 'Request for instructions regarding issues at USTC' (Zhu, 2008, p. 155–158). Wu Ruyang returned to the school after the meetings and organized a drafting group that completed the draft on 23 October. In the name of CAS, the draft proposed seven points to the State Council that should be followed to run USTC effectively. The sixth point concerned a 'trial middle school of science':

To meet the needs in the development of scientific undertakings, with reference to previous experiences of talent cultivation in the sports, literature and art communities, CAS will appoint USTC to open a trial middle school of science, allowing students to learn natural science theories and receive practical training that is essential in scientific research. Students of such a middle school may be enrolled based on nationwide selection and, after graduation, some students will be directly admitted by USTC for further study. (USTC Archives, 1975b)

However, the political environment changed in an unpredictable manner. Deng Xiaoping's comprehensive rectification of the negative effects of the 'Cultural Revolution' was regarded as 'a revenge on the Revolution' (Zhou, 1997, p. 152) by the 'Gang of Four' and was denied by Chairman Mao. From November 1975, a movement to 'criticize Deng Xiaoping and attack the rightists' thoughts' was raised nationwide. This resulted in Deng being overthrown, while Hu Yaobang, Li Chang and their comrades were accused of being capitalist thinkers. Wu Ruyang was also violently criticized for being a follower of Deng, who became known as the most stubborn capitalist

thinker, and Hu and Li, who were regarded as capitalist thinkers of CAS. The draft was deemed to be ‘a draft that totally repudiated the “Cultural Revolution” and the “Education Revolution”; a draft that called for the restoration of a revisionist education strategy; and proof of Deng’s attempt to restore revisionism in S&T and the education field’. The proposal to open a trial middle school of science was deemed to be ‘an attempt by capitalist thinkers to select the most skilled and intelligent pupils from across the country’ and was ‘completely antithetical to Chairman Mao’s education strategy’ (USTC Archives, 1976).

The trial middle school of science was a proposal by CAS and USTC for enhancing the cultivation of basic science talent at middle school level during the ‘Cultural Revolution’. It was impracticable due to the political situation during that period and was cancelled after only one month.

3. Trigger: a recommendation letter for Ning Bo

Although USTC’s conception of a trial middle school of science could not be put into practice at the time it was initially proposed, preparatory cultivation of selected youths remained a possibility once conditions were appropriate. There were tremendous changes in the political situation over the next two years, when a letter of recommendation for a Grade 2 senior middle school student inadvertently initiated an education reform leading to the accelerated cultivation of S&T talent.

3.1 A recommendation letter from Ni Lin to Fang Yi

On 20 October 1977, Ni Lin, a teacher at the Jiangxi Metallurgical College (now the Jiangxi University of Science and Technology), wrote a letter recommending a 13-year-old

Grade 2 senior middle school student, Ning Bo. The letter enumerated Ni’s extraordinary performances in understanding, memory, medicine, astronomy, *weiqi* (a game similar to chess, known in the West as *Go*), poetry and general learning. At the end of the letter, Ni wrote:

As a communist and also an engineering technician with more than twenty years of work experience, I am writing this letter to recommend a worthy person for the country. I have never met such an incredible child before. If he can be admitted and provided with professional education by USTC, I believe he will certainly become a groundbreaker. I hope your leadership can examine his abilities by some means, personally or by dispatching a suitable person or entrusted relevant department.³

On 3 November, Fang Yi gave instructions on Ni’s recommendation letter: ‘USTC should pay a visit to Ning Bo. If the student is qualified, USTC should recruit him for college study.’ (USTC Archives, 1978a)

Not only Ning Bo, but also other talented teenagers, including 15-year-old Shen Yu⁴ and 14-year-old Mu Qing,⁵ were recommended and admitted by the CAS leadership during the same period. On 22 December 1977, USTC submitted its ‘Report on enrolment work’ to CAS, mentioning the three recommended students:

As instructed by CAS leadership, the selection of talent follows no set form. We have carefully analysed letters from more than two hundred examinees and conducted special investigations of the most promising.

Following the instructions by Fang Yi and Li Chang, we have examined the academic performances of Shen Yu, a 15-year-old boy from Grade 3, Handan Middle School of Shanghai, Ning Bo, a 13-year-old boy from Ganzhou, Jiangxi Province, and Mu Qing, a 14-year-old girl from Grade 1, No. 99 Senior Middle School of Shenyang Province. (USTC Archives, 1977c)

There is little documentation about the recommendation and examination of Shen Yu and Mu Qing. We interviewed Shen Yu's mother and Mu Qing years ago, but many details are difficult to recall now. As we remember it, Ning Bo, the youngest among the three, showed potential in *weiqi*, pulse-based diagnoses in traditional Chinese medicine, and poetry composition, making him quite a 'legend'. Therefore, the ninth issue of *Letter Bulletin*, which was jointly run by the SSTC and CAS, reported his story in a feature article, after which he was described as 'the first teenage prodigy' by the general media.

3.2 Investigation of Ning Bo by USTC

USTC implemented the instructions of Fang Yi and other CAS leaders. According to *The Record of the SCGY at the University of Science and Technology of China: From 8 March 1978 to 8 March 1988*, 'From 19 November to the end of December 1977, USTC dispatched well-learned teachers to the relevant provinces and cities for the investigation and assessment of recommended teenage geniuses' (as cited in Zhu and Qin, 1988, p. 363).

On the question of how these teenage prodigies were investigated, Liu Xianrong,⁶ who was responsible for enrolment in 1977, recalled that the investigation mainly involved three dimensions: solid fundamentals, diligence and talent. The time and conditions for enrolment were limited that year, so the three dimensions were tested mainly through a mathematics examination and an interview.

Because few materials about Shen Yu and Mu Qing are available, we use Ning Bo as an example to describe the investigation procedure. On 17 December 1977,⁷ Luo Xiaopei and Du Xilu, teachers from the Department of Mathematics of USTC, went to Jiangxi Province to investigate Ning. Luo was the party secretary of the department, and Du was an expert in *weiqi* at the university. The ninth

issue of *Letter Bulletin* described the investigation in an article titled 'A 13-year-old teenager exceptionally admitted by USTC':

USTC's investigation: Ning Bo has performed well and is eager for further study. He participated in the NCEE this year.⁸ He was tested with two sets of mathematics examination papers. One was a test for fundamentals that contained seven questions. It took him twenty minutes to finish the first five questions correctly, while for the other two, which were beyond his knowledge, he correctly answered one of them after being provided with a hint. The other examination paper was the examination paper of the US Olympic mathematics competition in 1976, containing six difficult questions. Ning Bo correctly answered one and a half questions. In addition to the written examination, an oral examination was also given, involving classical literature, history, traditional Chinese medicine, and chemistry. Ning Bo gave clear and correct answers to those questions. In the game *weiqi*, the no. 4 player from USTC lost the first two rounds to Ning and won the third round by a neck. A USTC staff member asked Ning to make a diagnosis by taking the staff member's pulse. Ning listed the symptoms precisely. Finally, Ning was asked to compose a poem titled 'Sentiment toward examination'. He finished an eight-line Chinese poem with seven characters in each line within only twenty minutes.⁹ (USTC Archives, 1978)

The description of the examination in *Letter Bulletin* is consistent with Ning Bo's recollection and the details recorded in the diary of Ren Zhishu.¹⁰ However, according to Ning and Ren there was a further examination. As recalled by Ning, on the third day after the first examination, the two USTC teachers visited Ganzhou No. 8 Senior Middle School to investigate Ning's performance in the school. Cai Ze, the dean of teaching affairs at the school, recommended that to provide a fair opportunity and select more talent for the country the two teachers

should deliver another exam. A mathematics examination was thus organized by the Education Commission of Ganzhou and was given to Ning Bo and nine other outstanding students younger than 17. The exam results were presented later in the evening: Xu Jin, a 17-year-old student from Ganzhou No. 3 Senior Middle School, scored 75; Ning Bo scored 67; Ning Bo's classmate, Pan Xinling, a 15-year-old girl, scored 64; and all other candidates scored below 35.¹¹ At that time, the results of the NCEE in Jiangxi Province were already available. Xu Jin ranked first among the new graduates in Ganzhou, but he was admitted to the Mining Machinery Department of Jilin University rather than the Mathematics Department of Peking University, to which he had initially applied. His father wrote to Fang Yi to inform him of the situation. Fang Yi then instructed the Minister of Education, Liu Xiyao, to 'give some precedence', enabling Xu Jin to finally be admitted to study mathematics at USTC.¹²

4. Origin: Establishment of the preparatory class

After the investigation of Ning Bo, Shen Yu and Mu Qing, USTC began to consider how to educate them appropriately and finally decided to run a preparatory class with reference to the trial middle school of science. After more than two months of preparation, the preparatory class was established.

4.1 The decision-making process for establishing the preparatory class

At that time, the older exceptionally admitted youngsters were placed directly in the corresponding undergraduate or postgraduate class. However, USTC held several meetings to discuss the placement of teenagers younger than 15 years.

On 22 December 1977, the USTC enrolment team met to discuss the placement of

Ning, Shen and Mu. Wu Ruyang, the then secretary of the USTC Party Committee, was the team leader, and Xu Wenying, a standing member of the committee, was the deputy team leader. The minutes¹³ are as follows:

Liu Xianrong: Information from CAS.

a. The 15-year-old Shen Yu from Shanghai recommended by Fang Yi.

We wrote a letter to Shen asking him to participate in the NCEE before we sent representatives to assess him. He participated in the district-level preliminary examination. There were a total of 295 examinees, among which he was the only middle school student. Only three were selected for the NCEE, and Shen was not among them. Our representatives negotiated with the provincial enrolment office¹⁴ and agreed to let him participate in the examination. According to an article titled 'The ambition of a youngster' in *People's Daily*,¹⁵ Shen has mastered mathematics at the senior middle school level and showed competency in foreign languages.

b. The two teenage prodigies.

13-year-old Ning Bo: Prior to their return, the investigators wrote a letter stating that he played *weiqi* well, but his self-acquired knowledge was not solidly mastered. His performance in class fluctuated, but he would participate in the NCEE.

14-year-old Mu Qing: She finished eight questions of elementary mathematics,¹⁶ and finished middle school mathematics from the age of 10 to 20.¹⁷ More than one thousand differentiation questions had been completed in her leisure time by the age of 12. However, her performance in fundamentals was poor. She failed in the examination at the municipal level.

It was suggested in the meeting that the three students take correspondence courses this year and go to USTC for further study in the following year. Fudan University has already done this.

Can USTC admit all of the three teenagers? Is a preparatory class possible?

About the above-mentioned questions, Wu Ruyang said: 'A preparatory class would be similar to the trial middle school of science. 'There is no need to ask CAS for approval. The three students can be admitted. We may discuss this matter after the investigators return from Jiangxi.

'In future cases of this nature, no investigator is needed.

'As to the student from Shenyang (Mu Qing), the enrolment team can deliver an additional examination, including both differentiation and integration questions.'

Xu Wenyong noted: 'The student from Shanghai (Shen Yu) can take the NCEE. If the results are good, he will be admitted to the USTC undergraduate program, or otherwise can attend the preparatory class.'¹⁸

Wu Ruyang was in agreement.

From this description, we can see that the teachers responsible for enrolment thought that Shen Yu had basically mastered the knowledge provided at senior middle school level, but Ning Bo and Mu Qing were less solid in their understanding of the fundamentals. Accordingly, two resolutions were proposed: (1) give them correspondence courses according to Fudan University's practices, or (2) admit them to a preparatory class. This was the first time that USTC proposed the idea of a preparatory class. Wu Ruyang agreed to the second proposal based on the preparatory class being similar to the 'middle school of science'.

On 30 December 1977, Wu Ruyang, Ren Zhishu and other officials travelled to Beijing to report their work to Li Chang, who was then the Vice President and Deputy Secretary of the Leading Party Group of CAS and also Vice President of USTC. They proposed the idea of running a preparatory class. The details of their meeting were recorded in Ren Zhishu's diary:

Wu Ruyang: 'Can a preparatory class be run for gifted teenagers of 13 to 15 years of age?'

Li Chang: 'If science and arts education are conducted separately, will the Ministry of Education approve?'

Ren Zhishu: 'Separation of science and arts classes is being planned.'

Wu Ruyang: 'We can have a try with this method so that the students can study in their preferred fields.'¹⁹

The diary did not record Li Chang's response to the proposal, but from the subsequent developments it is clear that he agreed with the proposed idea. Li had previously proposed a trial middle school of science, and Wu had implemented it and incorporated the proposal into the draft, which later led to the two men being 'convicted' and overthrown. Two years after those events, the idea was finally executed in the form of a preparatory class for the three exceptionally admitted teenagers.

4.2 Proposal for the operation of the preparatory class

After reporting to the CAS leadership, USTC immediately started to arrange the enrolment procedure for the preparatory class. On 9 January 1978, USTC's enrolment office formally proposed a trial preparatory class in the document 'Suggestions on enrolment', which was distributed to the local enrolment groups of provinces and municipalities:

To accelerate the cultivation of scientific and technological talents who are competent in political qualities and professional skills, USTC, based on the institutions given by Fang Yi and after discussion, proposes to run a trial preparatory class. The students in this class will learn fundamentals for six months to one year and will then be assessed to determine their suitability to enter undergraduate study at USTC.

Enrolment targets: Candidates for the preparatory class should be excellent teenagers who are politically qualified and interested in natural sciences, have the knowledge of a senior middle school graduate and show potential to become worthy persons. They will be physically healthy and generally aged below fifteen years old.

Enrolment means: The preparatory class will not be publicly promoted. Those who are identified through an investigation of local admission offices will be given an examination (using the standard question set of USTC). The materials, including the examination papers, political examination files and health condition reports, will be sent to USTC's enrolment office, and admission notices will be issued once the materials have been examined and approved by USTC. (USTC Archives, 1977d)

On 16 January, USTC formally submitted the 'Report on the trial preparatory class' to CAS. Similarly to the 'Suggestions on enrolment' that was issued on 9 January, the report confirmed the intention to 'enrol about twenty extraordinarily intelligent teenagers'. However, this report proposed a different idea for the mode of instruction:

The preparatory class will give a six-month instruction on knowledge at the middle school level. Only students who are considered qualified can enter undergraduate study at USTC. For undergraduate study, the focus will be foundational courses such as higher mathematics, general physics, general chemistry and foreign languages. After two to three years, students will be transferred to more appropriate disciplines according to individual performances and specialties, where they will be able to participate in research activities. Those who perform exceptionally can apply for early entrance to postgraduate study. (USTC Archives, 1978b)

It was proposed in the 'Suggestions on enrolment' that foundational courses at the senior middle school level would be given in

the first six months or the first year, and that an examination would be required before the students entered undergraduate study. However, the report released on 16 January suggested that undergraduate study would still focus on fundamentals for the first two or three years.

On 21 January, Li Chang gave his opinions on the report, agreeing to a 'trial preparatory class at USTC', but he disagreed with the mode of instruction and enrolment:

It depends on the reality when determining whether two or three years of fundamental courses are needed in undergraduate study. It is unnecessary to limit enrolment to below fifteen years old. Talent is valuable. It is acceptable if some excellent candidates are a little bit older. This could be referred to the Bureau of Education. (USTC Archives, 1978c)

On 27 January, CAS formally issued the document 'Trial preparatory class agreed', which approved the USTC report and modified the enrolment conditions and instruction mode according to Li Chang's suggestions:

It is not necessary to limit enrolment only to youngsters aged below 15 years. Slightly older students are also acceptable.

The study duration for a preparatory class is about one year, and the courses to be studied may be set as compulsory or optional depending on an individual student's situation. (USTC Archives, 1978d)

It was only about one month from 22 December 1977, when USTC first proposed the idea of a 'preparatory class', to 27 January 1978, when the idea was endorsed by CAS. Before the 'Report on the trial preparatory class' was submitted, USTC had already started the enrolment of students in the preparatory class. This indicates that the establishment of a preparatory class conformed to the political situation at the time and highlighted the consensus between the leadership of CAS and USTC.

4.3 The establishment of a preparatory SCGY

After CAS agreed with the idea of a preparatory class, USTC submitted a 'Request for an increase in the 1977 enrolment quota' to the Ministry of Education (MOE) on 2 February 1978, which mentioned that:

To speed up the cultivation of scientific talent who are politically qualified and professionally competent, the CAS leadership requires USTC to discard uniformity of standards in discovering and selecting talent and exceptionally admit a small number of outstanding young people. Under the leadership and support of the admissions committees of colleges and universities in related provinces and cities, USTC has admitted five exceptional middle school students. They are under the age of 15, but their academic performance was similar to that required for university enrolment. With only a little tuition, they will be ready to study university courses. We plan to recruit 20 students from across the country into the USTC preparatory class and give them special training with appropriate methods (please refer to the document no. (78) 0117 issued by CAS on 27 January 1978) ['Trial preparatory class agreed']. Those 20 students will be the increased quota of the 1977 enrolment of USTC. (USTC Archives, 1978e)

We did not find a direct reply from the MOE regarding this request. However, according to the 'Summary of USTC enrolment in 1977', the enrolment quota of the preparatory class was included in the 1977 enrolment, and the final enrolment number for USTC as a whole was 738 (USTC Achieves, 1977a), which exceeded the 715 target proposed in the request. The reason for this was that 1977 was the first year in which the NCEE (which was interrupted during the 'Cultural Revolution' from 1966 to 1976) was resumed. Due to limited time and the imperfect enrolment system, some colleges and universities applied for additional quotas after finishing their enrolment. At the same

time, the MOE also encouraged colleges and universities to expand the number of students enrolled, based on the belief that 'the more students enrolled in the school, the more talent would be cultivated in the next few years to achieve the Four Modernizations' (Xinhua News Agency, 1978b, p. 2). It was for exactly this reason that the enrolment of the preparatory class was 'recognized' by the MOE.

Before submitting the report on the trial preparatory class to both CAS and the MOE, USTC had begun the enrolment of the class. First, USTC would seek excellent teenagers nationwide through letters and visits from the public, a basic survey conducted by enrolment staff, and recommendations from local education and admissions departments. Then, staff of the admissions office would be sent to the candidates' locations to conduct written and oral examinations. This method of investigation was similar to that used to investigate Ning Bo. The written examination was used to assess the students' basic knowledge, and the oral examination was used to test their scope of knowledge and their intelligence (USTC Achieves, 1977b).

