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Introduction: One hundred years of striving—Chinese scientists in the 20th century

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Scientists are regarded as elite because of their deep knowledge and great social contributions, but, on the other hand, they are also relatively distant from the public because of their long years of study and the profundity, and sometimes the confidentiality, of their research. Even in the academic community, the systematic study and summarizing of the life experiences of scientists and their academic growth from a historical and social perspective have only recently begun.

In 2010, the China Association for Science and Technology, together with 11 ministries and commissions, including the Organization Department of the Central Committee of the Communist Party of China, the Ministry of Education, the Ministry of Science and Technology, the Chinese Academy of Sciences (CAS) and the Chinese Academy of Engineering (CAE), launched the Project on Collecting the Historical Data of Chinese Scientists' Academic Life (PCDS). The project mainly covers CAS and CAE academicians who are over 80 years old and have rich academic experience, or old scientists who are not academicians but have made outstanding contributions to the progress of science and technology in China. PCDS focuses on the academic growth of old scientists, collecting and presenting the oral history data on their education, mentorship, academic achievements and key moments and events in their academic lives, as well as objects and images that reflect the development of their academic views and ideas.

One important feature of PCDS is that it is 'person-centred'. This feature is reflected in the fact that the information is collected mainly from individual scientists and a small number of scientist groups. This research is also focused on the growth of the scientists, using their personal experiences to demonstrate changes over time and the development of science and technology. Research on the life experiences of individual scientists presents typical cases in the construction of the Chinese scientific community and the development of science and technology in modern China based on the internal logic of personal growth. Seeking commonalities in a collection of personal data and answering specific questions framed in historical terms should become the focus of the research and the application of historical data on scientists.

This special issue includes five research papers on the history of science. It is based on the PCDS data and aims to explore the academic growth of scientists and their relationship with the external environment during the development of modern science and technology in 20th-century China. It is also an attempt to conduct academic research on the PCDS data. Four of the articles in this issue use the historical data collected in PCDS. Although Zhang Jiajing's article does

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not use the PCDS data, the case it cites – the National Defence Science Movement – helps to present a complete picture of the relationship between scientists and Chinese society in the 20th century.

'The economic lives of American-trained Chinese scientists after they returned to China in the 1950s: A case study of Huang Pao-tung and Feng Zhiliu' by Wang Xin is based on a diary provided by Huang and Feng's family members that recorded the couple's monthly income and expenditure from 1955, when they returned from the United States, to 1960. It analyses the couple's salary levels, the sources of their income, their expenditures and changes in expenditures, and compares their income and expenditures before and after their return to China, thus illustrating the economic lives and working conditions of scientists in the early days of the People's Republic of China. It also studies the attitude of the new government to the economic benefits of scientists who returned from the United States, and changes in that attitude, based on China's political, social and economic situation, wage systems, and policies towards intellectuals in the 1950s.

'The "neglected" chemistry: Fuels and materials preparation in China's "two bombs and one satellite" project' by Zhu Jing aims to find out what Chinese chemists did in that world-famous project. It explores the work of chemists in the preparation of materials for the project and their subsequent research, and analyses how the evolution of science and science policies affected their academic disciplines. The paper is a response to the call for the transnational circulation of scientific knowledge in research on the history of science. At the same time, by reviewing chemical research under this national project, the paper also examines how Chinese scientists understood and conducted basic and applied research and provides a complementary explanation of the uniqueness of basic and applied research in different national contexts.

'Science and national defence: Special editions on the National Defence Science Movement during the Anti-Japanese War' by Zhang Jiajing focuses on the National Defence Science Movement in China in the first half of the 20th century. The movement was officially launched by the National Government in 1941, when the war against Japanese aggression reached a stalemate. Many magazines and newspapers published special issues on the movement. The paper chooses six leading journals in that period and analyses the scientific issues covered, the changes in authors and content, and the influence of those special issues. It concludes that the authors of the special issues were from the political, military and scientific fields in the early period of the movement, but that authorship gradually shifted to scientific and technological circles, and the content of the articles changed accordingly. Given its important value in modern national defence and nation building, science inspired a number of young people to embark on the path of 'saving the nation with science'.

Slightly different from the above three papers, 'Born to do science? A case study of family factors in the academic lives of the Chinese scientific elite' by Wang Huibin adopts the analytical framework of the sociology of science. In the 100-plus years of modern science development in China, a number of Chinese scientific families have emerged. While sharing the characteristics of both traditional Chinese scientific families and Western scientific families, they are also unique in their own way. The Wang–He family covered in this paper is a microcosm of the localization of Western scientific culture and the modernization of Chinese family culture. Through this case study, the paper examines the family influences in the academic growth of three CAS academicians – He Zehui, Wang Shouwu and Wang Shoujue – and discusses the role of the family in shaping the cultural and social characteristics of scientific elites. The rise of scientific families, although somewhat coincidental, provides an entry point for observing how scientists are influenced by their families.