The organization of the NCEE in 1977 was conducted in very limited time. The entire admissions process continued from the end of 1977 to the end of the Spring Festival in 1978. The enrolment of the USTC preparatory class was even more complicated. 'The workload required to manage exceptional admission was several times greater than that of the NCEE' (USTC Achieves, 1977a). With the support and cooperation of the education and admissions departments in various regions, the preparatory class enrolled 21 students (Table 1).²⁰

The preparatory class opened on 8 March 1978 and was renamed the SCGY on the eve of the school year. After the SCGY became a form of fixed schooling, the preparatory class became the first SCGY. There were no official documents about the name change. Ren Zhishu used the term 'preparatory class'

Table 1: Number of students in the preparatory class (the first SCGY)

Gender	Male			Female		
		17			4	
Educational background	Primary school	Junior middle school		Grade 1 senior middle school	Grade 2 senior middle school	
	2	4		9	6	
Age	11 years	12 years	13 years	14 years	15 years	16 years
	1	1	1	7	9	2

Source: Zhu and Qin (1988, pp. 23–24).

in his diary on and before 2 March 1978 and sometimes called it a ‘children class’. In his diary on 6 March, he wrote: ‘I talked with Wang Huidi to encourage her to be the head teacher of the SCGY and explained the task to her.’²¹ This is the earliest record of the official use of the name SCGY. Based on this, we guess that the name was probably determined between 2 March and 6 March 1978. It has been used as the class’s official name to the present day.

The first SCGY was preparatory. Unlike the current SCGY, students of the preparatory class did not immediately rank as undergraduates after entering the school and did not enjoy the benefits of undergraduate students. After completing the first period of the SCGY, USTC submitted the ‘Request for the treatment of SCGY students’ to CAS and the MOE on 31 July 1978, suggesting that SCGY students be given the same benefits as undergraduate students (USTC Archives, 1978f). The students then became real college students.

5. Formation: The transfer of the SCGY from preparatory to undergraduate status

The trial preparatory class was an interim program in response to letters from the public and leadership instructions. After enrolment, there were some problems in the first SCGY. USTC faced up to the problems and conducted remedial discussions. After a comprehensive

discussion, USTC decided to continue with the SCGY, but to convert it to an undergraduate class during the second enrolment.

5.1 Problems in the first SCGY

When the first SCGY opened, Wang Huidi, a politically and professionally competent teacher, was appointed as the head teacher. She took good care of the youngsters and selected seven experienced teachers to give them instruction on the middle school curriculum. The first SCGY offered courses in politics, mathematics, physics, foreign languages and sports, using textbooks written by teachers in each subject. Later, because of the generally poor standard of Chinese among the students, USTC established special Chinese lectures for them (USTC Archives, 1978g).

During the enrolment of the first SCGY, a combination of written and oral examinations was conducted, but a uniform standard to assess the students was absent. The enrolled students had different educational levels, which led to difficulties in teaching after the class began. In addition, a small number of very young students were admitted by referring to their NCEE scores only, resulting in their poor performance after enrolment (USTC Archives, 1978h). In the USTC archives, we found a first-month physics and mathematics examination report for the first SCGY,²² which indicated that the gap between the best and worst performing students was particularly

large. For physics, the highest score was 99 points and the lowest was 24 points; for mathematics, the highest was 100 points and the lowest was 30 points; for the total score, the highest was 185 points and the lowest was 54 points (USTC Archives, 1978i).

The fact that some students were too young also posed management problems. In the 'Report on the SCGY' on 27 May 1978, USTC addressed the problems of two young students. One had problems with diet and rest, while the other was poorly behaved and did not study hard. For such students, it was considered that 'It's better for them to study for two more years in the original environment' (USTC Archives, 1978h).

At the same time, excessive promotion of the SCGY also created some problems. The SCGY was well reported by the country's major media during its preparatory stage. The media propaganda had a certain influence on the learning and mentality of the students. At the time, USTC realized that 'interviews, symposia and filmmaking took up too much time for the students, which affected their rest and study' (USTC Archives, 1978h), and began to 'control the number of visitors to reduce outside interference' (USTC Archives, 1978g).

After more than four months of tutoring, the performance of most students had improved greatly. In USTC's 'Report on the first SCGY', submitted to CAS and the Anhui Provincial Party Committee, several students whose academic performance had greatly improved were mentioned. They had improved their physics and foreign language scores from failing scores to 98 or 99 points (USTC Archives, 1978g). Ren Zhishu also recorded their improvements in his diary:

Excellent: Dong Ruitao, Lin Chengdian, Li Yucheng, Xiao Chen, Shi Lin, Yao Xin, Guan Junlin, Chen Shizhong, Jiang Feng.

Good: Xie Yanbo, Cao Xiaonan, Ning Bo, Zhang Baoguo, Li Ping.

Passed: five persons.

Failed: one person.²³

On 15 July 1978, the first SCGY was completed.²⁴ According to the students' academic performance and interests, USTC assigned them to various academic departments to study together with the 1978 intake of undergraduate students, who would be enrolled in October.

5.2 Discussion about whether to continue the SCGY

Before the first SCGY opened, many teachers thought that this was an expedient program rather than a permanent one. Ren Zhishu recorded his conversation with Qian Linzhao²⁵ and others in his diary on 17 February 1978. Qian and the others agreed to test the preparatory class for six months in case some students could not enter undergraduate study. Qian's concerns reflected some of the teachers' thinking at the time.

The founding of the preparatory class created a lot of extra work for admissions staff. On 20 February 1978, the 1977 NCEE enrolment was basically completed, but people's enthusiasm for recommending talents continued. On 22 February, Ren Zhishu made a special trip to CAS to seek advice on how to deal with the 'Ning Bo effect' and proposed three suggestions:

- The capacity of the school is limited, and there is a limit to the length of schooling that can be offered. Only a small number of exceptional students can be recruited each year.
- The 'children class' is an experimental program, and it is not advisable to recruit a large number of such students or to admit them at any time.
- There will be a large number of talented students throughout the country. They should be encouraged to study hard and develop in an all-round manner, so that they can be admitted to key universities in the future.²⁶

On 25 February, the *Letter Bulletin* clarified CAS's opinion on the 'Ning Bo effect':

- Students admitted to the school in 1977 are no longer subject to changes.
- Those who are found to be exceptionally superior can contact CAS.
- Those who perform at an ordinary level should be given special training.²⁷

The report in the *Letter Bulletin* indicated that CAS did not adopt Ren's suggestions. The opinions of the *Letter Bulletin* represented the attitude of the CAS leadership, which laid the ground for the continued operation of the SCGY.

On 24 May 1978, in response to the problems of the first SCGY, Wang Zheng and Kong Zhen, deputy secretaries of the USTC Party Committee, convened a seminar about the SCGY that included the teaching affairs department, the head teacher of the SCGY and other instructors. Wang put forward three options on the issues proposed by those teachers:

- After the first SCGY is completed and its students enter undergraduate study, it should be closed. The university would then recruit 14- to 15-year-old students through the NCEE in the future.
- Based on the first SCGY, USTC teachers should improve methods of admission and instruction.
- A middle school for sciences should be run.²⁸

Some teachers agreed with the first proposal. However, school leaders such as Wang and Kong were worried about the discontinuity, stating that 'It may cause a negative influence if the SCGY were to disappear at the time it became well known.'²⁹

The opinions of Wang Zheng and others reflected the general attitude to the SCGY. Since the admission of Ning Bo, the central leadership had paid great attention to the class. After its establishment, Wan Li, secretary of the Anhui Provincial Party Committee,

and Gu Zhuoxin, deputy secretary of the committee, visited USTC to meet the gifted young students. The major media provided intense coverage of the SCGY before and after its establishment. On 7 February 1978, the *People's Daily* published an article from Xinhua News Agency headed 'CAS discards uniform standards in selecting talent', which disclosed that USTC was planning a preparatory class. On 16 March 1978, the *People's Daily* published information from Xinhua about the enrolment of new students at USTC and specifically reported on the SCGY. On 29 March 1978, the *People's Daily* reported the establishment of the SCGY with an article headed 'The heroic vows of the SCGY at USTC: We will advance toward a bright future of the country'. In mid-May, the Central Newsreel and Documentary Film Studio produced a film titled 'Teenage college students', which would later be publicly shown around the country.

As a result of the media propaganda, the SCGY became a sensation throughout China. People from all over the country wrote letters to USTC, giving their support and encouragement for the class. The SCGY developed a political meaning that transcended education. As a vanguard in the education field, it became the 'spring flower' of science and received widespread attention across the country. USTC had a clear understanding of this and believed that 'this special class must be run well' (USTC Archives, 1978h).

5.3 USTC decides to continue the SCGY

Following further discussion and research, USTC submitted a 'Report on the SCGY' to Anhui Province and CAS on 27 May 1978. This document objectively described the problems of the first SCGY. It considered the three proposals discussed at the seminar on 24 May, and further proposed the following three options:

- The first SCGY is originally planned to run for six months. After three months of study, most students have already reached university level. Therefore, to produce talent earlier, those students will graduate from SCGY and study together with undergraduate students enrolled in 1978, while the other students will be managed according to their personal circumstances. After the first SCGY is completed as planned, it will be closed. There are two reasons for this: (1) The age of general college admissions has dropped to 14 or 15; and (2) each province has established key middle schools and middle schools of science to replace the duties of the SCGY, indicating that the SCGY has spread nationwide.
- The SCGY will continue to be held after the first term is completed. The length of schooling will be one year. Only 13- or 14-year-old students who have finished senior middle school education perfectly will be admitted. To speed up the development of talent, a knockout system will be used. This will enable middle school students to enter university one year earlier than planned.
- After finishing the first SCGY, it will be closed and a middle school of science will be established in its place, with two years of schooling. The school will recruit outstanding junior middle school graduates and implement a knockout system. The time required to complete study will not be reduced, but separate teaching of courses of arts and science will take place as early as possible, which will benefit undergraduate study in different subjects. (USTC Archives, 1978h)

USTC expressed a preference for the second option, which indicated that it was determined to continue with the SCGY and was seeking methods for improving enrolment by learning lessons from the problems caused by uneven education and very young ages in the first SCGY cohort.

In line with the instructions of CAS and the leaders of Anhui Province, USTC began to seek specific measures required to run a school in Anhui and drafted 'Proposals for further implementing the "Report on several issues of USTC" approved by the CPC Central Committee'. The report was submitted to CAS on 2 June 1978. It clearly stated that 'USTC will learn from experience and continue with the SCGY' and proposed further ideas for the enrolment and cultivation of talent:

The SCGY is a preparatory program for undergraduate study. In the future, USTC will design examination papers for SCGY each year and conduct a national unified examination. Alternatively, candidates will be selected from among teenagers participating in mathematics or physics or chemistry competitions. They will be 14 or 15 years old and will have achieved excellent academic results in senior middle school. The length of schooling will be one year. After this period, those students reaching the required standard will go directly to university.

The SCGY should develop its own teaching syllabus and study plans, teach students in accordance with their aptitude, make health a priority, and allow students to excel in single disciplines so as to accelerate the growth of special talent as soon as possible. (USTC Archives, 1978j)

From the report, it can be seen that the SCGY at USTC still had a 'preparatory nature' at the time. SCGY students could enter undergraduate study after one year of study in the preparatory class. However, USTC put forward clear proposals to improve enrolment: the first was to conduct a national unified examination and select students on merit; the second was that students should not be too young, and that 14 or 15 years was considered the optimal age.

On 9 June 1978, Yang Haibo, the then secretary of the USTC Party Committee, returned to USTC after reporting the proposals

to CAS in Beijing. He notified the standing committee of the party committee and directors of all departments of the instructions given by CAS: 'The preparatory class will be run as proposed in the report. It will continue and the length of schooling will be one year.'³⁰ On 15 June, CAS forwarded the USTC report to all of its units and agreed with the proposals in the report. At this point, the SCGY was no longer an expedient program in response to the instructions of leaders, but a long-term program at USTC to accelerate the cultivation of scientific talent.

5.4 The formation of the SCGY as an undergraduate programme

After deciding to continue with the SCGY, USTC immediately began to research enrolment methods for the second phase. On 15 and 17 June 1978, the school held meetings to discuss the SCGY enrolment and agreed to 'take the NCEE as the first test'.³¹

On 19 June, USTC submitted its 'Request for the enrolment of SCGY in 1978' to the MOE and CAS. In this report, USTC still regarded the SCGY as a preparatory program for undergraduate study, and the length of schooling would still be one year. However, it changed the qualifications for enrolment and proposed that the 'age of admission would generally be 14 and 15'. At the same time, it proposed methods to improve enrolment:

To know the candidates' level of basic knowledge and their ability to analyse and solve problems, USTC will need to conduct a preliminary test and a re-exam, for which local assistance will be required.

Preliminary test: All applicants for the SCGY will be required to take the NCEE organized by the County (District) Admissions Committee from 20 July to 23 July. The subjects for the examination will be the same as those required for undergraduate science and engineering courses. After a unified assessment conducted

by provinces, municipalities and autonomous regions, the examination papers of the first five to ten applicants will be sealed and sent to the USTC admissions office before 15 August. Provinces and cities with large numbers of students obtaining good test scores can select more than ten papers to send for assessment.

Re-exam: The school will select students to participate in a second-round exam from among the candidates recommended by all provinces, municipalities and autonomous regions. The number selected will be twice the final capacity of the SCGY. USTC will design a unified examination paper and send teachers to the candidates' locations for the examination. An oral test will be added to the re-exam to further examine the candidate's intelligence and thinking abilities. (USTC Archives, 1978k)

The enrolment method was of great significance because this was the first time that USTC tried the pattern of 'preliminary test+re-exam+oral test'.

The report was brought to Beijing by Liu Xianrong, the director of the student affairs office at USTC, who was responsible for enrolment, and was given to CAS and the MOE. CAS approved the report and forwarded it to the ministry on 28 June. The 1978 NCEE would be conducted from 20 to 22 July, but the MOE did not give an approval quickly. By 5 July, Liu Xianrong became anxious and wrote a letter to He Zuotao, the head of the Education Reform Group of USTC. In the letter, he mentioned the opinions of the Department of College Student Affairs of the MOE regarding the report:

Officials of the MOE thought that our requirements were too high if we use the method of 'preliminary test+re-exam+oral test'. They suggested that we recruit students based on the enrolment method of the first SCGY. (USTC Archives, 1978l)

On 11 July 1978, the MOE finally issued a 'Notice on the enrolment of the SCGY at USTC' to the admissions committees of

colleges and universities of all provinces, municipalities and autonomous regions, and made three recommendations for the enrolment of students to the SCGY:

- The enrolment requirements for the SCGY should be love of the Communist Party of China; love of socialism; love of labour; observance of revolutionary disciplines; a senior middle school education; outstanding academic performance; love of science; aspiration for natural science research; outstanding intelligence and the potential for future development; good health; and an age of 14 or 15 years.
- Admissions committees can recommend to USTC excellent teenagers whom they selected through mathematics and physics contests or through other ways.
- All examinations (including written and oral tests), assessments and admissions in SCGY are handled by USTC. (USTC Archives, 1978m)

In this notice, the MOE did not agree with USTC's proposal of 'using the NCEE for preliminary testing'; nor did it specify whether the SCGY should be a preparatory or an undergraduate program. We speculate that, unlike CAS, which actively supported the SCGY, the MOE, as the administrative department in charge of national education, was more cautious about the class. The ministry agreed that the SCGY should continue to enrol students, but it did not express an opinion on the quality of the SCGY. Judging from the later development of the SCGY, the MOE's adoption of a policy of 'silence' indicated that it acquiesced in the SCGY at USTC. This is also one of the important factors that enabled the SCGY to continuously develop, and to eventually become the 'trial field' of education at USTC.

After the MOE notice was issued, USTC changed the method of enrolment and released an 'Enrolment brochure for the SCGY in 1978' on 20 July. It decided to organize a unified examination on 22 and 23 August. In this brochure, USTC did not mention the

preparatory quality of the second SCGY (USTC Archives, 1978n).

The enrolment workload during the second period of enrolment was extremely heavy. USTC was responsible for the whole process of the examination and admissions, which was equivalent to organizing a small-scale NCEE. The subjects covered in the examination were the same as those in the NCEE, including politics, Chinese, mathematics, physics, chemistry and English (scores for which were used only for reference) (USTC Archives, 1978n). It was originally intended to admit 30–50 students during the second period of enrolment, but almost a thousand applied for the examination (USTC Archives, 1978o). Many candidates who participated in the 1978 NCEE also participated in the examination for the SCGY. After consideration, USTC eventually decided to increase the enrolment quota, and 67 students were finally admitted.

On 9 October 1978, students in the second SCGY enrolled. On the same day, USTC submitted its 'Report on the enrolment plan for 67 students in the SCGY and for adding 17 students in regular classes' to the MOE, which mentioned that:

With the approval of the MOE and CAS, this year USTC has continued with a second SCGY, enrolling 67 students. Students of the second SCGY were selected through a unified examination (the difficulty of the test was almost the same as that of the NCEE, and some questions were even more difficult). Some of the students also took part in the NCEE and gained excellent results, with a total score of 400 points or more. Some were selected from among the winners of national or provincial (municipal) mathematics contests. After enrolling in a class, students in the SCGY will no longer attend the preparatory courses, and will be specially trained according to the requirements of a regular university class. Therefore, the treatment of the SCGY students will be the same as that of the general college students. (USTC Archives, 1978p)

From the students' enrolment status in the second SCGY, it can be seen that they were classed as undergraduates after entering school. From the second phase, the quality of the SCGY began to change. Before then, the documents submitted by USTC to CAS and the MOE all clearly stated that the SCGY was 'a preparatory program for undergraduate study'. In the formal enrolment documents for the second SCGY, both the MOE and USTC did not mention the preparatory nature of the class. Following its experience of running the initial SCGY, USTC insisted on the implementation of uniform and strict criteria in the second phase of enrolment. The students in the second SCGY would no longer receive senior middle school courses after enrolment, and therefore the SCGY changed from a preparatory to an undergraduate program. The SCGY of USTC has remained that way ever since.

6. Discussion: Reasons for the establishment of the SCGY by USTC

The formation and development of anything cannot be separated from the historical background at that time. The establishment of the SCGY was a product of a special historical period. At the time, the 'Cultural Revolution' had just ended and there were many things to be done. There was an urgent need for talented people. The leadership of the CPC Central Committee was eager to develop professional talent, and the public actively recommend potential talent. Under these circumstances, USTC admitted three 'child prodigies' following Fang Yi's instruction on exceptional admissions, and further proposed a programme to bring talented teenagers together to accelerate their education. This was a pioneering move that conformed to the developmental trends at the time.

The desire of the CPC and state leaders, and of society as a whole, for the development of talented people was the external

motivation for establishing the SCGY. However, the fact that the SCGY was pioneered by USTC and will continue to develop through innovation has its own internal reasons.

6.1 The special advantage of USTC as a school directly administered by CAS

In 1958, USTC was established in Beijing by CAS. The establishment of the school was supported by CPC leaders such as Liu Shaoqi, Zhou Enlai, Chen Yun and Nie Rongzhen, and was covered by personal instructions from Deng Xiaoping. When Deng tried to reorganize CAS in early 1975, he required the organization to 'actively develop science and technology universities'. In 1977, Fang Yi assisted Deng to promote science education, which led to USTC once again receiving the attention of CPC leaders. With the support of CAS, USTC became a vanguard of science education. In addition, the reason why USTC was successfully established at the end of the 'Cultural Revolution' was that it was not in the centre of the political movement. Just as Ren Zhishu mentioned in an interview, 'The MOE was the target of the "Cultural Revolution", and universities governed by the MOE were thus difficult to restore to normal order.' However, as a college directly administered by CAS, USTC recovered relatively easily (Ren and Xiong, 2017).

From 20 June to 7 July 1977, CAS leaders Fang Yi and Li Chang proposed at the CAS working meeting to 'vigorously develop science and technology universities and cultivate talent who are politically and professionally competent'. From 5 to 13 August 1977, CAS convened the first working conference of USTC in Beijing and proposed to adhere to the principle of a 'combination of CAS institutes and USTC departments'. The aim was to establish USTC as the second academic centre of CAS and as a high-level teaching and research centre. On 18 August, the Xinhua News Agency reported the conference in an article titled 'USTC is sure to embrace a

bright future'. The next day, the *People's Daily* reprinted the full article and commented that 'USTC has taken a big step forward in the development of education.' On 5 September, CAS submitted to the State Council a 'Report on several issues of USTC', which was approved by Hua Guofeng, Deng Xiaoping and other leaders of the CPC Central Committee (Zhu, 2008, pp. 168–171). The report clearly stated that candidates for USTC study would be selected from among outstanding new graduates from senior middle school. This was half a month earlier than the decision to resume the NCEE was made at the second national college admissions conference on 19 September 1977. The USTC enrolment requirements were personally approved by Hua Guofeng. On 5 October, when the Political Bureau of the CPC Central Committee discussed admissions documents of colleges and universities, he stated:

Candidates for USTC study should have a solid foundation in mathematics and chemistry at middle school level. They should not be too old and should have continuous schooling. (USTC Archives, 1977d)

With the help of the CPC and state leaders, and supported by the leadership of CAS, USTC was able to quickly propose and implement a series of forward-looking and innovative reform measures after the 'Cultural Revolution', such as the initiation of a graduate school and the SCGY. All these actions made USTC a pioneer in the higher education system.

6.2 USTC's persistence in talent training

USTC was established to cultivate scientific talent for the development of atomic bombs, hydrogen bombs and satellites. It has shouldered the historical mission of serving the country through science education from its date of establishment. During its early years, many prestigious scientists in China joined

USTC and gave lessons personally. Teachers valued and enjoyed teaching, and students studied hard. This became the cultural consciousness of USTC. Therefore, even during the 'Cultural Revolution', USTC still dared to break through 'ultra-left thought' to run a special training class for graduates and give instructions on foundation courses. Once the political atmosphere eased, it proposed the operation of a middle school of science.

In the 'Report on the trial preparatory class' submitted to CAS on 16 January 1978, USTC proposed the idea of giving instruction to students in the preparatory class in courses at the senior middle school level, and determining majors after two or three years of study.

Why did USTC propose such a training program? We found a copy of the official records in Ren Zhishu's notes, which may provide evidence. On 17 February 1978, Li Chang, Wu Ruyang, Yan Jici, Qian Zhidao, Qian Linzhao and others met in Beijing to discuss how to improve the quality of teaching at USTC. Qian Linzhao said:

I taught part time in 1958 and joined USTC in 1960. I focused on fundamentals in my teaching, but this principle was affected in my later work in professional courses. On the way to a meeting held in Guangzhou, Professor Yan Jici proposed the idea of running a '00 Department'. Students of the department should be good in fundamentals, which would provide multiple options for future study. They can decide their majors three years later, rather than before enrolling. This is a goal that is difficult for us to reach.³²

USTC has always considered foundation courses to be important. In 1959, the second year after its establishment, Qian Xuesen wrote an article titled 'Foundation courses of USTC', which emphasized the importance of foundation courses (Qian, 1959). In the meantime, a group of senior scientists, including Yan Jici and Qian Linzhao, also considered the cultivation of scientific and technological talent in their teaching by learning from their

personal educational experiences. This may have directly or indirectly provided the inspiration for USTC to propose the idea of determining majors after two or three years of study in the preparatory class. Given the opportunity, USTC would put the idea into practice. Although Li Chang turned down the proposal, USTC never gave up.

After much discussion and research, the training method under which the SCGY students would spend three years on foundation courses was formally implemented in October 1979. In September 1985, USTC set up a pilot class for teaching reform based on the pattern of talent cultivation in the SCGY. It was referred to as the '00 Class'. These reformative and innovative measures stemmed from the educational philosophy proposed by the older generation of scientists and educators at USTC.

USTC's commitment to talent training drove the university to improve its enrolment method in the second SCGY. Learning lessons from the first SCGY, it selected students for the second special class by independently organizing a small-scale NCEE and changed the SCGY from a preparatory program to an undergraduate program.

During the four decades of the SCGY, this commitment has also provided the motivation for it to be practical and realistic, to be innovative, and to develop by following the laws of education.

6.3 The relationship between Tsung-Dao Lee and the establishment of the SCGY

In existing promotions, a connection has been made between the establishment of the SCGY and Professor Tsung-Dao Lee, a famous physicist who won the Nobel Prize in Physics. In an article titled 'Establishment of and reflections on the SCGY' written in December 2005, Lee stated that 'the establishment of special classes for youngsters in Chinese universities is, to a great extent, directly

related to my talent training proposal in 1974' (CCAST, 2008, p. 65). The available information suggests that the earliest statement about the establishment of the SCGY based on Lee's suggestion was made on 20 April 1979 in the welcoming address of Yang Haibo, when Lee visited the SCGY.³³ What, then, was the specific proposal put forward by Lee in 1974? What was the role of that proposal in the establishment of SCGY? These questions are worthy of further research.

Lee has always been concerned with the development of S&T and the cultivation of young talent in China. During the 'Cultural Revolution', he returned from the United States to China twice and had an intuitive understanding about basic science research and the development of scientific talent training in China. In May 1974, Lee returned to China for the second time. After visiting Fudan University, he became worried about the significantly reduced training in basic science. When visiting the Shanghai Dance School, he was inspired by the school's selection and training of dancers. In consideration of the special circumstances in China at that time, Lee wrote a proposal titled 'Thoughts after visiting Fudan University'. He made concrete suggestions about how to cultivate basic science personnel:

We should organize a basic science team consisting of few excellent people who are selected from the general public to serve the people. The team should be developed outside the university and maintain close contact with the masses.

People engaged in basic science should not be too many, but they should be excellent. Besides, the following two points should be noted. (1) Basic science researchers must be trained continuously for a considerable period. (2) The capability of basic science researchers is often maximized at a very young age of 20 to 30. Based on these two points, we should consider whether the training of basic science researchers can begin at the age of 13 or 14.

When we select teenagers who will engage in basic science research, we may follow similar procedures to the selection of dancers. First, a few potential teenagers of about 13 or 14 years old should be recommended by schools in the countryside and in cities. Of course, the requirements for basic science researchers and for dancers are different. Researchers must have a strong understanding ability and display sufficient competitiveness and good memory. (CCAST, 2008, pp. 57–59)

In Lee's proposal, he also proposed a specific scheme for the selection and cultivation of teenagers engaged in basic science research. First, potential candidates would be recommended by the public, and then teachers would live together with the candidates for six months to get a better understanding of their capabilities, thoughts and attitudes. The training process would emphasize manual labour, just as in the training of worker-peasant-soldiers, but also include strict basic science training to lay a solid knowledge foundation (CCAST, 2008, p. 60).

In 2005, Lee expounded on his original intentions for the 1974 proposal:

The real purpose of my suggestion was not to establish a special class for youngsters, but to overcome the situation in which the cultivation of basic science talent and other associated talents was not valued, and to get the cultivation of talent throughout the country back on track. (CCAST, 2008, p. 66)

On 20 May 1974, Lee submitted the proposal to Premier Zhou Enlai with the help of his friend Zhu Guangya, and asked Zhou to forward it to Chairman Mao Zedong. On the evening of 24 May, Zhou met Mr and Mrs Lee, together with Deng Xiaoping, Guo Moruo, Jiang Qing, Wang Hongwen, Zhang Chunqiao, Yao Wenyuan and nearly 20 famous scientists, including Qian Xuesen, Wu Youxun and Zhou Peiyuan. In discussing the proposal, Jiang Qing raised an objection, although the scientists present did not make a clear statement. On 30 May, Mao met the Lees and said,

'I agree with your proposal for talent training' (as cited in Shi, 2008).

Lee's proposal was not implemented at that time, although it was approved by Mao. 'The state leader asked USTC to implement my proposal,' Lee recalled (CCAST, 2008, pp. 66–67). However, there is no direct evidence available to prove this. So, what is the basis for Yang Haibo proposing that 'the SCGY was established according to Lee's proposal' in 1979? We think this is probably because Lee's idea of cultivating teenagers aged 13 or 14 was similar to the managerial concept of the SCGY, and may also be related to the establishment of a middle school of science by USTC in 1975.

On 15 August 1975, when Li Chang recommended that USTC establish a middle school of science, he mentioned that 'Chairman Mao and Premier Zhou have discussed the cultivation of basic science talent with Tsung-Dao Lee and Yang Zhenning, respectively' (USTC Archives, 1975a). On 23 October, the draft of the 'Request for instructions regarding issues at USTC' organized by Wu Ruyang mentioned the issue of the establishment of a middle school of science: 'With reference to previous experiences of talent cultivation in the sports, literature and art communities, CAS will appoint USTC to open a trial middle school of science' (USTC Archives, 1975b). It can be inferred that the idea of Tsung-Dao Lee for the selection and cultivation of young basic science talent influenced the leaders of CAS and USTC. Li Chang's proposal for a middle school of science may be associated with Lee's idea, and Li's idea led directly to Wu Ruyang's decision to open a trial preparatory class in 1977. Therefore, it may be considered that Lee's proposal led indirectly to the establishment of the SCGY.

7. Conclusion

With the support of the CPC and state leaders, and under the influence of ideas about the cultivation of scientific talent proposed by the

older generation of scientists and educators, the SCGY was established independently by USTC in a special historical period. As a novel mode of education, the SCGY has been constantly improved and developed through exploration and practice rather than being well designed and planned from the beginning. During the early years of the special class, it had extensive social influence and greatly promoted the development of education.

The first SCGY was a preparatory program that developed into an undergraduate program after the second enrolment. For better development of the class, USTC learned from previous practices and conducted a series of educational experiments. After the second enrolment, USTC held successive discussions on the SCGY, which involved the participation of school leaders, the teaching affairs department, the student affairs department, SCGY teachers and students. This provided opportunities for the university to learn from the past and seek methods to develop a unique SCGY.

In May 1980, the USTC established an SCGY research group led by Qian Linzhao and began to study the growth and education of teenage undergraduates. SCGY became a veritable experimental field for education at USTC.

In January 1985, based on Deng Xiaoping's proposal, the MOE approved 12 key universities, including Peking University and Tsinghua University, to launch special classes based on the SCGY at USTC. However, the situation of special classes gradually changed. At present, only USTC, Xi'an Jiaotong University and Southeast University retain the special program, while other universities have cancelled it and continued the cultivation and exploration of supernormal undergraduates in various other forms of elite education (Xin, 2008, pp. 16–17).

In 2007, academician Zhu Qingshi, the former president of USTC, said in an interview with *Guangming Daily*:

The SCGY initiated the pattern of cultivating all-rounders in China. It is a best model for higher education even today in the enrolment, cultivation and management of students. The SCGY's education model was first promoted by USTC and was later used by the key universities in China. The establishment of both Chu Kochen Honors College of Zhejiang University and Yuanpei College of Peking University was influenced by the SCGY at USTC. (Li and Ye, 2007)

This year marks the 40th anniversary of the 'reform and opening-up' policy and the 40th anniversary of the SCGY. The SCGY is a pioneer of higher education reform in China, and the educational research conducted during the development of the special class still provides inspiration for educational reform and the cultivation of top-class innovative talent today.

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Notes

- ¹ From 15 April to 31 July 1971, the State Council convened a national education conference in Beijing that lasted for more than 100 days. During the conference, the 'Minutes of the National Education Conference', drafted by Chi Qun and finalized by Zhang Chunqiao and Yao Wenyan,

- were discussed and passed, comprehensively approving the 'Education Revolution' during the 'Cultural Revolution' and repudiating the educational achievements gained in the first 17 years after the foundation of the People's Republic of China. The conference also proposed the 'Two Estimations'. The first was that the education strategy during those 17 years had been a 'dark part of anti-revolution revisionism' in which 'Chairman Mao's education strategy for the proletariat was basically not implemented'. The second was that 'intellectuals' views of the world are basically bourgeois' and that they needed to be further modified. See Gao and Yao (2009, pp. 158–161).
- ² On 3 April 1973, as instructed by Zhou, the educational science office of the State Council made two adjustments to the enrolment of worker-peasant-soldier students. One was adding an academic subject examination; the other was changing the requirement for practical experience from three to two years. Zhang Tiesheng, an educated youth from Liaoning Province, submitted a blank answer sheet in a physical chemistry examination, on the back of which he wrote a letter raising an objection to the academic subject examination for college enrolment. This event was reported by *Liaoning Daily* on 19 July 1973 and the story was reprinted by the *People's Daily* on 10 August, together with the following comment: 'This letter proposes an important issue regarding the conflicts between the two strategies and two ideologies in the education field.' The academic subject examination was then upgraded to a strategic conflict and was violently criticized. See Gao and Yao (2009, pp. 168–169).
- ³ This is from the autobiography that Ni Lin is working on (unpublished). Ni provided us with the section titled 'Recommendation of a genius adolescent to promote the establishment of the SCGY' for reference. Ni transcribed his recommendation letter to Fang Yi, which was included in his autobiography. Although the transcript was lost after two house moves, the content in the autobiography was consistent with the original.
- ⁴ According to *The Secrets for Becoming Excellent Elementary and Secondary School Students* by Si Youhe, Shen Yu, under the influence of his father from childhood, studied mathematics, physics and chemistry courses by himself and learned four languages (English, French, Japanese and Russian). His father wrote to the central leaders, recommending him for USTC.
- ⁵ As recalled by Mu Qing during a telephone interview on 10 March 2018, she mastered calculus by herself when she was a Grade 1 senior middle school student, and her mathematics teacher wrote to CAS to recommend her.
- ⁶ Liu Xianrong (1936–), the then leader of the students in the political work group of USTC Revolution Committee, was appointed director of the student affairs office in March 1978, after the institutional reform of USTC. He was in charge of USTC's enrolment in 1977 and witnessed the establishment of the SCGY. One of us interviewed Liu on 18 March 2018.
- ⁷ As recorded in Ning Bo's letter to one of the authors on 25 October 2010, it was on the Saturday after the college entrance examination that two USTC teachers responsible for enrolment went to Ganzhou for his investigation, and they spent one week there. According to the minutes of the USTC enrolment team, on 22 December 1977, the teachers had finished their investigation of Ning Bo's academic performance but had not yet returned. Therefore, the date on which Ning was investigated was 17 December.
- ⁸ According to a short message sent by Ning Bo on 23 March 2018, he was recommended by Ganzhou No. 8 Senior Middle School to participate in the college entrance examination at the end of 1977 (at that time, senior middle school operated a two-year system, and Ning was in the first semester of Grade 2; therefore, he took the college entrance examination half a year early). The examination involved four subjects: mathematics, physical chemistry, Chinese, and politics. The threshold for enrolment was an average score of 51. Ning's average score was 57.5. In addition to Ning, Pan Xinling and Chen Ying were also recommended to participate in the examination. Pan obtained an average score of 55 and was admitted to the Department of Grain and Oils Processing at Zhengzhou University of Technology (now Zhengzhou University). Chen obtained an average score of 54 and was admitted to the Department of Mathematics at Hunan University. Ning Bo applied to study chemistry at USTC, mathematics at Zhejiang University, astronomy at Nanjing University and mathematics at Jiangxi University.
- ⁹ The original poem is: 正叹惆怅身无处，不待今朝闻明昭。倦时倍觉丹卷美，喜后更思天路高。朱日明松笑健伟，银月暗柳乐菲瑶。九天遨游指日待，何见小丑奈何桥。
- ¹⁰ Ren Zhishu (1924–) graduated in physics at Zhejiang University in 1947, worked at CAS from 1952, worked at USTC in teaching management from 1958, and was appointed as deputy leader of the education revolution group of USTC Revolution Committee in 1971 and then as deputy dean of teaching affairs in 1978. From 1982 to 1984, he was the Director of the Bureau of Education of CAS. Ren has been working on a diary for 66 years, since 1952. His diary provided valuable data

- for research on the history of CAS and USTC and the development of S&T and education in contemporary China. Ren witnessed the establishment of the SCGY and was a decision-maker in its early development.
- ¹¹ Ren Zhishu's diary on 16 February 1978 is very consistent with Ning Bo's recall, differing only in a few details. According to the diary, 13 teenagers took the examination; Xu Jin scored 75, Ning Bo 67, Pan Xinling 62, and six or seven scored zero.
- ¹² From Ren Zhishu's diary, 16 February 1978.
- ¹³ The minutes of the meeting were not placed in the USTC archives, but were copied and kept by Liu Xianrong. This is the first documentation describing the establishment process for the preparatory class.
- ¹⁴ We note that this should be Shanghai enrolment office.
- ¹⁵ The article was reported in *People's Daily*, 16 December 1977, p. 4.
- ¹⁶ We note that this should be 'finished elementary mathematics by the age of eight'.
- ¹⁷ We note that '20' should be '12'.
- ¹⁸ Shen Yu was excellent in the fundamentals. In the examination after the first SCGY opened, Shen obtained excellent scores and soon became an undergraduate in the Department of Physics. See USTC Archives (1978h).
- ¹⁹ From Ren Zhishu's diary, 30 December 1977.
- ²⁰ The first SCGY initially took in 20 students and later added Yao Xin. According to a telephone interview with Yao on 27 March 2018, he passed the examination for the preparatory class conducted in Fuzhou, but his health was not qualified. He was admitted after passing a re-examination of his health. At the end of March 1978, he joined the first SCGY.
- ²¹ From Ren Zhishu's diary, 3 June 1978.
- ²² The report is a list of the first SCGY students, in which their physics and mathematics scores follow their names. This transcript exactly matches the records in Ren Zhishu's diary for 4 May 1978.
- ²³ From Ren Zhishu's diary, 7 October 1978. Following Ning Bo's suggestion, the students who only just passed or who failed the exam remained anonymous.
- ²⁴ From Ren Zhishu's diary, 15 July 1978.
- ²⁵ Qian Linzhao (1906–1999) was a famous physicist and historian of science, an academician of CAS, a professor at USTC, and the director of the physics teaching and research office. In December 1978, he served as Vice President of USTC. In May 1980, he served as the head of the research team for the SCGY.
- ²⁶ From Ren Zhishu's diary, 22 February 1978.
- ²⁷ From Ren Zhishu's diary, 2 March 1978.
- ²⁸ From Ren Zhishu's diary, 24 May 1978.
- ²⁹ From Ren Zhishu's diary, 24 May 1978.
- ³⁰ From Ren Zhishu's diary, 9 June 1978.
- ³¹ From Ren Zhishu's diary, 15 and 17 June 1978.
- ³² From Ren Zhishu's diary, 17 February 1978.
- ³³ From material collected by Si Youhe, 'Professor Tsung-Dao Lee's visit to USTC'. *Research on the SCGY (vol. 1)*, printed by USTC.