'Collecting and compiling the oral accounts of Chinese scientists trained in the Soviet Union in the 1950s and 1960s: Practice and reflection' by Wang Liyuan discusses how to conduct historical studies of the rich oral history materials of PCDS. Through data collection, candidate selection, framework construction and concrete presentation, the paper sorted through oral interviews of 16 Chinese scientists to present the life details and real feelings of scientists who studied in the Soviet Union in the early days of the People's Republic of China, thus revealing a full picture of the academic growth of scientists against a specific historical background. The paper stresses that the oral histories must be examined with specific questions and perspectives in mind. Scholarly annotations may be added to provide additional information on the historical background and significance of the scientists' experiences. Such a principle and method can provide useful references for future research on scientists' oral accounts.

In the 10 years since the launch of PCDS, hundreds of thousands of pieces of data have been collected. They are not only visible footprints in the academic journeys of individual scientists, but also the original records of how modern science and technology have taken root, sprouted and grown in China. Data involved in this special issue is only the tip of the iceberg of the PCDS database. In the history of science and technology in the People's Republic of China, many scientists went through a unique historical stage of readjusting their academic paths and restarting their research careers to serve the country's development needs. Through their joint efforts, China achieved major breakthroughs in science and technology. The similar growth patterns and generational features of the scientists also revealed their common life goals. It is therefore very important to explore their academic growth and their relationship with the external environment and dig deeper into the important historical events experienced by the scientists during a specific historical period. We look forward to more research results emerging from this important field.

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Article

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The economic lives of American-trained Chinese scientists after they returned to China in the 1950s: A case study of Huang Pao-tung and Feng Zhiliu

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Abstract

This article is a case study of Huang Pao-tung (1921–2005), who was a polymer chemist and academician of the Chinese Academy of Sciences, and his wife, Feng Zhiliu (1921–2015), who was a polymer physicist. The couple studied in America and returned to China in the 1950s. Based on an analysis of first-hand data from the two scientists' archives, diaries and memoirs, which recorded their economic lives after they returned, I found as follows: (1) their income after returning to China was about one-fifth of their income in the United States; (2) their income channel was narrow (there was no mechanism for wage increases, and their wages were unchanged for 25 years); (3) the main expenditure of their family was on food, and that proportion increased year by year; and (4) no taxes, low rents, free medical care and other benefits helped to reduce their cost of living in China. The importance of their profession as scientists and the government's advocacy of scholars returning home brought them relatively good treatment, and their economic benefits and living standard were several times better than those of other ordinary social classes. However, this kind of preferential treatment was dependent on many other things, which caused them to lose independence and autonomy.

Keywords

American-trained Chinese scientists, economic life, scientists' salary, Huang Pao-tung, Feng Zhiliu

As a new occupational group that emerged in 20th-century China, scientists had and continue to have an important influence on the country's historical development. In the 1950s, under the vigorous advocacy and effective organization of the Communist Party of China (CPC) and the newly founded Government of the People's Republic of China (PRC), a large wave of Chinese scientists and students studying abroad returned to the country. According to data from an official 1956 document (*A Report on Job Assignments of Students Returning from Capitalist Countries*), as many as 1536 senior intellectuals returned from Western countries in the period from August 1949 to November 1955. Among them, 1041 people came back from the United States (US) (Jin, 2008: 1077). After the beginning of the 'Anti-Rightist Movement'

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in 1957, the number plummeted and only a few people returned to China.

According to the latest research, there were about 5000 Chinese students in the US in 1949 (Wang, 2010). Less than half of them chose to return to China at that time, so two scientist groups formed: those who returned and those who stayed in the US. Research on the two groups, especially comparative studies, has received much attention from historians of science. However, because historical material is limited and this kind of research is difficult (the people involved are numerous and scattered; little historical data was retained because of political pressure at the time; transnational research is needed), few scholars have been involved in the field (see He et al., 2007; Hou et al., 2013; Li, 2000; Wang, 2010; Wang and Liu, 2012; Wang and Zhang, 2018). There remains a lack of clear, detailed descriptions and accurate data to assess the economic conditions of scientists who returned.

Huang Pao-tung, an expert in the field of polymer chemistry in China, and his wife Feng Zhiliu studied in the US. After returning to China in 1955, they worked in the Changchun Institute of Applied Chemistry (CIAC) of the Chinese Academy of Sciences (CAS) until they retired. Huang's diary manuscripts, which were collected by the Project on Collecting the Historical Data of Chinese Scientists' Academic Life organized by the China Association for Science and Technology, recorded their living conditions in the first few years after their return, including their monthly income and expenditure details from 1955 to 1960.[1] Based on those materials and statistics, in this article I analyse their wage level, sources of household income, specific expenditure structure and changes in it over the years, and the balance of their income and expenditure before and after their return, thus illustrating the economic lives of Chinese scientists in the early years of the PRC. By combining background information on China's political, social and economic situation, wage systems and policies relating to intellectuals in the 1950s, I also explore the attitudes of the newly established government to the returning scientists and changes in that attitude.

1. The economic conditions of Huang Pao-tung and Feng Zhiliu after their return to China

Huang Pao-tung (1921–2005), who was born in Shanghai, was a polymer chemist and an academician of CAS. He graduated from the Chemistry Department of the Central University in 1944, studied in the US from 1947 and received his PhD from the Brooklyn Institute of Technology in New York in October 1952. He then worked in the Plastics Research Laboratory at Princeton University.