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Author biographies

Haohua He is a member of the Party Affairs Office at USTC and a PhD student in the history of science.

Zhihui Zhang, PhD, is a professor of the Department for the History of Science and

Scientific Archaeology at USTC. His expertise covers the history of science and technology in modern China, scientific policy and oral history. He has been in charge of many research programs and published more than 30 research articles and four books.

Qian Xuesen's 'cultural design' and the development of engineering science at the University of Science and Technology of China

Yumei Tang

University of Science and Technology of China, China

Yun Zhu

Communication University of Zhejiang, China

Abstract

Engineering science at the University of Science and Technology of China (USTC) is hosted by its School of Engineering Science. From the perspective of scientific culture, this article examines Qian Xuesen's initial concept of engineering science and the formation of the discipline's cultural elements at USTC, such as institute–department integration (research–teaching integration), the training model, its emphasis on practice and its development as a research platform.

Key words

University of Science and Technology of China (USTC), Qian Xuesen, engineering science, cultural design

What is culture? It is a conceptual system marked by diversity that developed with human knowledge and also a set of patterns of actions underlying the formation of all civilizations. According to German cultural thought, culture encompasses all designs made by us to achieve our own and our posterity's happiness. Of course, happiness is desirable to all, and the pursuit of happiness is a fundamental right of everyone. However, the attainment of happiness is not that easy. It depends on the soundness and operability of our designs.

1. Qian Xuesen's initial concept of engineering science and the formation of its cultural elements at USTC

Since the 16th and 17th centuries, science and technology (S&T) have developed rapidly. With the sharp growth in independent scientific research, specialized science education and industrial technology applications, a relatively independent system of scientific culture has gradually emerged. It is a result of the efforts of the scientific community—an

Corresponding author:

Yun Zhu, School of Cultural Creativity, Communication University of Zhejiang, 998 Xueyuan Street, Higher Education Zone, Xiasha, Hangzhou 310018, Zhejiang, China.
Email: zhuyun89@mail.ustc.edu.cn.

emerging civilization community—to carry forward values, create paradigms and form rules. The scientific culture system encompasses three dimensions: scientific spirit and concepts (the directional and ethical layer), scientific methods and thinking paradigms (the utility layer) and scientific knowledge (the foundation layer). Scientific spirit, which is at the core of scientific culture, is defined as a spiritual temperament and a value orientation formed in the research activities of the scientific community and individual scientists, such as seeking the truth underlying nature and the world.

At the 2018 Science and You international conference, Han Qide noted that, in early modern China, the mainstream of scientific culture was characterized by the pursuit of national survival, development and prosperity, and that S&T were embraced as a way to save, stabilize and rejuvenate the nation. It was in the process of accepting, safeguarding, spreading and promoting scientific culture that Chinese scientists and technologists developed a rational spirit, democratic thinking and the concept of freedom—ideas that were foreign to traditional intellectuals—and were imbued with a profound collective feeling, national awareness and patriotism. This spiritual attribute of scientific culture has been passed down till today and has manifested itself in generations of Chinese scientists. It was against this backdrop that Qian Xuesen (Figure 1) posed the question ‘Why have our universities been unable to cultivate top-notch talent?’ as a special cultural appeal.

1.1 Establishing the Department of Modern Mechanics to meet pressing national needs

In the early days after the founding of the People’s Republic of China, because of enormous pressure from international actors who wanted to ‘contain’ China, there was a pressing need to modernize its industries and



Figure 1: Qian Xuesen.

national defence, and that need highlighted the importance of modern mechanics. The functional layout of the modern scientific system is based on the belief that mechanics is theoretical and methodological but, as a basic discipline of engineering, mechanics is the bridge between the natural sciences and engineering technology, and it provides a fundamental support for major national projects, including in aerospace, mechanical engineering, civil engineering and national defence. It can be said that a country’s level of development in mechanics reflects to a large extent its industrial and national defence strength.

Before 1949, Chinese universities offered only a limited range of courses in mechanics through their machinery, civil engineering and water conservancy programmes, but there was no programme or research institute dedicated to mechanics or to the development of talent specializing in mechanics. This led to a lack of talent and a low level of research in that field. In 1956, China formulated the Long-Term Plan for Scientific and Technological Development (1956–1967) (the ‘12-year plan’), which specifically identified an urgent need

to develop atomic energy and rocket technology. Against that backdrop, China's educational development plan for the basic disciplines began to emphasize subjects related to mechanics, such as aerodynamics and physical mechanics, in support of the development of the country's aviation industry. To provide theoretical support for many major construction projects, disciplines including solid mechanics and fluid mechanics were identified as priorities for development. The national scientific and technological strategy raised the importance of mechanics to an unprecedented level.

However, there was a yawning gap between the weak foundation and the national strategic goal, which Qian Xuesen and other experts in mechanics immediately became aware of and began thinking about. At that time, China's top mechanics institute, the Institute of Mechanics of the Chinese Academy of Sciences (CAS), had 86 senior and junior researchers, including only five first-rate mechanics experts at or near the international level. Barely 40 students graduated from the mechanics programme of Peking University each year, and, even if they were added to the mechanics graduates from other universities, there would be only about 300 graduates after two or three years. That talent base was obviously insufficient to meet the massive demand for mechanics talent from the top scientific projects specified in the 12-year plan. In 1958, Qian Xuesen, then serving as the director of the Institute of Mechanics, put forward a plan for conducting research to meet the requirement of 'going up to the sky, going down into the earth and the sea and serving industrial and agricultural production' in line with national needs. At that time, China's Two Bombs and One Satellite programme was at its initial stages. The targets were the development of atomic and hydrogen bombs and artificial satellites. CAS was an important participant in the programme and had a great need for high-calibre research talent to support its work.

On 9 May 1958, on the advice of scientists such as Qian Xuesen, Guo Yonghuai and Yan Jici, and taking advantage of the vigorous development of the 'Great Leap Forward in Education', the leading party group of CAS presented a proposal for the establishment of a new university to Vice Premier Nie Rongzhen, who was in charge of the programme, and the Publicity Department of the Central Committee of the Communist Party of China (CPC) (CAS, 1958). Later, Qian Xuesen mentioned this matter in his letter to Zhu Qingshi, USTC president from 1998 to 2008: 'Forty years ago, China formulated a 12-year plan for scientific development, which required talent versed in both worlds of S&T; in view of aeronautics and astronautics as the integration of engineering and mechanics, USTC was established' (Qian, 2008). It was against this backdrop that the Department of Modern Mechanics at USTC was conceived.

1.2 Applying the model initiated by Qian Xuesen to develop mechanics at USTC

After a massive reorganization of higher education institutions on the Chinese mainland in 1952 in accordance with the Soviet Union's model, the higher education system focused on training industrial construction talent and teaching faculty in comprehensive universities and on developing engineering science colleges, particularly specialized colleges dedicated to specific disciplines. The result was stronger technological education, and the expanded engineering colleges and disciplines provided talent that was able to absorb the technologies being introduced from the Soviet Union. In line with talent development goals at that time, the reform strengthened the development of teaching faculty and engineering talent needed for the Soviet Union's aid projects, but it also weakened the importance of basic research.

Another characteristic of the reform was the separation between sciences and engineering. Mechanics was included in the departments

of mathematics and mechanics of comprehensive universities in order to develop engineers with a science background, as represented by the Department of Mathematics and Mechanics at Peking University. In contrast, engineering science colleges were geared to developing technical engineers through academic programmes designed according to industry or product categories. As a result, engineering programmes were further differentiated to serve specific industries directly. The reform shortened the duration of training and condensed and simplified relevant basic subjects, including mechanics, which was a compulsory course in all engineering programmes. This training model, while effective in developing engineers and technicians and in driving the rapid development of general industries, led to engineering graduates having a weak grounding in the basic sciences.

According to Professor Li Pei, the wife of Guo Yonghuai, a winner of the Two Bombs and One Satellite Meritorious Award, when Qian Xuesen, Guo Yonghuai and Yang Gangyi discussed the tasks of the Institute of Mechanics based on the 12-year plan in April 1958, they agreed on the need for a large number of young new-generation scientists (Guo was vice director and Yang was party secretary of the institute at that time). They also agreed that university graduates assigned to the institute in recent years had not been solidly trained, as those from Peking University were oriented towards the sciences and those from Tsinghua University towards engineering; however, the institute had a pressing need for graduates who were strong in both science and engineering (Huang, 2012). As a result, they proposed the establishment by the institute of a 'University of Astronautics'. They discussed the idea several times, and the proposal was supported by all senior researchers at the institute.

In late April 1958, at a meeting of the directors of the Beijing-based CAS institutes chaired by Guo Moruo (the CAS president),

Qian Xuesen officially submitted the institute's proposal to establish a university. The proposal received immediate support from all directors attending the meeting, as they had experienced similar problems when young researchers assigned to their institutes failed to meet their research needs. At that time, the directors of the CAS research institutes were mostly leading scientists, such as Zhao Zhongyao of the Institute of Atomic Energy, Shi Ruwei of the Institute of Physics, Ma Dayou of the Institute of Electronics, Wu Ruyang of the Institute of Automation, Wu Zhonghua of the Laboratory of Dynamics, Hou Defeng of the Institute of Geology, Hua Luogeng of the Institute of Mathematics, Bei Shizhang of the Institute of Biology, and Zhao Jiuzhang of the Institute of Geophysics. They expressed a strong interest in a new university established to meet national needs.

With the strong support of Guo Moruo, a consensus was quickly reached for CAS to establish a new university. On 9 May, CAS vice president Zhang Jinfu submitted a report concerning the matter to Vice Premier Nie Rongzhen, who was in charge of S&T. On 21 May, Nie reported it to the secretariat of the CPC Central Committee and received the approval of Premier Zhou Enlai. At a meeting of the secretariat chaired by Deng Xiaoping on 2 June, CAS was officially approved to establish a new university. A preparatory committee was formed, comprising nine members: CAS president Guo Moruo, Vice Minister of Education Huang Songling, CAS vice presidents Zhu Kezhen and Wu Youxun, CAS Academic Division Committee director Yan Jici, Qian Xuesen, Du Runsheng, Yu Wen and Zhao Shougong. The preparatory committee worked very efficiently, and, after only three months of preparation, USTC, a new university integrating sciences and engineering, opened officially at 19 Yuquan Road in the western suburbs of Beijing on 20 September 1958. All these milestone events are fully recorded in the CAS archives.

Even before the preparation for USTC, Qian Xuesen had been facing an onerous workload. He returned from the United States to China with his family on 8 October 1955. Premier Chen Yi approved the CAS report on the establishment of the Institute of Mechanics on 16 January 1956, and Qian was appointed by CAS as the director of the institute. In February 1956, Qian submitted the 'Proposal for establishing China's defence aviation industry'; in April 1956, the Aviation Industry Commission of the People's Republic of China was founded, with Nie Rongzhen as its chair. On 18 February 1957, Premier Zhou Enlai appointed Qian as the director of the Fifth Institute of the Ministry of National Defense and the director of its first branch institute (the predecessor of today's China Academy of Launch Vehicle Technology).

Qian was the only director among all the Beijing-based CAS institutes to join the preparatory committee. To support the committee, he agreed to serve as the dean of the Department of Mechanics and Mechanical Engineering, a position that he went on to hold for 20 years (1958–1978). He recommended Guo Yonghuai, deputy director of the Institute of Mechanics, for the position of dean of the Department of Chemistry and Physics; Wu Zhonghua, director of the Laboratory of Dynamics, for the position of dean of the Department of Engineering Thermophysics; and Jin Zengyi, deputy director of the Institute of Mechanics, for the position of vice president of USTC.

At the inception of the Department of Modern Mechanics and based on his broad international view and rich experience in big science projects related to national defence, Qian realized the importance of aligning the development of talent in mechanics with the needs of national defence projects. Despite his heavy workload, he was personally involved in the design of curricula, academic programmes and teaching plans, and he created a highly visionary talent development framework, in addition to personally giving

classes and instructing students in scientific research.

Regarding the kind of talent urgently required by the nation and to be trained by the department, Qian said:

The work to integrate natural science and engineering technology and produce scientifically based engineering theories requires a different type of specialists. And this work itself constitutes a new department of knowledge: engineering science. It can be seen that, in the effort to continuously improve methods of production, we need to advance all the three departments of natural science, engineering science and engineering technology at once. It is necessary for these three departments to specialize in their own respective fields, for we definitely need natural scientists and engineering scientists as well as engineers. (Qian, 1957)

In applied mechanics, which serves engineering technology directly, engineering scientists are indispensable for making breakthroughs in key areas of aeronautics and astronautics. In China's higher education system at that time, there was no programme dedicated to training engineering scientists, which indicated a great need for a university to explore a model for their training. The training model, as an important cultural element in the initial design of mechanics at USTC, holds a special significance to this day as a concept and practice.

Today, the world is undergoing a profound transformation in science, technology, economy and society. A new round of industrial revolution gains momentum, driven by emerging technologies such as big data, cloud computing, the Internet of things (IoT) and artificial intelligence (AI). As part of this development, engineering has assumed new characteristics that are expected to become more pronounced in the coming years. Advances in engineering technology will lead to disruptive changes that will increasingly become the norm in engineering and manufacturing. Examples include digitalization, informatization and the

IoT in technology; diversification, personalization and customization in scale; and macro-thinking, interconnection and platformization in industrial development. This process will be accompanied by disruptive changes in production and services as the conceptual and cultural orientation towards ‘harmonious coexistence’ gains increasing currency. These changes include cross-regional interaction and extensive collaboration in the political arena, greater empathy and inclusiveness in popular culture, and so on.

It is beyond all doubt that, as emerging technologies develop and converge to trigger disruptive trends and needs for industrial development, higher education in engineering is facing new opportunities and new challenges worldwide. In China, there are still a number of prominent structural issues in engineering education and talent training, including the gravitation of engineering education towards science education, engineering talent’s lack of comprehensive hands-on abilities, a lack of clarification of the core abilities required of engineering education and a mismatch between the knowledge and skills acquired and the needs of big science projects on a national scale. It can be expected that, in the medium- and long-term strategy for the next 20 to 40 years, the new face of engineering caused by technological and industrial reform will be likely to place new disruptive requirements on the training of engineering science talent.

Since 2016, there has been an increasingly heated discussion on engineering education from a ‘new engineering’ perspective, partly because of the Ministry of Education’s emphasis on the concept. The ‘new engineering’ initiative reflects China’s engineering educators’ support for and reflections on major national strategies, including Internet+, Made in China 2025 and the Belt and Road Initiative. Its core goal is to create a large-scale talent training plan to meet major national and industrial needs and to include the plan quickly as part of China’s higher education

system to reverse the shortage of engineering science talent needed by emerging industries. As the discussion goes deeper, a series of programmatic documents, such as the *Fudan Consensus*, *Tianjin University Action* and *Beijing Guidelines*, has gradually been developed.

Based on the ‘new engineering’ initiative and cultural traditions such as willingness to serve the country, educational philosophy and operational wisdom passed down from the founders of engineering science, USTC has adopted a model of combining science, technology and art (design) in talent training, as proposed by Qian Xuesen in his letter to the university in 2008. According to a speech by Bao Xinhe, president of USTC, at the second Micius Forum on 14 April 2018, USTC will prioritize 18 academic disciplines in accordance with its ‘11+6+1’ blueprint (11 world-class disciplines, six interdisciplinary subjects and one system of disciplines of environment and ecology). Besides ‘new medicine’, USTC will develop ‘new engineering’, including such subjects as quantum information science, AI, big data, engineering science and new energy. In interdisciplinary subjects, it will prioritize brain science and brain-inspired intelligence; quantum information and network security; medical physics and biomedical engineering; management science and big data; mechanics and material design; information computing and communication engineering; and so on. For example, the university’s collaborative teaching programme, launched in 2015, has been committed to expanding and extending ‘new engineering’ and developing talent versed in science, technology and art in cooperation with partners such as the School of Design in the China Academy of Art, Intel, IBM, Baidu and iFLYTEK.

2. Research–teaching integration: then and now

From the outset, and based on his experience at the California Institute of Technology

(Caltech), Qian Xuesen based his pedagogy of engineering science on a radical integration of research and teaching. With the development and deepening of this integration, collaborative innovation by USTC and CAS institutes has become a new model for talent training.