Feng Zhiliu (1921–2015), who was born in Haiyan County, Zhejiang Province, was a polymer physicist. She graduated from the Textile College of Nantong University in 1944, studied in the US from 1946, received a master's degree in science from the Rowell Textile Institute in Massachusetts in 1948, and then worked as a visiting scholar at the National Bureau of Standards in Washington DC. In 1950, she began to work as an engineer at the Textile Research Institute in Princeton, Jersey.

Huang and Feng met in November 1952. In October 1953, they married in the US. In March 1955, both of them resigned and returned to China (Figure 1). They arrived on the Chinese mainland via Hong Kong in early May.

Before they officially joined CIAC at the end of October 1955, Huang and Feng visited Shanghai, Beijing and Changchun, visiting relatives and friends and waiting for assignments. At that stage, they had no formal income and lived on their savings. During that period, they also borrowed money from CAS and CIAC. After they joined CIAC, their family income and expenditure stabilized. In March 1956, the academic department of CAS assessed their professional titles and decided their salary levels. Huang was rated as an associate researcher with a monthly salary of 187.92 *yuan*, and Feng was rated as an associate researcher with a salary of 172.8 *yuan*. In 1956, after the national wage adjustment, their monthly wages were raised to 207 *yuan* and 177 *yuan*, respectively. Their total annual salary income was 4608 *yuan*.

According to Huang's written records, the couple's average annual expenditure during the period from 1956 to 1960 was 5280 *yuan*. If they had relied only on wage income, it would have been

Figure 1. Huang (first from left) and Feng (second from left) on board the SS President Wilson on their way home in 1955.
Source: Project on Collecting the Historical Data of Chinese Scientists' Academic Life, Huang Pao-tung ZP-002-078.

difficult to pay for household expenses. They used the money that they had accumulated in 1955 and 1956 when family expenses exceeded their wage income. In addition to their savings, they had several other sources of income: a reimbursement of more than 1200 *yuan* for international travel from the US to China; nearly 500 *yuan* from CAS for books that Huang bought in the US; a settling-in allowance of 1000 *yuan* from CAS in August 1956 (500 *yuan* for each); and about 350 *yuan* from Huang's mother and mother-in-law. From 1956 to 1960, Huang's family deposit averaged 7100 *yuan*, which would earn 400 *yuan* in interest each year – far more than the average annual income of about 50 *yuan* for writing articles.

The family's main expenditure was on food. In 1956, they spent about 102.5 *yuan* a month on food, or 26.5% of their total household expenditure. That proportion grew year on year, rising to 38.4% in 1960. According to the Engel coefficient, which measures the standard of living of families, their household affluence declined year by year, but they were still much better off than the average urban Chinese family (the coefficient of which was 58.4% in 1957) (National Bureau of Statistics, 1984: 463).

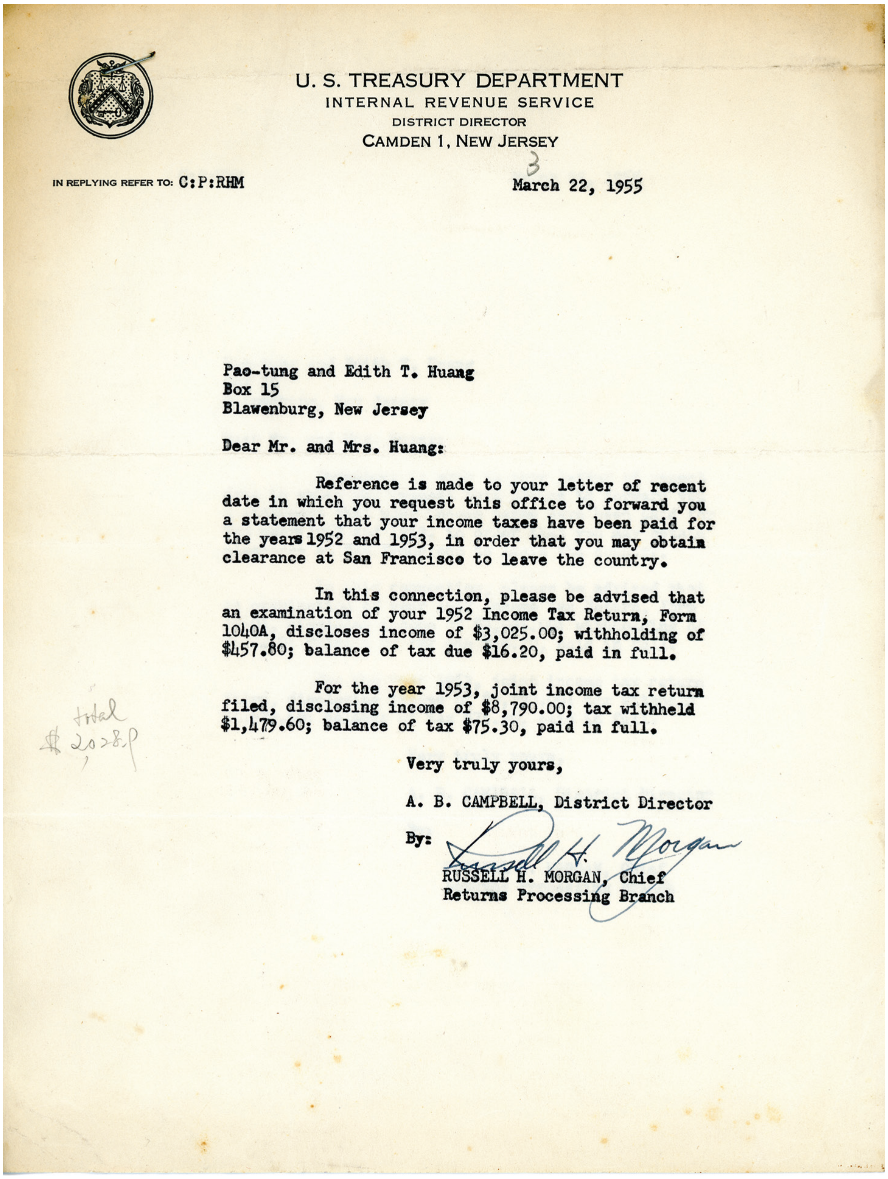
In addition to food expenses, about one-fifth of the household expenditure went to support their mothers, and about one-tenth was used to pay a nanny. Together, food, parental support and the nanny accounted for 60% to 70% of their total household expenditure.

Other regular expenses included transportation, rent, medical expenses, daily necessities and cultural and entertainment expenses. Culture and entertainment required only about 5% of their spending. On Sundays (they worked as usual on Saturdays), they would read books and newspapers, write letters, listen to records, go shopping, watch movies and dramas, eat Western food and visit parks. Since most of the films were free, the cost was not significant.

2. Comparison between Huang and Feng's income and expenditure before and after their return

In 1955, before Huang and Feng left the US, US authorities required them to provide proof of their tax payments during their stay. They demonstrated that their income was $3025 and they paid $474 in tax in 1952; in 1953, their income was $8790 and they paid $1554.90 in tax (Figure 2). According to the details of income and expenditure in January 1954 recorded by Huang, Huang's salary was $390.90 in that month and Feng's was $231.80, totalling $622.70. In the same month, they had a saving account of $159.62, a checking account of $458.72 and $111.40 in cash (Figure 3).

In 1968, Huang recalled that their annual income in the US before 1955 amounted to $9600, including $6000 from Huang and $3600 from Feng. Thus, their annual income before returning to China was $9000 to $10,000. According to a survey conducted by CAS at the end of 1955, senior US scientists were usually paid an annual salary of $10,000 to $20,000, and ordinary scientists $5000 to $10,000 (CAS Archives, 1955). The wage levels of Huang and Feng were basically consistent with that. Calculated using the USD to RMB exchange rate of 2.4618 in 1955, their annual



U. S. TREASURY DEPARTMENT
INTERNAL REVENUE SERVICE
DISTRICT DIRECTOR
CAMDEN 1, NEW JERSEY

IN REPLYING REFER TO: C:P:RHM

March 22, 1955

Pao-tung and Edith T. Huang
Box 15
Blawenburg, New Jersey

Dear Mr. and Mrs. Huang:

Reference is made to your letter of recent date in which you request this office to forward you a statement that your income taxes have been paid for the years 1952 and 1953, in order that you may obtain clearance at San Francisco to leave the country.

In this connection, please be advised that an examination of your 1952 Income Tax Return, Form 1040A, discloses income of $3,025.00; withholding of $457.80; balance of tax due $16.20, paid in full.

For the year 1953, joint income tax return filed, disclosing income of $8,790.00; tax withheld $1,479.60; balance of tax $75.30, paid in full.

Very truly yours,

A. B. CAMPBELL, District Director

By: Russell H. Morgan
RUSSELL H. MORGAN, Chief
Returns Processing Branch

Figure 2. Tax payment proof of Huang and Feng in 1955.
Source: Project on Collecting the Historical Data of Chinese Scientists' Academic Life, Huang Pao-tung SG-002-026.

income in the US was about five times their annual income after they returned to China.

Their income in the US was high, but so was their expenditure. Their total expenditure in January 1954 was $485.38 (Figure 3), including a monthly repayment of $100 to the United Board of Christian Colleges in China,[2] which accounted for 20% of that expenditure. Other large monthly expenses included $90 for rent, $84.29 for food and $81.98 for the use and maintenance of their car, which together accounted for 52.8%.