2.1 Qian Xuesen's talent development plan and its implementation

After the large-scale integration of military and civil industries in World War II, the cycle of transformation of basic scientific theories into engineering and technological applications was greatly shortened. By the middle of the 20th century, S&T required and reinforced each other and developed rapidly. This led gradually to the formation of the S&T system and the S&T education system. Technological inventions were increasingly dependent on science. In many fields, basic science research had reached a mature stage. Basic science theories continuously opened up new directions for technological advances and accelerated the application and industrialization of technology. Similarly, the advance of modern science required support from technical equipment. Driven by national science projects, equipment technology developed into a systematic supporting force after the middle of the 20th century.

In 1955, China announced its commitment to developing science. Economically, a fundamental consensus was reached: that the attainment of major economic goals would rely on advances in S&T. Politically, the international situation required China to develop top S&T for national defence to protect the country, which was a daunting task in view of the weakness at that time of the scientific community and the nation's S&T foundations. The 12-year plan put scientific and technological advances high on the agenda. It became important to make breakthroughs as soon as possible in the scientific and technological fields of key importance to national

defence. There was a great need for talent equipped with both science and engineering abilities in many high-tech and national defence fields, such as atomic energy, aeronautics, astronautics, computing technology and automation. In 1957, CAS and the Ministry of Education jointly launched a temporary mechanics programme at Tsinghua University. Later, engineering universities such as Dalian University of Technology and Harbin Institute of Technology, and comprehensive universities such as Fudan University and Sun Yat-sen University, also launched their departments or programmes of mechanics.

Qian Xuesen, influenced by the Göttingen school of applied mechanics and with experience in scientific research, military science projects and teaching at prestigious institutions in the United States, had a deep understanding of developing S&T. In his view, scientific development in the 20th century had led to revolutionary changes in engineering technology, especially the invention and use of important weapons and equipment such as missiles, high-speed aircraft, radar and nuclear weapons during World War II, which fundamentally transformed production and warfare. These major inventions were clearly different from previous ones. They were not designed on the basis of engineering practice and experience; instead, they had theoretical bases in mathematics, mechanics and physics. They came about as the products of close collaboration between scientists and engineers. With this S&T relationship in mind, Qian, at the inception of the Department of Mechanics at USTC, clearly put forward its mission as being to serve major national needs through engineering science education.

The new university operated by pooling the resources of CAS and its institutes. Under this mechanism, the Institute of Mechanics was responsible for the design of the Department of Modern Mechanics, and Qian Xuesen, as

the director of the institute, set about developing the department's educational goals and programmes with the aim of developing engineering science talent. Qian benchmarked the department against Peking University in sciences and Tsinghua University in engineering, and his opinions and suggestions were largely implemented in all relevant aspects, including curriculum design and the selection of teaching staff. He planned four majors for the department: high-speed aerodynamics; high-temperature solid mechanics; rock mechanics and soil mechanics; and chemical fluid mechanics. The majors represented the developmental trends of the discipline in the world at that time (USTC Archives, 1958).

Specialized courses were emphasized from the second semester of the junior year (for a long period, USTC implemented a five-year system). Besides the required courses on their respective majors, students of the department were also required to take courses in engineering mechanics (including material mechanics), theoretical mechanics and rocket technology, totalling approximately 800 class hours. These new majors in mechanics had never been offered by most departments of mechanics at other universities in China, and the courses in high-speed aerodynamics, for example, were experimental attempts never before attempted in the country.

In the senior year, in addition to graduation thesis writing, the curriculum was organized into three layers: basic courses, specialized courses and thematic courses. The specialized courses, which gave full expression to 'institute-department integration' (the integration of research and teaching), demonstrated the characteristics of frontier, emerging and interdisciplinary majors. Emphasis was placed on combining basic sciences and frontier research. According to Tong Binggang, a retired professor at the Department of Modern Mechanics, the high-speed aerodynamics major was led by Lin Tongji, an expert in fluid mechanics and a researcher at the Institute of Mechanics, who had rich front-line

experience in the aviation industry and experience of studying in the United States and the United Kingdom. He also took charge of a full range of matters relating to the major, including curriculum design, textbook compilation, teaching staff appointments and thesis writing in the second half of the last academic year. Lin was assisted by Bian Yingui, a researcher at the Institute of Mechanics, who also had front-line experience in aeronautics and astronautics and experience of learning and working in first-rate institutions in the United States. Both Lin and Bian devoted a huge amount of effort to the work. For a time, Tong Binggang visited the 11th Office of the Institute of Mechanics almost every week to meet Lin and Bian and discuss issues involving the major and its courses before attending to specific matters at the university.

With the advocacy of Qian Xuesen, curriculum design placed a particular emphasis on interdisciplinary development. Thanks to his coordination, the courses were also delivered by first-rate researchers and experts from relevant research institutes, such as Guo Yonghuai (viscous fluid mechanics), Lin Tongji (hypersonic aerodynamics), Li Minhua (plastic mechanics) and Hu Haichang (bar and truss system, and sandwich structure). These top mechanists, who were participants in the country's cutting-edge research projects, had a solid understanding of the knowledge system of mechanics and deep insights into relevant technical issues. They informed students of the latest developments, frontier issues and solutions in their fields of study and helped them gain a solid grounding in their research fields as quickly as possible. All thematic courses were based on ongoing research programmes at the Institute of Mechanics (such as rarefied gas dynamics, high-temperature and high-enthalpy devices and testing technologies) and were usually given by young teachers.

Due to the completely new curriculum design, suitable textbooks were not available for many courses. Through the efforts of Qian

Xuesen, the Department of Modern Mechanics and the Institute of Mechanics collaborated to compile 11 teaching handouts in a short time. By 1962, the first junior students (enrolled in 1958) had received their textbooks. Based on teaching practice and continuous improvement, USTC had by 1965 put in place China's first curriculum system dedicated to high-speed aerodynamics, along with the corresponding textbooks. Those textbooks represented China's latest research achievements and constituted an internationally advanced knowledge and solution case system.

Qian attached great importance to student thesis writing, considering it a transition from systematic classroom learning to the application of knowledge to real-world research work (including research on engineering solutions) and a mentored hands-on exercise of scientific research and engineering practice. Speaking of how to conduct research and write papers, Qian once shared his story of carrying out research on the nonlinear instability of cylindrical shells under axial compression—a hot issue in the international mechanics community. The issue defied classical theories with a significant difference between calculation results and experimental data. His sheets of calculations (more than 600) ended up going nowhere, but the process took him closer to the truth, step by step. Eventually, it was found that the linear theory applied only to small deformations and that a nonlinear theory was needed for large deformations. Hitting the nail on the head, Qian established a model of nonlinear instability. The final draft was a little more than 60 pages long, further reduced to 10 pages when the study was published. The story did not end there, however. Qian had spoken of this in 1961. In the 1990s, when more than 15,000 pages of his research paperwork were taken back to China from the United States, it was found that on the cover of the expanding file containing the 10 pages of manuscript, the word 'final' was written, crossed out and

replaced by 'nothing is final'. This episode speaks volumes for Qian's consistently rigorous attitude towards scientific research.

In the eight years from 1958 to 1965, USTC produced a total of 1,000 graduates, including eight who would become academicians and nine who would become military generals. Its unique educational model of 'research-teaching integration' was extraordinary and prominent, and it was in no small part attributable to Qian's visionary pedagogical thought and practices.

2.2 From research-teaching integration to collaborative innovation

USTC was founded on the principle of 'Being both responsible and professional, integrating theory with practice.' In this motto, 'responsible' means serving the country through S&T, 'professional' means being professionally competent, and 'integrating theory with practice' brings out the true meaning of engineering science put forward by Qian: emphasizing the importance of theoretical knowledge and the ability to use that knowledge to solve practical problems. Being responsible is about having the right attitude, and being professional means having the required set of abilities. Over the 60 years since its founding in 1958, USTC has fully leveraged the advantages of research-teaching integration and created a unique talent development model of 'two parts, three integrations, and a long term', which holds a seminal significance in the history of China's higher education. 'Two parts' refers to the division of study into classroom learning on the university campus and the completion of specialized courses and some master's courses in research institutes. 'Three integrations' refers to department-institute integration, research-teaching integration and theory-practice integration. 'A long term' refers to comprehensively integrating undergraduate and post-graduate programmes in terms of teaching

resources, curriculum systems and talent development plans to develop a long-term talent development system that integrates bachelor's, master's and PhD programmes.

On 7 July 2014, the National S&T System Reform and Innovation System Construction Leading Group adopted CAS's 'Pioneer action plan and outline for comprehensively deepening reforms'. The plan put forward four 'pioneer initiatives': to achieve leapfrog development in S&T, to establish a national innovation talent centre, to establish a national high-level think tank and to build an internationally first-rate research institution. To become actively involved in the plan, the School of Engineering Science at USTC, the successor of the Department of Modern Mechanics, has entered into new types of collaboration with relevant research institutes of CAS, including the Institute of Nuclear Energy Safety Technology and the Guangzhou Institute of Energy Conversion. With steadily widening and deepening collaboration between the school and CAS institutes, the 'base + network' concept in the strategic design has been implemented, and various new integration platforms, such as joint colleges, S&T elite classes and joint laboratories, have been launched.

A compelling example is the CAS Research Centre for Solar Thermal Conversion, which was established jointly by the School of Engineering Science and CAS on 27 July 2009, in line with the Solar Energy Action Plan of CAS. The centre specializes in solar thermal conversion, the integrated utilization of light, thermal energy and electricity, and the development of large-scale technologies by integrating CAS strengths in fields such as thermodynamics, thermochemistry, heat and mass transfer and materials science. It aims to solve key scientific issues of solar energy conversion related to thermodynamics and energy conversion, storage and transfer; to advance the development of energy technology and technologies related to thermal energy, light and electricity; and to develop a

solar thermal conversion research platform with distinctive characteristics that guides national basic research and applied research on the integrated utilization of solar energy. It works in line with the USTC spirit of 'being both responsible and professional'. With its focus on the research and development (R&D) of key technologies, including building-integrated photovoltaics/thermal systems, low- and medium-temperature solar thermal technology and low- and medium-temperature solar power generation, the centre has established an integrated testing and demonstration platform committed to developing innovative talent in solar energy and has exemplified the meaning of 'engineering science'.

3. Education based on science—engineering integration to produce top scientists and national defence researchers

In a *People's Daily* article of 13 November 2018 titled 'Being responsible and professional, serving the country through S&T', Yang Jinlong, vice president of USTC and executive vice president of the USTC Graduate School, was quoted as saying, 'Being professional speaks of USTC's scientific spirit and pursuit of innovation and expertise. Over 60 years, USTC has produced a large number of top scientists and engineers in diverse fields who are trained across disciplines and versed in both sciences and engineering.'

The period from its establishment in 1958 to the eve of the 'Cultural Revolution' in 1965 was the first stage of USTC's development and a golden period for the university. In those seven years, the Department of Modern Mechanics had established a complete and new training system and had cultivated an impressive amount of top talent.

The Department of Modern Mechanics of the School of Engineering Science currently has 46 full-time faculty members, including

30 professors and 14 associate professors. The faculty team is young and highly competitive. It includes one CAS academician, six recipients of the National Science Fund for Distinguished Young Scholars, six recipients of the Excellent Young Scientists Fund, five scholars supported by the national '1,000 Talent Plan' Youth Project, and nine supported by the CAS Hundred Talent Programme. The discipline of mechanics is a national key first-level discipline. The research team consists mainly of the innovative research group for 'complex flow with vortex and interface' supported by the National Natural Science Foundation of China, the CAS Key Laboratory of Mechanical Behaviour and Design of Materials, and the Institute of Applied Mechanics.

Among the 1,000 graduates in the eight years from 1958 to 1965, there were eight academicians (Bai Yilong, Xu Jianzhong and Wang Ziqiang enrolled in 1958, Wu Yousheng and Du Shanyi enrolled in 1959, and Yang Xiumin, Fan Weicheng and Liu Lianyuan enrolled in 1960). In particular, the first two classes (1958 and 1959) of the Department of Modern Mechanics, to which Qian Xuesen gave courses in person, graduated five academicians, or one academician per 100 graduates. In addition, graduates of the department during the eight years included nine generals, including seven major generals and two lieutenant generals (Yang Xiumin enrolled in 1960, and Jiao Anchang enrolled in 1961). They worked on the development of national defence technology. Therefore, in addition to one academician per 100 graduates, there were nine generals per 1,000 graduates. Yang Xiumin was both a general and an academician, so the combination of the eight academicians and nine generals gives a total of 16 people rather than 17. In addition, according to incomplete statistics, the 1,000 graduates also included 375 professors, researchers and professor-level senior engineers. With the academicians and generals, the total number is brought to 391. In other

words, nearly 40% of the 1,000 graduates were promoted to senior specialized technical positions.

Bai Yilong graduated from the Department of Modern Mechanics in 1963. He was elected to CAS as an academician in 1991 and was elected to the European Academy of Sciences in 2002. He served as president of the Chinese Society of Theoretical and Applied Mechanics, director of the Academic Committee of the State Key Laboratory of Nonlinear Mechanics, and director of the Department of Mathematics and Physics of the National Natural Science Foundation of China. He received many prestigious prizes and awards, including Second Prize of the National Natural Science Award (1992, first winner, in thermoplastic shear belts), the Ho Leung Ho Lee Prize (1999) and the John Rinehart Award (2007).

Xu Jianzhong graduated from the Department of Modern Mechanics in 1963. He was elected to CAS as an academician in 1995. As an expert in engineering thermophysics, he serves as a researcher at the Institute of Engineering Thermophysics and as director of the National Energy Wind Turbine Blade R&D Centre.

Du Shanyi graduated from the Department of Modern Mechanics in 1964. He is an expert in the structural mechanics of aircraft and composite materials and an academician of the Chinese Academy of Engineering. He served as vice president of the Chinese Society of Theoretical and Applied Mechanics, president of the Chinese Society for Composite Materials, and a member of the advisory group of major national research programmes. He is currently the dean of the School of Engineering Science at USTC, a member of the S&T Committee of the State Administration of Science, Technology and Industry for National Defence, and a member of the advisory group of the Commercial Aircraft Corporation of China.

Fan Weicheng graduated from the Department of Modern Mechanics in 1965 with a major in engineering thermophysics and has been working at the university since graduation. He became vice president of USTC in 1996 and was elected to the Chinese Academy of Engineering in 2001. As an expert in fire safety science and engineering, he serves as director of the State Key Laboratory of Fire Science and dean of Hefei Institute for Public Safety Research, Tsinghua University.

Jiao Anchang graduated from the Department of Modern Mechanics in 1966 with a major in aerodynamics. He served as deputy director of the S&T Committee of the General Armaments Department of the Chinese People's Liberation Army (PLA) from January 2002 to December 2005. With the rank of lieutenant general, he is the commander of a military base and director of China Aerodynamics R&D Centre.

Jing Yinglong graduated from the Department of Modern Mechanics in 1965. He served as deputy director and director of the Political Department of the Air Force of Ji'nan Military Area from April 1994 to 1999. He was awarded the rank of major general in July 1995. He became deputy director of the Political Department of the PLA Air Force in December 1997.

Yang Xiumin graduated from the Department of Modern Mechanics in 1965. He was a senior engineer at the Fourth Institute for Engineering Staff of the General Political Department of the PLA. His expertise covers the numerical simulation of weapons explosion effects, theoretical analysis of protection engineering, and systems verification. He has participated in several nuclear field tests.

There are many scientists and defence technology experts like them. By following Qian Xuesen's concept of training engineering science talent and adhering to the 'two integrations' (sciences–engineering integration and teaching–research integration) and the 'three first-rates' (first rate top-down

design, first-rate teaching faculty and first-rate students), the Department of Modern Mechanics achieved glorious success in USTC's first stage of development.

4. Orienting theoretical disciplines to real-world applications

Involving students in scientific research from the early years of study is a tradition at USTC, where students are required to do laboratory research with their supervisors and PhD students from the first year.

4.1 Emphasizing practice in the education process

USTC's emphasis on practice equips students with high-quality research skills, such as the ability to consult frontier work and research literature.

4.1.1 Students' involvement in scientific research and engineering projects from the freshman year

USTC was established as a science-focused university, it has encouraged students to be involved in scientific research from their first year, so that they can combine theoretical knowledge with practice. For example, the Department of Modern Mechanics established an artificial rain rocket R&D group and a pulse jet engine R&D group in 1958 and a wind turbine generator R&D group in 1959. Despite his heavy workload, Qian Xuesen managed to answer questions for the rocket R&D group (such as by explaining the reason for unstable combustion in solid-fuel rocket engines) and offer suggestions (such as putting small rockets into the service of agriculture and meteorology through such applications as artificial rain generation and hail mitigation).

According to Zheng Zhemin, a colleague of Qian at the Department of Modern Mechanics

and at the Institute of Mechanics, Qian had very rich experience in field research as well as theoretical research and teaching. As early as 1937, when Qian was studying at the Aerospace Engineering Department of Caltech, he and his classmates formed a five-member rocket research group to research solid-fuel rockets. The group's first result was a small rocket designed to help aircraft take off from short runways. The group later formed a company to which Qian served as adviser. After the company began achieving positive results, Qian gave a summary report at USTC's first scientific research conference on its attempts to make artificial rain rockets and pulse jet engines, and in this way inspired the innovative spirit of the students.

After several discussions, the students of the class of 1958 decided to dedicate the results of their pulse jet engine R&D project to the 10th anniversary of the establishment of the People's Republic of China. By the beginning of the second semester of 1959, the project had made significant progress. In early September, however, the assembled rocket failed to ignite and did not work properly despite several attempts. Just when everyone was at their wits' end, Qian Xuesen came to the R&D group and explained to them the thermal process of the pulse jet engine. On 28 February 1960, USTC convened a scientific research conference where Zhu Xiaoguang, representing the majors of mechanics and engineering thermophysics, gave a report on the trial production of the artificial rain rocket, and Huang Kaixi gave a report on the trial production of the pulse jet engine. Qian summarized the reports. He spoke highly of the R&D activities of the sophomore students. In his view, they had reason to be proud of their accomplishments, which, though not scientifically significant, allowed them to get close to leading-edge technologies and would prepare them well for their future scientific research work.

Currently, USTC has many interest groups through which students can participate in

laboratory research activities according to their interests. As a result, USTC undergraduates have reached the academic level of postgraduates of many other universities.