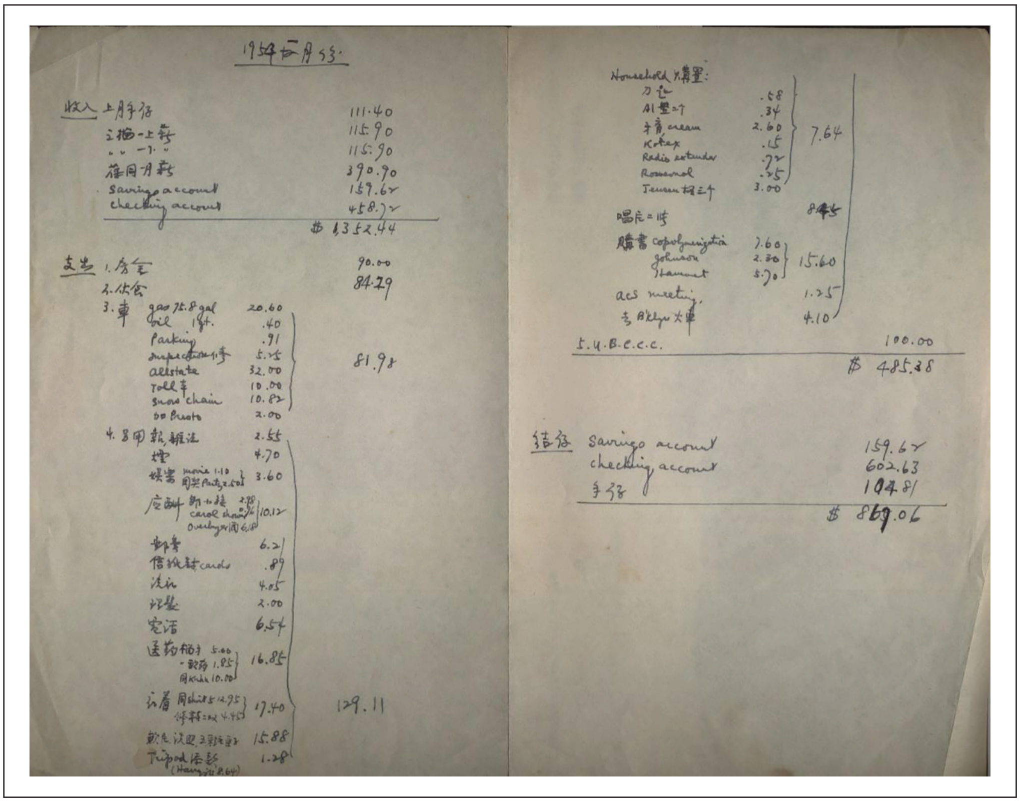


Figure 3. Income and expenditure in January 1954 recorded by Huang.
Source: Project on Collecting the Historical Data of Chinese Scientists' Academic Life, Huang Pao-tung SG-033-001.

A comparison between specific expenditures before and after their return to China revealed that their expenses for rent, food, transportation and medical care were higher in the US. Their rent was $90 per month in the US, or 18.5% of their total monthly expenditure. After returning to China, their rental expenses were relatively low, averaging 8.2 *yuan* per month, accounting for only 2% of their monthly expenditure. Their food expenses were more than $80 a month in the US (17.4% of their total expenditure); in China, those expenses were about 100 *yuan* per month (26.5% of their total expenditure). For transport, they used private cars in the US, costing them about $80 for use and maintenance (16.9% of total expenditure); in China, they could use official cars in emergencies, such as illness, and for business travel. Usually, they would travel in the city by public transport or tricycle, and their monthly expense was about 10 *yuan* (only 2.7% of their total expenditure). In China, they enjoyed free medical treatment. When it was necessary to purchase medicine, the expense was far less than in the US. Cultural and entertainment expenses accounted for a relatively small proportion of their monthly expenditure (about 10% in the US and only 5% in China). In addition, their personal income tax rate was 17.7% in the US in 1953. In the early days of the PRC, there was no income tax in China.

According to a survey conducted by CAS concerning the life of Chinese scientists in the US:

> The average rent accounted for 10% of their wage income. The condition of their housing was similar to that in China, but the equipment was better; transportation was more convenient; the price of cloth and wool fabrics was about the same as in the domestic [Chinese] market;

> their food was better than in China, mainly comprising meat and milk, supplemented by staple foods. A family of three people that enjoyed a medium level of life needed $300 per month. (CAS Archives, 1955)

The monthly expenses of Huang and Feng were obviously higher than that level. High income and high consumption were the prevailing conditions among Chinese scientists in the US. Therefore, many of them could not accumulate large amounts of money. When returning to China, Huang and Feng had only about $1000 with them.

3. Changes in the wages of scientists who returned from the US in the 1950s

To develop China's scientific culture after the founding of the PRC, specialists were highly valued by the CPC and the central government. In addition to recruiting the scientific researchers of the former National Government and cultivating its own scientific and technical personnel, the government also tried to encourage Chinese scientists who were overseas to come home in order to overcome the serious shortage of senior scientific and technological talent.

At first, patriotism and political propaganda were the main tools of the government and produced remarkable results in a short period. From August 1949 to December 1951, a total of 1144 students returned to China, including 821 returning from the US (Zuo, 2016). Among them were scientists with high social prestige, such as Hua Luogeng, Ge Tingsui and Zhao Zhongyao. However, most of them were students who had just graduated or had worked for a few years, such as Deng Jiaxian, Zhu Guangya and Ye Duzheng. After they returned to China, they were welcomed by the government and enjoyed preferential treatment. However, some preferential treatment was not universal but was targeted at scientists with higher prestige. There were also many problems in placing the students:

> Many specialized students were assigned to jobs that were incompatible with their majors. It would take a long time to achieve an academic title. Some were awarded no title even after two or three years from their return to the country; some were given a low title and a very low salary. (Shanghai Archives, 2016: 320)

In 1954, CAS conducted a survey on the living conditions of senior intellectuals. The survey specifically mentioned that several scientists had problems in adjusting their lifestyles. For example, Yang Chengzong, a researcher at the Institute of Physics, earned 650 points a month.[3] His wife had no job, and they had three children. They had difficulties even in buying clothes, books and magazines, despite a monthly subsidy of 30 *yuan*. Thus Yang had no choice but to sell apparatus that he had brought back for research. There were many other such cases.