4.1.2 Developing talent through frontier research in S&T

In an article published in the *People's Daily* on 26 May 1959, Qian Xuesen stated that, apart from the division into specialized basic courses and general basic courses, courses at USTC could also be divided into basic theoretical courses and basic technological courses. This arrangement was in line with USTC's mission to train engineering science talent, which differentiated it from all other Chinese universities. According to Qian (1959), 'USTC graduates will engage in research in new sciences and new technologies after graduation, which will lead them into uncharted waters and require them to explore and feel their way ahead. Their exploration should not be blind, but be based on previous research.' Previous research constitutes a mature system of basic disciplines. 'USTC is for training scientific and technological leaders, and its students must be well prepared for their future research work.' Research in new sciences and new technologies requires talent versed in both sciences and engineering.

Emphasis on theories and technologies was a key characteristic of the courses of the Department of Modern Mechanics (Qian, 1959). For example, the two disciplines of high-speed aerodynamics and high-temperature solid mechanics had the same basic courses and credit hours; their basic courses were divided primarily into basic theories and basic technologies, with the former mainly consisting of advanced mathematics, general physics and general chemistry.

Basic disciplines were emphasized because mechanics, as a classic discipline in engineering science, is founded on them. Physics is the source of the most fundamental principles

of mechanics, mathematics is an indispensable research tool, and engineering science provides the theoretical base for engineering technologies. Therefore, at the third meeting of deans at USTC, the participants focused their discussions on the allocation of credit hours to basic courses and arrived at the decision to divide advanced mathematics into two types: Type 1, spanning two and a half years with 430 credit hours, and Type 2, spanning a year and a half with 260 credit hours. The departments of mechanics, applied mathematics and computer technology were included in Type 1 (Qian, 1959).

In the two disciplines of high-speed aerodynamics and high-temperature solid mechanics, complex chemical changes should be fully considered. In the development of cutting-edge engineering technologies, in particular, mechanists were supposed to come up with solutions to problems encountered in production, and this called for the full use of existing physical and chemical achievements, pointing to the necessity of a strong grounding in mathematics, physics and chemistry. Given the complexity of real-world engineering problems, which often involve different disciplines, researchers were required to have a solid training in a broad range of basic disciplines in order to investigate and solve problems of engineering science.

Another important course category was basic technological courses, including engineering design technology (mechanical drawing and mechanical design), experimental technology (electrical engineering and electronics; electronic measuring of non-electrical quantities) and computing technology (computing methods and computers). These courses offered the most basic training for engineering students. They were tools for engineering implementation, and they were as indispensable in scientific research as physics and mathematics. Only by mastering the basic tools of engineering technology could students apply basic scientific knowledge to solve engineering science problems and make experimental data

go beyond the laboratory to practical engineering.

Basic courses in both categories were included in the general courses at USTC, where the first three years were mainly dedicated to basic courses. General courses took up half of the total credit hours, and basic theoretical courses and basic technological courses featured prominently. Compared to the departments of mechanics at comprehensive universities, such as the Department of Mathematical Mechanics at Peking University, and engineering programmes at multidisciplinary engineering universities, such as Tsinghua University, the Department of Mechanics at USTC had more credit hours for basic theoretical courses than the related programmes at Tsinghua University (which focused on engineering design) and also far more credit hours for basic technological courses than the Department of Mathematical Mechanics at Peking University (which focused on mathematical and scientific computations). This emphasis reflected the concept of science–engineering integration in the training of engineering science talent, which differentiated itself from the talent training philosophies of basic disciplines and engineering disciplines.

In Qian Xuesen's view, while natural science was undoubtedly the foundation of engineering technology, it did not inherently include the laws of engineering technology. Actually, the research methodology of engineering science is based on the integration of the research methods of natural science and those of engineering technology. However, applying theories of natural science to engineering technology is not a straightforward matter of theoretical reasoning; it requires the integration of scientific theories with engineering technology. Therefore, a scientifically grounded engineering theory is neither natural science nor engineering technology but an organic combination of the two. Research in new sciences and new technologies requires talent that spans both science and engineering. In the process of exploring

new knowledge, it is important to adhere not only to theory and technology but also to an objective scientific spirit and noble scientific ideals and values from a cultural perspective.

4.2 Engineering science at USTC in its third stage: frontier undergraduate education epitomized by RoboGame

At USTC, robotics is not only a field of frontier research but also a training ground for innovative talent. The Intelligent Mechanics and Robotics Laboratory at the School of Engineering Science began training robotics talent as early as the late 1990s and sent its first team to the fourth RoboCup held in Australia in 2000. The school offers a course in robotics study that combines theoretical learning and hands-on practice to build undergraduates' practical ability and develop their innovative spirit. After completing the course, interested students can apply to study in the laboratory. After some time spent there, top-performing participants are selected and assigned research tasks. If RoboCup is an arena of top-level competition, then the annual RoboGame competition at USTC is an extracurricular S&T event geared to promoting robotics among USTC students, and it attracts hundreds of students every year. The participants design programmes, fabricate and assemble hardware in their spare time, and put on show the robots they have created using multidisciplinary knowledge and skills. The competition has created a strong environment for robotic research at the university.

USTC organizes a RoboGame competition each year. It has been a tradition since 2001. To participate in the competition, each team is given five months and a certain amount of funds for the design and creation of a robot. A team cannot have more than five members. They must be junior and lower grade students, and may be from different schools or departments. The competition has two components: one is performance-oriented and the other

is contest-oriented. Every year has a unique theme selected from many alternatives solicited from the students and decided by the students through a vote. After years of development, RoboGame has become a unique and widely influential hands-on programme for education, students' innovative research and science popularization at USTC that integrates a robot design course, competition and performance. Students can take optional courses to acquire the necessary knowledge and skills to participate in the competition, and their class performance, design and creation will serve as the basis for the determination of course credits. In addition, innovation practice credits are awarded on the basis of performance in the competition. By integrating education with competition and by combining technological innovation and stage performance, RoboGame has played a positive role in stimulating students' enthusiasm for learning, exploration and innovation, fostering their innovation, collaboration and leadership abilities.

Kejia, an intelligent service robot independently developed by USTC, won the 18th RoboCup championship. This is the first time a Chinese-made robot has taken first place in the international standard service robot test, marking a historic breakthrough for China's service robot R&D. Meanwhile, USTC has won five 2-D robot simulator championships and five runner-up titles.

The spirit of engineering science at USTC is not only reflected in real-world applications of frontier knowledge, as in robot competitions and the effective release of innovation potential, but is also known beyond the academic community through achievements with social impacts, such as the robot Jiajia. The university began research in intelligent robotics in 1998. In 2008, on the eve of the 'birth' of Jiajia, the university launched the Kejia Project, dedicated to independent R&D on service robots, including both software and hardware. The Kejia Project has become an interdisciplinary robotics research platform.

Since 2012, Kejia has received a succession of awards, including first place in the national standard test of service robots for three consecutive years. Despite being one of the intelligent service robots to receive the greatest number of awards internationally, Kejia lacked a recognizable public identity of the kind most of its international peers had, which was much to the embarrassment of the USTC team. Therefore, designing a visual identity for Kejia was put on the agenda.

In July 2012, the Kejia team solicited real-life models among female USTC students for the visual identity design of Kejia, and five students were selected as the prototype for Kejia's appearance. After discussions, it was determined that the visual identity should manifest kindness, diligence and intelligence. The result was the now well-known Jiajia. According to the research team, Jiajia displayed the three qualities well.

In 2015, after much research and deliberation, the team further refined the visual identity of Jiajia and finalized the overall image by endowing it with a unique temperament and personality. Later, the team collaborated

with a mannequin manufacturer in Xi'an to create a lifelike Jiajia with intelligent and graceful looks. In April 2016, the third-generation intelligent interactive robot developed by USTC, Jiajia 3.0 (Figure 2), came into being. The new-generation Jiajia is capable of extensive advanced functions, including conversation, matching of facial micro-expressions and body gestures and dynamic autonomous navigation. In addition to being a USTC brand in its own right, Jiajia expresses the spirit of engineering science on the USTC campus.

5. The development of the Department of Modern Mechanics as a platform integrating science and engineering

Scientific culture is an important part of the human economic and social system, and its characteristics evolve with economic and social development. This determines that the advocacy of scientific culture has different values and emphases at different stages of economic and social development. Scientific



Figure 2: Jiajia, the interactive robot.

culture not only enriches science with a cultural dimension but also reveals the social and cultural effects of science in a critical or reflective way. It thereby provides inspiration for the construction, enrichment and renovation of human culture. Our mission is to construct a cultural prototype, an ideal cultural blueprint and a cultural value system on the basis of the normal development of the scientific community, so as to provide spiritual underpinning and conceptual support for social progress. It is through navigation by the scientists and leaders in cultural design, such as Qian Xuesen, that USTC has formed its unique cultural ambience and orientation in a thoughtfully constructed scientific community culture.

5.1 Interdisciplinary education, science–engineering integration and science–engineering–art integration

USTC has been committed to expanding its philosophy of educational integration to encompass new fields.

5.1.1 Training talent by integrating science and engineering

With the rise of Internet technology and emerging technologies such as AI and the IoT, two major approaches to scientific and technological research and higher education have emerged. The first approach is applied science, such as applied mechanics, which was born out of the transition from the separation between basic sciences and engineering technologies to their integration. The process was significantly driven by the Göttingen school of applied mechanics represented by Felix Klein and Ludwig Prandtl, and the GALCIT (Graduate Aerospace Laboratories of the California Institute of Technology) school of applied mechanics represented by Theodore von Kármán. For example, in the

development of aerodynamics and aircraft technology, the boundary layer theory and the aerofoil theory led to the advance from biplane to monoplane, and the compressible flow theory led to the breaking of the sonic barrier, realizing supersonic flight. In his book, *Aerodynamics: Selected Topics in the Light of their Historical Development* (written in 1954 in commemoration of the 50th anniversary of powered flight), von Kármán noted that aerodynamics was an example of cooperation between mathematicians and creative engineers. Mathematical theories were found suitable to describe the airflow produced by aircraft with such accuracy that they could be applied directly to aeroplane design. It was this kind of marriage between S&T that gave rise to a model of higher education centred on academic research, represented by modern research universities that integrate scientific research and teaching to train innovative talent.

Qian Xuesen was a student of von Kármán and also an outstanding representative of the GALCIT school of applied mechanics. He played an important role in driving the development of high-speed aerodynamics and jet propulsion technology, integrated and carried forward the quintessential ideas of the Göttingen and GALCIT schools of applied mechanics, and developed his own concept of engineering science and related educational concepts. As early as the 1940s and 1950s, Qian had anticipated the rise of high technology in extensive areas and was advocating the development of a group of applied sciences, which he collectively referred to as ‘engineering science’, to support it.

In his words, ‘The sector of natural science and technology has basic sciences (such as physics and chemistry) at its top layer and finds actual application through engineering technology at its bottom layer and between the two is engineering science.’ He sandwiched the two layers together with a middle layer called engineering science, which ‘is

born from the integration of natural science and engineering technology and is a science in the service of engineering technology'. He advocated that 'we need to advance natural science, engineering science and engineering technology at once.' Qian considered it to be infeasible to train talent in engineering science through conventional engineering education, because engineering science was on a mission to create scientifically sound engineering theories, which 'is highly difficult and highly creative'. Thus an entirely different type of specialist was needed to do the work (Qian, 1957).

The establishment of the Department of Modern Mechanics at USTC provided a platform through which Qian could put into practice his educational concept of training engineering science talent. It was the longest, most committed and most systematic educational activity conducted by Qian after his return to China, and it created a successful paradigm for training engineering science talent in a new model. Qian and other scientists of the older generation had, at the very inception of USTC, laid down its educational principle of 'running the university based on all available resources of CAS and integrating departments and CAS institutes' and specified the goal of training top-level scientific and technological talent. The top-down framework design, including the majors and the curriculum system, also demonstrated the concept of science–engineering integration and teaching–research integration. Based on the principle and concept, the university has developed its distinctive educational model.

Emphasis on basic courses is one of the signature features that differentiates USTC from other engineering universities, and it is a tradition that the university has adhered to over the 60 years since its establishment. In his article titled 'Basic courses at USTC' published in *People's Daily*, Qian (1959) expounded the significance, scope and learning methods of the basic courses:

We emphasize basic theories for the reason that USTC graduates will engage in research in new sciences and new technologies, which will lead them into uncharted waters . . . Therefore, they will have to rely more on general knowledge . . . [and] general laws of nature . . . especially the laws about the structure, properties and motion of things, i.e., physics and chemistry, which will serve as a compass in their research exploration . . . the development and growth of new fields of mechanics cannot go without the progress of experimental techniques, and these experimental techniques have been developed on the basis of many achievements of modern physics and chemistry.

At USTC, the basic courses were divided into theoretical courses, including mathematics, physics and chemistry; technological courses, including engineering design technology, experimental technology and computing technology; and foreign languages (Figure 3). Theoretical courses accounted for approximately one-third of the total credit hours, and technological courses for more than 10 percent. Therefore, the university had significantly more theoretical courses than conventional engineering universities and significantly more technological courses than conventional science programmes. This arrangement clearly expressed the concept of science–engineering integration.

In 1958, when China developed its first electronic computer, Qian Xuesen added the Theory of Electronic Computer course to the curriculum of the Department of Modern Mechanics. As there was no algorithmic language at that time, students had to write programmes using binary code, completely unlike today, when computers have become a common tool used in all complex mechanical computations. After rigorous basic training, students mastered three sets of basic knowledge and abilities: solid mathematical grounding and computational and analytical skills; solid basic physical and chemical knowledge;

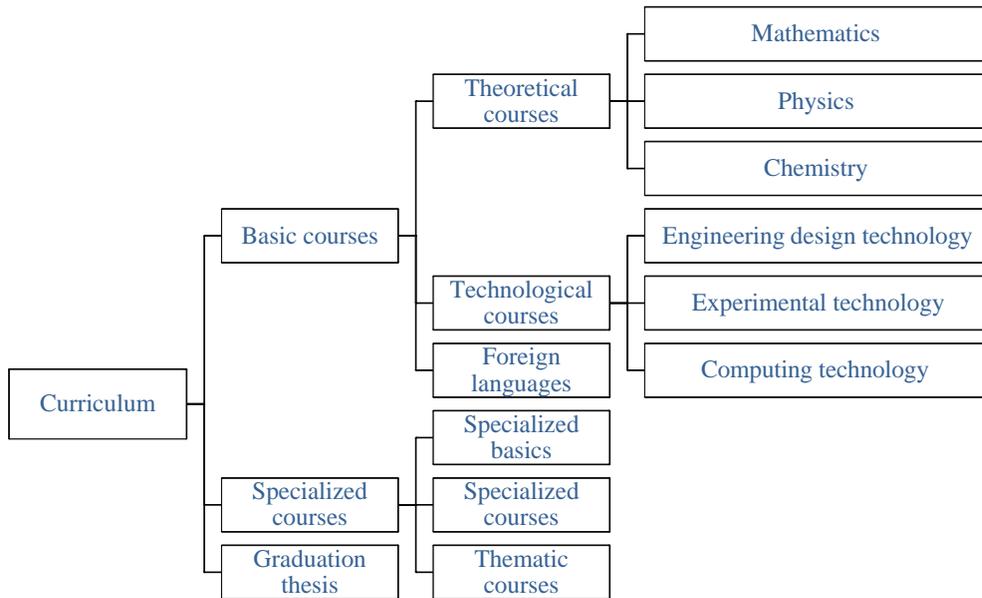


Figure 3: The curriculum system at USTC.

and principles and corresponding practices of engineering design.

Qian Xuesen planned the academic disciplines of mechanics and engineering at USTC with the strategic aim of accelerating the training of top-level talent for China's aerospace programmes. The university's educational system focused on the integration of science and engineering and was geared to training engineering science talent: research-oriented engineers capable of keeping abreast of the latest developments of engineering technology and equipped with solid natural science knowledge and leadership abilities. Under the guidance of Qian's thinking on the development of engineering science talent, the Department of Modern Mechanics became a pioneer in training talent that spans science and engineering, and its approach influenced other departments at the university. By adhering to the goal of training talent with solid and broad basic knowledge and deep up-to-date expertise in specialized areas, and by promoting the '2+X' model of general science education and specialized training (students take general courses in the first two years and

select a specialized discipline in the third year, according to their interests), USTC formed a distinctive educational system for training top innovative talent in S&T and graduated a great number of interdisciplinary scientists and engineers.

5.1.2 Training talent by integrating science, technology and art

Although there have been many updates and changes in extensive aspects of the academic programmes (including teaching plans, curricula and textbook content) in line with developments in S&T, USTC has always adhered to the goal of training research talent in engineering science and has always emphasized the integration of science and engineering and of teaching and research.

In his later years, Qian Xuesen continued to pay close attention to the development of USTC. During the 50th anniversary of the university in 2008, he wrote a letter to CAS vice president Bai Chunli to celebrate the anniversary. In the letter, he said:

USTC has selected a right path in its emphasis on integrating science and engineering. As it develops further, it can aim at the greater integration of science, engineering and art. I believe USTC will certainly be able to train internationally first-rate scientists and technology leaders in the future.¹

With the quick succession of technological breakthroughs and cross-boundary integrations since the dawn of the 21st century, emerging technologies such as AI, clean energy, automated control, quantum communication, virtual reality, bioinformatics and genetic engineering have come to take centre stage in S&T. The inherent need of modern S&T for cross-boundary integration and interdisciplinary research has further advanced the integration of S&T at a deeper level, and this has validated the concept of engineering science put forward in the early part of the 20th century.

The requirement for talent with broad interdisciplinary expertise in both science and engineering has significantly influenced not only frontier research areas but also the transformation of education in engineering universities. The Excellent Engineer Training Programme and the design of ‘new engineering’ are appropriate adjustments to address new challenges after the inadequacy of traditional science and engineering education has been realized. With the business world attaching increasing importance to user needs and user experience, the integration of science and art represents new thinking and exploration, as well as a new trend. This is reflected, for example, in the progression of industrial design to information and network design (interface design, interaction design and so on), information aesthetics, AI agents design and the new field of life aesthetics, including gene editing, which poses new challenges for greater integration of engineering science and technology. Qian Xuesen, with his keen foresight, conveyed this visionary concept to USTC, which he served for 20 years.

5.2 Summarizing the educational concept and spiritual values of the Department of Modern Mechanics and the School of Engineering Science

Scientific culture is science seen from the cultural perspective. It penetrates a broad spectrum of scientific activities by speaking not only to the technological, empirical, mathematical and logical dimensions but also to the dimensions of spirit, concepts, ideals and values. USTC was established as a new type of university, drawing upon the example of Caltech. The integration of science and engineering has always played a crucial role in shaping its scientific culture.

According to CAS academician Tong Binggang, who enrolled in 1958 in high-speed aerodynamics, the scientific spirit of the Department of Modern Mechanics, the predecessor of today’s School of Engineering Science, was shown in four main aspects. The first aspect was its striving spirit. At that time, courses were very strenuous and demanding, to the extent that the dorms were mostly still empty at 11:00 at night, and Sundays were for self-study in the classroom rather than rest. During the busiest periods, classrooms were always full of students night and day, because the early risers would arrive before those burning the midnight oil had left. This reflected USTC’s characteristics of heavy academic load, long class hours and deep lecture content. In the words of a popular saying of that time, ‘Poor students go to Tsinghua University, rich students go to Peking University, and strong-willed students go to USTC.’ The second aspect was its innovative spirit. USTC was on a mission to train top talent in frontier S&T, which could be demonstrated in the words of its anthem, ‘We scale the height of science, the steadily ever rising height of science.’ Thanks to the integration of institutes and departments, students were able to learn the latest scientific knowledge and access the newest scientific findings. The third aspect was its rigorous scientific spirit. Qian

Xuesen often urged students to be serious, rigorous and strict in scientific research. The fourth aspect was its democratic spirit. Imbued with the scientific spirit of scientists of the older generation, the USTC campus always had an encouraging academic environment and rich academic atmosphere. Most teachers in the early years of USTC also served the CAS institutes. The full-time teachers were very young and took on important research projects at a very early stage; they quickly stood out and had a lot of research opportunities to choose from.

An organization's culture is always faced with a colourful road map of options in its orientation, formation and development. USTC's development in engineering science, including the formation of its cultural elements, the talent training model, its emphasis on practice and development as a platform, is based on the wisdom of its designers and the practice of countless successors. USTC has been able to live up to its motto of 'being both responsible and professional, integrating theory with practice' and to form the distinctive scientific spirit and cultural orientation of the engineering discipline that integrates science and engineering.

Note

- ¹ Source: Qian Xuesen's letter to Bai Chunli, 28 January 2008. Available at: http://www.cas.cn/zt/rwzt/qxs/zydn/200911/t20091113_2654745.shtml (accessed 15 November 2018).

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Author biographies

Yumei Tang is an assistant researcher at the Institute of New Media Research, University of Science and Technology of China. She graduated in 2016 with a master's degree from the Product, Ceramic and Industrial Design Programme at Central Saint Martins.

Yun Zhu is a lecturer at the School of Cultural Creativity, Communication University of Zhejiang. She graduated in 2017 with a PhD from the Centre for Scientific Communication Research and Development, University of Science and Technology of China. Her main research area is cultural communication.

Guiding principles in developing world-class disciplines at the University of Science and Technology of China: A case study of the development and innovation of quantum information science

Bin Zheng, Shukun Tang and Qiong Fan

University of Science and Technology of China, China

Abstract

In developing world-class disciplines, the University of Science and Technology of China (USTC) has made swift progress in the field of quantum information, which is an all-new and non-mainstream discipline in physics. From a cultural perspective, this paper analyses the construction of the academic–research–production–application chain of USTC’s quantum information discipline. It also explores the values and implementation schemes adopted in the development of a leading and open scientific research platform and a high-calibre research team. Based on the analysis, it summarizes the features of scientific culture in this discipline, such as an emphasis on basic education, the integration of research institutes with teaching departments, inclusiveness to cater for various interests, and persistence in serving the country through science.

Key words

University of Science and Technology of China (USTC), quantum information, scientific culture, basic education, institute and department integration

1. Introduction

In 2017, after years of preparation, China officially initiated a programme of world-class universities and world-class disciplines (the ‘double first-class’ initiative) in a bid to enhance the influence of Chinese universities in the wider world. According to Essential Science Indicators, which is an academic assessment instrument developed by Thomson

Reuters, the number of citations in the physics papers of Tsinghua University, Peking University and the University of Science and Technology of China (USTC) reached 161,578, 153,573 and 150,857, respectively, in the period from July 2012 to September 2018. Their rankings are far above those of other universities in China and close to the world’s highest. Meanwhile, China has moved from being a follower in some fields of physics to

Corresponding author:

Shukun Tang, Department of Science Communication and Scientific Policy, University of Science and Technology of China, no. 96 Jinzhai Road, Baohe District, Hefei 230026, China.
Email: sktang@ustc.edu.cn.

being a leader. The rise of emerging research fields such as quantum physics and quantum information is an important factor that has led to the rapid development of this competitive edge. There is no doubt that USTC leads in the quantum information discipline in China. Its academic–research–production–application chain of quantum communications, in particular, has earned USTC its reputation.

At USTC and elsewhere in China, an important starting point in quantum physics has been quantum optics. In 1981, when Guo Guangcan, who was then a teacher at the Department of Physics of USTC, visited the Department of Physics at the University of Toronto as a visiting scholar, he sighed:

Only after I had arrived, did I find the university already had a mature theoretical framework of quantum optics. Alas! China has paid little attention to this field and is almost 20 years behind the international forefront. (Hao, 2012)

In 2018, only 37 years after Guo uttered that sigh, USTC has attained a competitive edge in the development of the whole academic–research–production–application chain of quantum communications, which has amazed fellow researchers at the international forefront and earned their recognition. Consider, for example, the research team led by Pan Jianwei. Pan has received many awards in quantum communications, including the Fresnel Prize, the Quantum Communication Award and the Willis E. Lamb Award for Laser Science and Quantum Optics. Chen Yuao and Lu Zhaoyang, who are on Pan's team, also won the Fresnel Prize in 2013 and 2017, respectively. Chen won the award when he was only 32 years old.

Based on an analysis of the values and mechanism of USTC's scientific culture, this paper examines the key factors in the rapid development of and later boom in quantum information (especially quantum communications and some areas of quantum computing) at the university.

2. The activation of cultural elements and the choice of a development pathway

Culture is the basis for the development of civilization and institutional innovation, and scientific culture is a form of and an important factor in culture. From the perspective of cultural construction, scientific culture usually refers to a set of values, behavioural patterns and systems created or inherited by the scientific community in the course of scientific research and science communication, and recognized and followed by the public (Wang and Zheng, 2018).

The scientific practice revealed by scientific culture involves not only research based on discipline classifications, such as mathematics, physics, chemistry, astronomy, geography and biology, but also metaphysical factors such as scientific spirit, values and ethics and the selection of development pathways (Jia, 2015; Liu and Chen, 2018).

As a national-level flagship university administered by the Chinese Academy of Sciences (CAS), USTC focuses on frontier science and high technology while including unique management and liberal arts courses. USTC was founded in Beijing in September 1958 and moved to Hefei, Anhui Province, in early 1970. During the 60 years since its establishment, it has followed the principle of 'running the university by the whole academy and integrating institutes and departments', and the motto of 'being responsible and professional and combining theory with practice'. It has been committed to training talent by setting up departments according to China's pressing needs for technology and by integrating frontier science with frontier technology. USTC attaches great importance to basic courses and advocates freshmen's engagement in frontier research projects. It has sought to train top scientific personnel specializing in emerging, marginal and interdisciplinary subjects, emphasizing a high-level starting point for students and broad scope of their

knowledge. USTC has created a unique pathway of development highlighting ‘high-quality education and top talent training’, fostering a scientific culture with distinctive USTC features (Jiang, 2015).

3. USTC’s stance and attitude: a story of making rational choices

USTC’s successes have been based on its defence of high-quality education and rational choices about its own development.

3.1 Persisting in high-quality education despite larger enrolments

In the late 1990s, the Ministry of Education promoted increased university enrolments. Most of China’s universities answered the call and embraced the market to start increasing enrolments. However, this unusual mode of development soon resulted in high student to faculty ratios and a shortage of teachers and experimental resources. Moreover, the shortage of faculty in certain disciplines was growing serious, especially in basic and general courses that all students were required to take. There was also a lack of instructors for specialized experiments and training, so super-packed classes and simplified experiments became usual. In order to offer enough courses, many universities began to use newly graduated teachers without any systematic and professional training, or teachers whose expertise did not match the courses. This led to worsening teaching quality.

Counter to the mainstream, however, USTC persisted in its goal of producing top scientific talent for the country, becoming the only university that has never increased its undergraduate enrolment. During the past 20 years, it has held its annual undergraduate enrolment at 1,860. According to USTC’s ethos, only when each student is guaranteed adequate and excellent learning resources can the university ensure the high quality of its graduates.

The results of USTC’s persistence can be quantified:

- According to data published by Wu Shulian on Chinese university graduates’ quality and faculty members’ average academic level, USTC ranked first for both among universities on the Chinese mainland in 2016 and 2017; it ranked third in terms of the quality of employment of undergraduates in 2018, scoring only 0.0093 lower than the top scorer, Tsinghua University.
- Thomson Reuters released data identifying the world’s top 100 materials scientists in 2018. Among the 15 Chinese scientists on the list, 10 finished their undergraduate study in universities on the Chinese mainland, and seven of them were from USTC (they ranked 1st, 2nd, 4th, 5th, 6th, 20th and 43rd).

Former USTC president Zhu Qingshi was a representative opponent of the enrolment expansion initiative when it was proposed. He later argued that:

I hope USTC will adhere to its founding principles and guidelines, which it has been following for 50 years. It can be expected that USTC will remain one of the leading universities in China long into the future. Moreover, USTC cannot be compared to the plateau-based Himalayas, any point of which is very high. It should be another Yellow Mountain of Anhui Province, which means we don’t need to be the best in all fields, yet we should have our own features in some areas and be the best in those areas. (as cited in Wang, 2008)

In our view, Zhu means that each university should have its own ethos and mode of development, with varied styles and expectations. What makes one university successful might not be suitable for others. Rational choice will always be a cornerstone for developing a strategy and a unique development pathway.

USTC's persistence in high-quality education under the principle of rational choice has allowed it to achieve much:

- Since 2014, USTC has won more than 10 national-level scientific awards, including two first prizes and five second prizes for natural science projects conducted independently or jointly with others. USTC ranks the first in first prizes among all the Chinese universities.
- Two breakthroughs (in quantum communications and high-temperature superconductors and nanomaterials) have been listed in the '12th five-year plan' for major scientific achievements and milestone progress (in the top 20). The breakthrough in quantum control has been listed in the '12th five-year plan' for major scientific achievements in fundamental frontier areas (as one of three in China).
- Since its establishment, USTC has produced 48 CAS academicians, 21 academicians of the Chinese Academy of Engineering and 28 fellows of other famous institutes worldwide. This is the highest such achievement of any Chinese university.
- According to the fourth discipline assessment by the China Academic Degrees and Graduate Education Development Centre under the Ministry of Education, released on 28 December 2017, USTC achieved seven 'A+' scores among the 28 disciplines assessed, ranking fifth in China despite its relatively smaller number of disciplines.

3.2 Selection and cultivation: pooling resources to explore scientific frontiers

USTC is at the forefront of innovation and has many newly developed disciplines, such as fire science and quantum science. Although few people understand the need to set up such disciplines, USTC continues to encourage the

exploration of scientific frontiers and maintains an inclusive attitude towards excellent and original research. The development of the quantum discipline at USTC from a very low starting point to a peak shows that the university has made a rational and wise choice when considering which disciplines to develop. The new discipline has been cultivated by breaking barriers of traditional norms and pooling the maximum resources. This has made it possible to produce a group of eminent quantum scientists, including Guo Guangcan, Pan Jianwei, Du Jiangfeng, Lu Zhaoyang, Chen Yuaoyao and others.

In 1978, China's 'reform and opening-up' policy and the National Science Conference inspired people's enthusiasm for science. Guo Guangcan, a lecturer in the Department of Physics (now a CAS academician), developed the molecular nitrogen laser, which was an instrument of important industrial value. However, he suffered setbacks in translating his experimental results into industrial applications due to a shortage of government funds for scientific research. He then shifted from experimental research to quantum optics, which interested few researchers in China. This was an important turning point in his academic career.

At that time, most researchers in China held a negative attitude towards quantum optics, believing that classical theories were good enough to solve optical problems and that quantum optics did not seem to have good prospects or possibilities for theoretical research. According to academician Hou Jianguo, a former USTC president, it was almost impossible for Guo, who was teaching Hou at that time, to develop quantum optics under the four classical arms of physics. However, Guo was determined to stick to his choice and to follow his interest.

He went to the University of Toronto to study quantum optics in 1981. After he returned to China, Guo immediately dedicated himself to the development of the field. In 1984, with funding of 2,000 yuan from USTC, he hosted

the first quantum optics conference at the Zuiweng Pavilion of Langya Mountain, which had been described by Ouyang Xiu, a literary master in the Song Dynasty. The conference has been continued in the 34 years since then. On the basis of the conference, he later founded the Committee on Quantum Optics. Largely because of his commitment to this academic activity, China's quantum optics research team has grown bigger and stronger, and the discipline has developed rapidly.

Guo was the first to offer a quantum optics course in China, and his lecture notes were published in 1991. His enlightening book was the only classic textbook in the early days of the discipline and laid a solid foundation for its future development.

Innovation and cross-field innovation and creation have become mainsprings of science and technology (S&T) and industrial development. In this context, the international competition for scientific talent and the flow of talent triggered by that competition are unavoidable. As an emerging scientific power, China is growing stronger and has the ability and chances to compete against leading countries in attracting scientific talent.

Because research in quantum science calls for the integration of cutting-edge theories in multiple disciplines, talented people from various backgrounds are needed to make breakthroughs. Pan Jianwei's research team is an example: the most important team members are mostly around 30 years old. The team has one person on the list of the 1,000 Talent Programme launched by the Department of Organization of the Central Committee of the Communist Party of China, and 11 on the lists of the 1,000 Young Talent Programme launched by the department, CAS's Hundred Talent Programme and the National Science Fund for Distinguished Young Scholars.

Pan firmly believed that quantum information would become a leading research field. He returned from Austria to China in 2001 and began to develop a talent training strategy. He sent selected students to study abroad in the

world's leading research groups on quantum information in order to form a research team with distinctive but complementary features when they returned. After finishing their studies and returning to China, those people became competent researchers, which led to the growth of Pan's team. For example, after completing undergraduate studies, Lu Zhaoyang was directly admitted to the National Laboratory for Physical Sciences at the Microscale, doing research on optical quantum information under his adviser, Pan. With the help of Pan, Lu won a full scholarship for study at the University of Cambridge in 2008, specializing in solid-state quantum optics in Cavendish Laboratory. Within three years, he finished his PhD programme at Cambridge. Meanwhile, he was also accepted as a young researcher at the Churchill Institute of Cambridge (fewer than 1% of those who applied were accepted). There are also many other top talents like Lu, including Chen Yuao, Chen Tengyun, Bao Xiaohui, Zhao Bo, Yin Juan and others.

Thanks to the scholars' individual commitment and the university's inclusive attitude towards scholars, what was once the least popular discipline has developed quickly, gained early success and grown into a productive research platform for frontier science in China.

4. Focusing on talent training with continuous innovation

USTC has achieved much by inspiring students and researchers, by following its special traditions and by integrating research with teaching.

4.1 Allowing young researchers to follow their interests so as to inspire potential

In its educational philosophy, USTC echoes China's most famous ancient educator, Confucius. The university offers student-oriented

education through small classes and special instruction according to students' aptitudes. For example, USTC respects personal interests, individuality, strengths and potential, and offers small-sized academic programmes (Ding, 2018).

Since 2002, all students have been allowed to choose their specialties based on their interests. They have two chances to switch to other departments, and their original departments do not interfere in their new choices. This is a first-ever move in Chinese universities. USTC set up a centre for career guidance in 2012 to provide tailored training programmes for students who wish to change their majors but have been refused by their target departments. It aims to meet all students' needs for independent specialty selection.

Table 1 shows that many undergraduates enrolled in 2016 prefer applied sciences, such as computer science, information science and management. However, the ratios of the current number of students to the original

number of students at the schools of Physical Sciences and Mathematical Sciences rank fourth and fifth, respectively, which demonstrates that undergraduates still have a strong interest in physics and mathematics.

In 2016, among the 33 graduates who won the university's highest award, the Guo Moruo Scholarship, five once changed their majors. This means that changing majors will not stop students from winning the highest honours; rather, independent selection of specialties helps to arouse students' interest in academic study and achieve better results.

USTC has remained committed to training top talent in S&T. While emphasizing a solid foundation in mathematics and physics, the university also values the cultivation of abilities relating to innovative practice. Teaching through experiments and practice is an important part of its educational reforms. To train the abilities of undergraduates in scientific research, USTC has launched a range of research and innovation programmes, through

Table 1: Independent selection of specialties by undergraduates enrolled in 2016

Schools	Original no. of students	No. of students coming	No. of students leaving	Net increase	Current no. of students	Current no. / original no.
School of Computer Science and Technology	104	54	4	50	154	148.08
School of Information Science and Technology	264	119	20	99	363	137.50
School of Management	78	28	12	16	94	120.51
School of Mathematical Sciences	126	19	3	16	142	112.70
School of Physical Sciences	277	56	30	26	303	109.39
School of the Gifted Young	340	0	0	0	340	100.00
School of Chemistry and Materials Science	172	7	28	-21	151	87.79
School of Life Sciences	92	5	29	-24	68	73.91
School of Earth and Space Sciences	106	8	47	-39	67	63.21
School of Nuclear Science and Technology	65	2	26	-24	41	63.08
School of Engineering Science	225	7	106	-99	126	56.00
Total	1,849	305	305	0	1,849	100.00

which students have achieved good results. For example, they have improved their abilities in research and developed an awareness of innovation and team spirit.

From Table 2, we see that USTC launched a total of 885 research and innovation programmes for students in 2017, covering a wide range of disciplines. Specifically, 86 programmes were conducted outside the university, such as in CAS institutes, while 347 were conducted in schools or departments of the university.