At the end of 1955, the CPC Central Committee adjusted its policies relating to intellectuals, changing its focus from 'transforming' them to 'using and training' them. Solving the problem of the treatment of senior intellectuals became a top priority. In February 1956, Zhou Enlai delivered important instructions regarding the *Report on Encouraging Students to Return Home from Capitalist Countries*, which was delivered by the working group that was responsible for this matter. He stated that 'all departments in all regions should conduct a general inspection, solving the problem of improper job assignment and improving working conditions and treatment' (General Office of the Publicity Department of the CPC Central Committee and the Editorial and Research Department of the Central Archives, 1996: 1085). After that, students returning from abroad received greater attention. They were now paid more than other scientific researchers with the same qualifications and educational backgrounds. They were paid a settling-in allowance, and senior experts were usually offered personal apartments. Some enjoyed special benefits in the form of a fixed amount of supplies each month (Xie et al., 2008).

In 1956, wage reforms were carried out nationwide, and the wages of scientists were greatly improved. The salaries of scientific researchers of CAS were an example. Researchers and associate researchers were paid 149.5 to 345 *yuan* per month; senior researchers were paid 450 *yuan* per month

(Zhu, 2008: 354). Hua Luogeng, Zhao Zhongyao and Qian Xuesen, who returned from abroad, were senior researchers. At that time, the monthly salary of national leaders such as Liu Shaoqi, Zhou Enlai and Zhu De was 581 *yuan* (Zhang, 2009: 112), so the salaries of some senior scientists were relatively high.

Reputable scientists with higher prestige would often be offered some extra income. For example, in 1954, National People's Congress representatives enjoyed a monthly subsidy of 50 *yuan*; in 1955, members of CAS, of whom more than 90% had backgrounds in the natural sciences and had studied abroad, had a monthly allowance of 100 *yuan* (Li, 2000: 183). In 1957, Hua Luogeng, Qian Xuesen and Wu Wenjun, all of whom were scientists who returned in the 1950s, won the first prize in the Science Prize and were awarded 10,000 *yuan*. A number of scientists who returned from abroad won the second prize and the third prize and were awarded 5000 *yuan* and 2000 *yuan*, respectively. The prize money was equivalent to the salary of a general scientist over several years (Guo, 2008).

However, few scientists who returned in the 1950s had high prestige, and most of them were young. Their salary was, like that of Huang, about 200 *yuan* per month, and there were few other allowances. Their standard of living varied from person to person. In general, most families were relatively well off, but not wealthy.

Some families could not enjoy a high living standard even if they had a high income. For example, Tang Youqi and Zhang Lizhu were returnees who had studied abroad. Their combined salary was higher than that of Huang and Feng, but it was difficult for them to save money. Zhang recalls that, in 1953 and 1954, the family added two children, and their wages were all used to pay for two nannies and a cook (Committee of Cultural and Historical Data of the CPPCC, 1999: 325).

After the salary adjustment in 1956, scientists' wage income did not increase substantially for a long time. According to a survey conducted by CAS in 1963, most science and technology employees, especially senior research and technical personnel who returned from capitalist countries, had not been promoted since 1957 (CAS Archives, 1963). Huang was rated as a fourth-level associate researcher in 1956, with a salary of 207 *yuan*. It was not until 1982 that he was promoted to a fourth-level researcher, and his salary increased to 212 *yuan*. That means that Huang's salary remained the same for about a quarter of a century. Moreover, the special treatment enjoyed by scientists was weakened or cancelled during the development of various political movements. As I have mentioned above, members of CAS enjoyed a monthly subsidy, but that treatment was attacked by many large newspapers after the beginning of the Rectification Movement in 1957, and many members gave up the allowance (CAS Archives, 1959a).

4. Discussion and conclusion

After the establishment of the new PRC Government in 1949, due to the low level of the national economy, the country implemented the policy of low wages and the egalitarian principle of 'five people share three people's meals' (三人饭五人吃). At that time, due to shortages of food and other materials, the economic lives of scientists were frugal.

In the case of Huang and Feng, we can draw the following conclusions:

(1) After they returned to China in 1955, their economic income was much lower (about one-fifth) than it had been in the US.
(2) Due to the lack of a salary promotion mechanism, they had no salary increase for 25 years after 1956.
(3) The main expenditure of their family was on food, and that proportion increased year by year.
(4) They found that it was difficult to cover their household expenditure by using their wage income alone.
(5) Interest from their savings and relatives' support were their main sources of non-wage income.
(6) No income tax, low rent, free medical services and other benefits reduced their cost of living.

(7) Shortages of supplies and the coupon-based supply system restricted their consumption, allowing them to accumulate some savings.
(8) Their economic condition and standard of living were better than those of ordinary workers.

Although the economic position of American-trained Chinese scientists who returned to China was quite different from their position in the US, the importance of their profession and the government's advocacy for their return brought them relatively good treatment. Thus, they were better off than many other social groups. However, their superior economic treatment was just a result of policies adopted by the government, and it could change as the situation developed. Such change began in the late 1950s and became more apparent in the 1960s.