4.2 Inheriting traditions, but with inclusiveness and diversity

USTC boasts a tradition of respecting senior scholars, but without any practice of promotion by seniority or unfair competition among different academic schools. Since the university was founded, the older generation of scientists has followed USTC's 'harmony in diversity' ethos in teaching and research. For example, all of the three professors in the

Department of Mathematics (Hua Luogeng, Guan Zhaozhi and Wu Wenjun) offered the Introduction to Advanced Mathematics course. They took turns to give lectures in their own styles. This demonstrated a state of harmony in diversity and has been immensely appreciated throughout the university.

In the early stage of his research in quantum optics, Guo Guangcan was not truly recognized by his fellow researchers. Some believed that quantum optics was a pseudoscience, and gaining funding from the government seemed impossible.

Then, in 1999, he won the support of Lu Yongxiang, then the CAS president, and received funding of 50,000 yuan from CAS's Bureau of High Technology Development. The bureau also suggested founding a laboratory, for which it would provide long-term support. This was the first formal funding that Guo had received as the founder of USTC's quantum information discipline. Later, he set up a key laboratory for quantum information. One year later, the lab was assessed as a key

Table 2: USTC student research and innovation programmes in 2017

Schools	Programmes off campus	Programmes on campus	Robot contests	Innovation and entrepreneurship programmes	Total
School of the Gifted Young	15	57	10	31	113
School of Mathematical Sciences	6	25	0	13	44
School of Physical Sciences	20	71	13	40	144
School of Chemistry and Materials Science	6	38	0	31	75
School of Engineering Science	0	12	46	25	83
School of Information Science and Technology	5	58	49	70	182
School of Earth and Space Sciences	16	23	0	29	68
School of Life Sciences	1	21	0	20	42
School of Computer Science and Technology	0	6	7	28	41
School of Management	9	18	0	4	31
School of Nuclear Science and Technology	8	15	0	33	56
School of Humanities and Social Science	0	3	0	3	6
Total	86	347	125	327	885

lab of CAS and turned out to rank first among all candidates.

Guo had been applying for the National Basic Research Programme of China (the 973 Programme) since 1997, jointly with other universities and institutes. After four years of effort, the first 973 Programme of quantum communications and quantum information technology was approved in 2001. Just as for quantum optics, Guo hoped that the study of quantum information would progress through efforts across China. Therefore, he called on more than 50 scientists from more than 10 research organizations to join in the programme. Labs were set up, and the research field was broadened to include quantum cryptography, quantum computers, quantum communications and quantum networks. Later, eight of the researchers in the programme became academicians. In both quantum optics and quantum information, Guo, who was once believed to ignore his duties, provided the primary driving force at the initial stage.

4.3 The institute–department integration model: past and present

Under the institute–department integration model, USTC is run by the whole of CAS and research institutes are integrated with teaching departments. Guo Moruo, the first president of USTC, noted when he proposed the establishment of the university, ‘We should make good use of all the best resources of all CAS institutes in a bid to make the university a success in training talents’ (as cited in Zhang et al., 2015). As a special arrangement and as part of the initial design, the most representative scientific personnel of high-level CAS institutes would be involved in USTC’s training of top talent. In this way, the institute–department integration model, which combined research and education, became the initial tradition in talent training.

During the university’s early years, when it was based in Beijing, USTC departments and

CAS institutes were so closely integrated that all work relating to the departments, including the development of teaching resources, professional training, equipment construction, the opening of experiment and practice platforms, and the design of the teaching system and academic programmes, was hosted or assisted by corresponding institutes. After USTC was relocated to Hefei, Anhui Province, more than a hundred high-level CAS institutes were used as bases for research and practice for USTC students. USTC and CAS institutes launched the new model of joint colleges integrating research and education (Zhang et al., 2015). USTC was in charge of the postgraduate programmes in joint colleges, unifying postgraduate admission, training, administration and awards of degrees and deepening the integration of advisers, disciplines and research platforms.

By the end of August 2017, USTC had established all-round cooperation with the 12 arms and 25 institutes of CAS, setting up 22 joint labs. Meanwhile, the university jointly set up bases for students’ practice with more than 40 institutes, forming a ‘research–teaching alliance’ that integrated talent training, discipline construction and scientific research. For example, Han Jinheng, who was enrolled in the School of Information Science and Technology in 2015, applied for internship at the Institute of Optics and Electronics in Chengdu during his second winter vacation. Through practice, he gained a deeper understanding of urgent challenges in quantum communications and decided to continue his study and research in that field.

Figure 1 shows USTC undergraduates’ practice at CAS institutes from 2004 to 2016. A large number of students served as interns, and that figure will keep growing.

In view of China’s developing needs, USTC has launched multidisciplinary programmes for top scientific talent as a new strategy by further integrating institutes and departments. Since 2009, USTC has partnered with 18 CAS

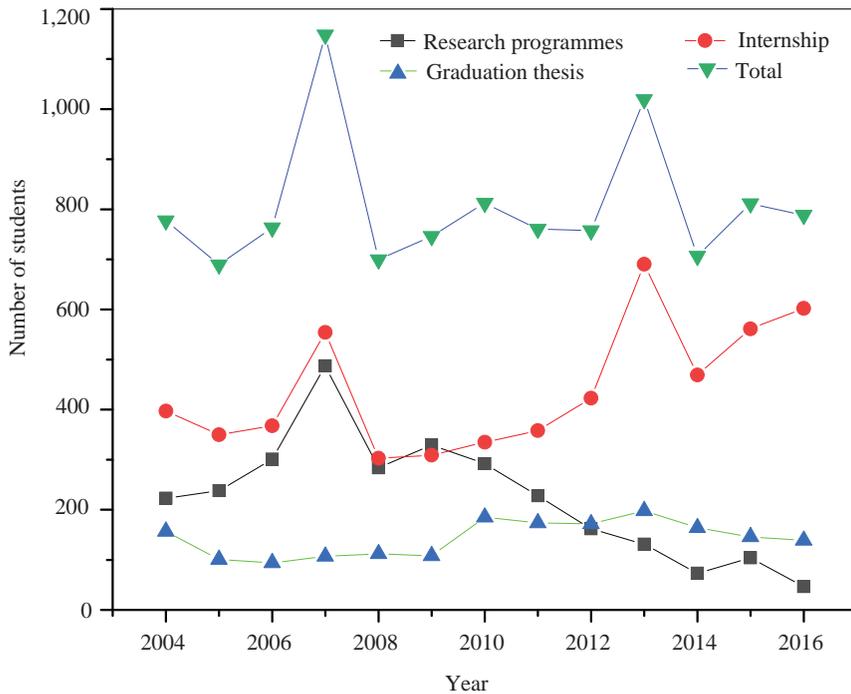


Figure 1: Practice of USTC undergraduates at CAS institutes, 2004 to 2016.

institutes (such as the Academy of Mathematics and Systems Science and the Institute of Physics) to offer 14 programmes for top scientific talent, including seven for fundamental sciences, such as the Hua Luogeng mathematics programme and the Yan Jici physics programme, and another seven for high-technology, such as the Zhao Zhongyao applied physics programme.

In October 2010, five programmes were accepted into the ‘trial programme for top students in fundamental disciplines’: the Hua Luogeng mathematics programme, the Yan Jici physics programme, the Lu Jiaxi chemistry programme, the Bei Shizhang life sciences programme and the computer science programme. By the end of August 2017, the five programmes had enrolled 1,408 students, of whom 820 had graduated and 588 were still studying. Of the graduates, 787 (96%) pursued further study, including 96% of the graduates from the Yan Jici physics programme.

For example, of all the 49 students in that programme in 2017, 37 (76%) went to the world’s leading universities for further study, including Stanford University, the California Institute of Technology, the Massachusetts Institute of Technology, Princeton University, Yale University and the University of Pennsylvania. Those figures reflect the achievements of USTC’s programmes for top talent.

In recent years, the rapid emergence of quantum information technology has become a strategic development trend supported by many countries (Losee, 1997). With further development in this field, some quantum technologies have entered into a critical stage of industrialization and system integration. Therefore, an all-round reform of mechanisms and institutional systems is needed in order to gain complementary advantages and make breakthroughs through cooperation. In this way, we can embark on a new pathway of leapfrog development, laying a foundation

for China to become a leader in the quantum S&T revolution in the future.

In this context, USTC has partnered with other universities and institutes to set up the Synergetic Innovation Centre for Quantum Information and Quantum Science. The partners include Nanjing University, CAS's Shanghai Institute of Technical Physics, CAS's Institute of Semiconductors and the National University of Defense Technology. Through cooperation with those universities and institutes, USTC can fully play its unique role in developing S&T and providing talent.

As a centre of innovation, USTC carries out fundamental research in S&T. Following the principle of 'having limited targets, making critical breakthroughs', the university conducts systematic fundamental research in frontier S&T with a focus on several physics systems that have the potential for expandable quantum information processing. It also aims to develop new interdisciplinary research fields relating to the discipline. The collaborating partners are responsible for providing technical support and working together with USTC in translating research results into technologies. For example, the Shanghai Institute of Technical Physics has developed and produced the main body of the first quantum communication satellite (nicknamed Micius).

By integrating institutes and departments, USTC has made full use of the strengths of CAS's knowledge and role as a platform, allowing students to combine theory with practice. In particular, this model allows top students to be able to work together with scientists as early as possible, so they can have opportunities to be involved in frontier scientific research and experience both the processes and the attraction of research. By allowing undergraduates to work on research projects in research institutes, USTC can not only enhance the research abilities of those students, but also pave the way for them to go directly to the institutes in the future.

5. Integration and innovation in a prestigious university and a famous city

At the end of 1969, the Zhenbao Island conflict between China and the Soviet Union made the relationship between the two countries highly tense, and it seemed that a war might start at any moment. To protect the scientists and disciplines relating to the Two Bombs and One Satellite programme, the Chinese Government decided to move USTC to the south. The then head of Anhui Province, General Li Desheng, who had great foresight, proposed that the university move to Hefei in that province. With great efficiency, the university was moved to the sites of what were then Hefei Normal University and the Anhui School of Banking Cadres, using their classrooms and dorms.

Due to poor transportation in Hefei and the city's small population and low level of economic growth, USTC was at a geographical disadvantage. However, the quietness and low mobility also brought chances for the development of a much-needed teaching and research atmosphere (Xiong, 2018). Admittedly, being far away from the centre of news, politics and the economy, USTC missed many opportunities to gain popularity, but its inherent potential to graduate students who would merit the attention of the whole world was strengthened.

When USTC first moved to Hefei, it seemed that the university would have nothing to do with the small rural city, as the university had been enjoying great prestige for its frontier scientific research and science education. In the eyes of people in Hefei and other less developed places in Anhui, USTC had little to do with everyday life in the province, except that a couple of top local students might be able to study there. It seemed that the university was more used to communicating with people in the United States, Japan and Europe, and in cities such as Beijing; it had never become a part of Anhui. From the 1970s to the 1990s, the biggest value of USTC

for Anhui people was its ‘brand’ as a frontier science and science education centre. It seemed merely to nestle in the city, wearing a mysterious veil and appearing sacred.

As time passed, the culture of USTC, including its principle of being generous, bold, committed and innovative, gradually integrated with the culture of Hefei. In 2004, with national research institutions including USTC and CAS’s Hefei Institute of Physical Science, Hefei filed a bold application to be China’s first pilot city of S&T innovation. The application was approved, pushing the city to advance and promote the idea of ‘starting from scratch’. Hefei, which used to follow suit with other provincial capitals, began to follow USTC’s approach of aiming for frontier industries and technologies for greater development. At the end of the first decade of the 21st century, Hefei defined its brand as ‘a city boasting the advantages of the Chao Lake and a height of innovation’. It aims to become a home to overseas talent by the end of the second decade, with booming high technology and manufacturing that merit the world’s attention.

In June 2017, the Chinese Government approved three comprehensive national science centres that aim at international scientific frontiers: Zhangjiang Comprehensive National Science Centre in Shanghai, Hefei Comprehensive National Science Centre in Anhui, and Huairou Comprehensive National Science Centre in Beijing. Four centres are planned, and the fact that Hefei is listed as the second one has surprised China and the world. The mission of the Hefei science centre is to conduct interdisciplinary research focusing on the fields of information, energy, health and the environment; to promote innovative technologies and emerging industries; and to develop into a basic platform of the national innovation system, a centre for scientific research, a source of economic growth, and a pioneer in innovation-driven development.

National laboratories and large scientific facilities make up the core of the Hefei science centre. Hefei has three such facilities,

involving synchrotron radiation, a fully superconducting tokamak and steady high magnetic fields. It is the second largest centre for such facilities (the largest is Beijing). As well as upgrading existing facilities, Hefei has constructed new ones, including a main fusion reactor, an all-round probe of the atmospheric environment, and a fourth-generation synchrotron radiation light source. This has allowed the centre to produce a collective research effect of ‘1 + 1 > 2’. Most of the facilities are owned by USTC and the Hefei Institute of Physical Science—two organizations of CAS.

In 2018, leveraging these facilities, Hefei planned to build new types of research platforms, such as a national laboratory for quantum information science, a megagene centre and an ionic medical centre. The mission of those platforms is to conduct research in important research areas, including national information security, nuclear fusion energy, the prevention and control of air pollution, and cancer treatment. The aim is to make pioneering breakthroughs in the international S&T competition.

At present, the quantum information industry is still in the preliminary stage of development (Dowling and Milburn, 2003; Huang, et al., 2013), while USTC has become one of the world’s leading institutions in this field. Thanks to the university’s pioneering work, it is very likely that China will surpass competitors in the field.

USTC has been committed to serving the country through S&T and making bold explorations. It has founded four high-technology enterprises of quantum information (Table 3), which help to translate research results into applications and promote industrial production.

Examples of USTC’s achievements are as follows:

- In 2005, the research team led by Guo Guangcan realized 125 kilometres of unidirectional quantum key distribution between Beijing and Tianjin by using commercial optical communication.

Table 3: Quantum companies with USTC as a shareholder

Companies	Business scope
QuantumCTek Co., Ltd.	Research and development of quantum communication technologies and facilities
CAS Quantum Network Co., Ltd.	Development of quantum communication technology and network S&T
Anhui Qasky Science and Technology Limited Liability Company	Quantum devices and equipment
Hefei Quantum Precision Instrument Co., Ltd.	Research and development and sales of quantum precision measurement instruments

- In 2009, the research team led by Pan Jianwei succeeded in constructing the world's first optical quantum telephone network in Hefei, and the research team led by Guo Guangcan constructed the quantum network for government affairs in Wuhu.
- In 2010, Pan Jianwei's team constructed the world's first all-pass quantum communication network in Hefei.
- In 2014, the experimental network for quantum communication in Ji'nan was put into operation (Yan, 2017).
- On 16 August 2016, China's Jiuquan Satellite Launch Centre launched Micius, the world's first quantum science experimental satellite.
- In 2016, the world's first quantum encrypted communication network—the 2,000-kilometre Beijing–Shanghai network, which passes through many other cities—was completed. It aims at encrypted transmission of important information (Gao, 2017).
- On 18 January 2017, Micius was delivered for scientific experiment. It achieved its three targets as planned, with satisfactory results in August. The research has been published online in the world's leading academic journal, *Nature*.

The national laboratory for quantum information science is the no. 1 project undertaken by USTC under the partnership between Anhui Province and CAS. As one of the major

frontier science projects strongly supported by the Chinese Government, it has been included in Anhui's 2017 Key Projects Investment Plan. Upon completion, it will focus on making breakthroughs in frontier science and core technologies relating to quantum information during the 'second quantum revolution', with the aim of addressing the needs of national information security and enhancing computing capability. It will also promote the development of new strategic industries relating to quantum communication and strive for a leading position in international competition and the future development of quantum S&T (Devoret and Schoelkopf, 2013; Chiang et al., 2012).

USTC's Institute of Advanced Technology serves as a research results application platform, and its hi-tech campus is a platform for frontier technology development and talent training. The national laboratory for quantum information science will collaborate with those two institutions to make the Hefei National Hi-tech Industry Development Zone an important centre for quantum information that integrates industry, teaching, research and application.

Among all the enterprises dealing with quantum science, one can always find USTC graduates, either as founders or as core technical personnel. There are four such enterprises in which USTC is a shareholder (Table 3). Based on these achievements, the university's quantum information system in Hefei has already taken shape. The goal is to become a

frontier research centre for quantum information, a platform for talent training that attracts the largest number of researchers, and a platform for the development of industries and intellectual property.

6. Conclusion

USTC was founded to promote the development of China's Two Bombs and One Satellite programme and has remained committed to its founding values and education ethos: focusing on the world's scientific frontier, serving the nation's major needs, being a model of morality and education, and pursuing breakthroughs and innovations. This year marks its 60th anniversary. It has made great contributions to the nation in its fundamental work on science and education and in its strategic work on national development, and has become a leading university with Chinese features and cultural traditions.

At the intersection of quantum mechanics and informatics, the quantum information discipline is one of the strongest disciplines at USTC. Due to its potential for application and great scientific significance, the discipline is receiving more and more attention from all over the world as an emerging discipline that has grown rapidly in the past 10 years or so. USTC has developed an academics–research–production–application chain in the field. In its design of guiding principles and its practice of innovative research in developing the new discipline, USTC serves as a good example with unique cultural values that provide guidance for other Chinese universities in developing world-class disciplines.

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Author biographies

Bin Zheng is a PhD candidate majoring in the philosophy of S&T at USTC. He gained a bachelor's degree in materials science and engineering from Zhejiang University in 2015.

Shukun Tang is Professor of the Department of Science Communication and Scientific Policy and Director of the Research and Development Centre for Science Communication,

USTC. He also serves as the vice chairman of the China Science Writers Association. His expertise includes science communication, science policy and cultural philosophy.

Qiong Fan is the Director of the International News Office and a PhD candidate majoring in science communication at USTC. Fan's research areas include scientific policy and industry ecosystems in the field of quantum information.

Aims and Scope

Cultures of Science is an international journal that provides a platform for interdisciplinary research on all aspects of the intersections between culture and science.

It welcomes research articles, commentaries or essays, and book reviews with innovative ideas and shedding a fresh light on significant issues. Research articles report cutting-edge research developments and innovative ideas in related fields; commentaries provide scientific perspectives on emerging topics or social issues; book reviews evaluate and analyze the context, style and merits of published works related to cultures of science.

The topics explored include but are not limited to: science communication, public understanding of cultures of science, values and beliefs of the scientific community, history of science, public science education, indicators of science literacy, science fiction, political science, philosophy of science, sociology, comparative study of cultures of science, public attitudes towards a new scientific and technological phenomena, the influence of scientific inventions on the society.

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