Their preferential treatment was not protected by a contractual system and related laws, causing a loss of their independence and autonomy after their return to China. They now had to follow national arrangements and change their lifestyle to one of self-discipline. For example, when Huang Pao-tung returned to China, he could make his own choice about where to work. However, he followed the arrangements made by the Personnel Bureau of the State Council and went to CIAC.[4]

After returning to China, as a political task, Huang wrote letters to his Chinese acquaintances abroad to encourage them to return home. Also, to meet China's needs, he changed his research directions several times, so that he produced no decent results for many years. He once claimed, 'I, like the other students who returned to China in the same period, have not made any academic achievements for more than 10 years. In contrast, my classmates and colleagues in the US have already published many papers'.[5]

On 5 November 1955, CIAC held a welcome meeting for Huang and Feng. On the same day, Huang wrote in his diary: 'Our colleagues regard us as senior researchers and have expressed high expectations for us to provide guidance in their work. We feel guilty and have to work hard and make more contributions in the future'. However, in subsequent diary entries, the words 'busy', 'tired' and 'extremely tired' began to appear frequently, and he would also complain that 'I'm terribly busy; there are so many things to do and so many meetings to attend.' This change in feelings may reflect the lives of many American-trained Chinese scientists after their return in the 1950s.

After 1957, it became more and more difficult to encourage scientists who had studied abroad to return home. Instead, some scientists began trying to leave. For example, Tang Shoubo, of the Institute of Electronics of CAS, was dissatisfied with his status, income and political life after he returned to China from Malaysia in 1957. He wrote to the British Embassy several times and asked for a visa to go to Malaysia via Hong Kong. He was allowed to return to Malaysia with his wife in May 1959. When he arrived in Singapore, he made a speech saying that he could not bear the lifestyle in China. In another example, Min Naida, known as the pioneer of computer science in new China, once attended various institutions, such as the Institute of Mathematics, the Institute of Computing and the Institute of Electronics of CAS. His wife, a West German, did not want her children to go to Chinese schools and was not properly cared for on a daily basis. In 1957, with the approval of the State Council, Min was allowed to go to East Berlin to enrol his children and engage in the work of writing books at the German Democratic Republic Academy of Sciences. Min took German citizenship after arriving in East Germany. There were also unsuccessful attempts; Shi Lvji, of the Institute of Biophysics of CAS, wrote to Premier Zhou Enlai twice asking to go abroad, but he failed in the end (CAS Archives, 1959b).

Declaration of conflicting interests

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Notes

1. See 'Diary from 1 July 1955 to 31 July 1958 and income and expenditure from June 1955 to December 1960' in the database of the Project on Collecting the Historical Data of Chinese Scientists' Academic Life: Huang Pao-tung SG-002-026. Materials and data about Huang Pao-tung used in this paper are all from this source unless otherwise indicated.
2. On 25 May 1951, Huang was arrested by the US Citizenship and Immigration Service and sent to Ellis Island for his part in the work of the Association of Chinese Scientific Workers in the US. After several twists and turns, the United Board of Christian Colleges in China agreed to pay his bail of $1400, but Huang had to repay $100 a month after he got a job. On 2 February 1955, the board returned the $1400 bail to Huang (see Wang and Zhang, 2018).
3. 'Wage point' was a temporary wage system introduced in the early years of the PRC to cope with different local prices, and it was abolished in 1955. In 1955, each wage point was about 0.22 *yuan* (see Shanghai Archives, 1955).
4. In his 1968 account, Huang wrote that one of the reasons for entering CIAC was his willingness to obey the government's assignment and unwillingness to offend the leadership (although Feng Zhiliu wanted him to go to the East China Textile Institute in Shanghai or the Beijing Textile Research Institute). From the Project on Collecting the Historical Data of Chinese Scientists' Academic Life: Huang Pao-tung SG-021-114-250.
5. From the Project on Collecting the Historical Data of Chinese Scientists' Academic Life: Huang Pao-tung SG-003-034-045.

References

CAS Archives (1955) *Investigation on the Living Conditions of Senior Researchers of the Chinese Academy of Sciences in Beijing*. File no. 55-10-16 (in Chinese).

CAS Archives (1959a) *Related Documents on Cancelling Subsidies for Members of the Chinese Academy of Sciences*. File no. 59-2-19 (in Chinese).

CAS Archives (1959b) *Report of the Chinese Academy of Sciences to the Central Committee on the Issue of Some High-Level Intellectuals*. File no. 59-1-4 (in Chinese).

CAS Archives (1963) *The Current Salary of Employees in Our Academy and Opinions on This Year's Adjustment of Employee Wages (first draft)*. File no. 63-7-22 (in Chinese).

Committee of Cultural and Historical Data of the CPPCC (Chinese People's Political Consultative Conference) (1999) *A Chronicle of Journeys Home of Students Studying Abroad during the Early Years of the People's Republic of China*. Beijing: China Culture and History Press (in Chinese).

General Office of the Publicity Department of the CPC Central Committee and the Editorial and Research Department of the Central Archives (1996) *Collection of Publicity Documents of the Communist Party of China: 1949–1956*. Beijing: Learning Press (in Chinese).

Guo JH (2008) The establishment of the Science Award System of the Chinese Academy of Sciences and the evaluation of the first Science Prize. *Science & Culture Review* 5(4): 17–40 (in Chinese).

He XL, Li SS and He SQ (2007) *Hai Guo Xue Zhi: American-Trained Chinese Scientists*. Shanghai: Shanghai People's Publishing House (in Chinese).

Hou XL, Luo PL and Shi CX (2013) *Interview with the Scientists Who Returned in the 1950s*. Changsha: Hunan Education Publishing House (in Chinese).

Jin CJ (2008) *Biography of Zhou Enlai (1898–1976)*. Beijing: Central Literature Publishing House (in Chinese).

Li T (2000) *The History of Chinese Students' Overseas Study: After 1949*. Beijing: Higher Education Press (in Chinese).

National Bureau of Statistics (1984) *China Statistical Yearbook 1984*. Beijing: China Statistics Publishing House (in Chinese).

Shanghai Archives (1955) *Letter on the Implementation of Monetary Wages for the Staff of the Chinese Academy of Sciences*. File no. b127-1-944-71 (in Chinese).

Shanghai Archives (2016) *Research on Shanghai Archives and Historical Data*, vol. 21. Shanghai: Sanlian Publishing House (in Chinese).

Wang DL and Liu ZG (2012) The destiny of scientists who returned from the United States in the 1950s. *Science & Culture Review* 9(1): 68–87 (in Chinese).

Wang JH and Zhang L (2018) The historical process of Huang Pao-tung's return to China: Factor analysis of the motivation for Chinese students' return from the United States to China in the 1950s. *Chemistry* 81(6): 571–575 (in Chinese).

Wang ZY (2010) Transnational science during the Cold War: The case of Chinese/American scientists. *Isis* 101(2): 367–377.

Xie LP, Zhang L, Huang J, et al. (2008) A study on Shanghai students who returned from abroad in the

1950s and 1960s. *Shanghai Party History and Party Construction* 2: 19–24 (in Chinese).

Zhu KZ (2008) *The Works of Zhu Kezhen*, vol. 14. Shanghai: Shanghai Science and Technology Education Press (in Chinese).

Zhang L (2009) The economic life and social reputation of scientists (1949–1966): Taking the Chinese Academy of Sciences as an example. In: Center for Contemporary Chinese History, East China Normal University (ed) *Research on Contemporary Chinese History*. Beijing: Jiuzhou Press (in Chinese).

Zuo L (2016) The wave of students returning home from abroad in the early years of the People's Republic of China. *Qinghai Social Sciences* 4: 190–197 (in Chinese).

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The 'neglected' chemistry: Fuels and materials preparation in China's 'two bombs and one satellite' project

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Abstract

The 'two bombs and one satellite' project was a major achievement of China after 1949 and has since been an important subject in historical and sociological research on science and technology in modern China. However, most accounts of the history or sociology of the project focus on physicists and engineers, rather than the chemists. This study examines the chemists' work of preparing fuels and materials in the project and their post-project research. By analysing how Chinese scientists engaged in the project, how they understood the relationship between basic and applied research in their scientific practice and how they positioned themselves on issues of science policy, this article offers different and shifting concepts of basic and applied research with cultural variation in the context of China.

Keywords

Bomb project, history of chemistry, global history of science, basic and applied research

1. Introduction: The global history of science and a new perspective on basic and applied research

The 'two bombs and one satellite' project was a major achievement of China after 1949 and has since then been an important subject in historical and sociological research on science and technology in modern China. There has been much historical and sociological literature on this big-science project, covering topics ranging from the organizational structure of the project, such as operating mechanisms, science planning and management (Liu et al., 2004) to the work of the Chinese Academy of Sciences (CAS) in the project (Liu, 2019), which captured a lot of historical details, including major decisions on China's nuclear bomb development; the preparation of nuclear fuel; the design, manufacturing and testing of China's atomic and hydrogen bombs; and the production factories and test bases (Lewis and Xue, 1991). There were also studies that examined the teacher–student relationships of researchers in the project from the perspective of organizational sociology (Zhang and Fu, 2017), and the inspiration for scientific research and engineering innovation derived from the project, such as the

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non-contractual spirit of the scientists (Wu and Shen, 2018).

However, the role of chemists in the project and the chemical dimension of the project have been overlooked. The 23 scientists awarded the Two Bombs and One Satellite Merit Award were mostly physicists who focused on fields such as nuclear physics; applied mechanics; theoretical physics; materials science and structures; control systems and radio; engine technology; and optics. In contrast, chemists participating in the project were little known and did not receive the same recognition as the physicists. This phenomenon also occurred in other major science projects immediately before and during the Cold War era, such as the Manhattan Project, in which attention was focused on physics and engineering. The Cold War has been described as a physicists' war (Manning and Savelli, 2018: 8), and research on the subsequent impact and legitimacy of atomic energy science has rarely gone beyond the sphere of physics (Creager and Santesmases, 2006).

The scientific and cultural supremacy of physics has continuously asserted itself in different countries. I do not doubt the soundness of the selection of the 23 recipients of the Two Bombs and One Satellite Merit Award or negate the greater priority of the work of physicists, but I aim here to explore the work of chemists in the project.

Why should research on the project pay attention to the work of the chemists who were involved? In recent years, new historiographical perspectives have been used in the study of the history of science.

The first change is the promotion of a new global approach to the history of science, which advocates the exploration of the flow and contextuality of knowledge around the world. The study of science during the Cold War also made new progress and included obvious changes in historiography of science by shifting the main focus from governments' big-science projects to the circulation of knowledge on the global scale, the transnational development of knowledge and how those factors shaped local decisions (Van Dongen et al., 2015).

In advocating this approach, historians of science explored ways to best place the history of science in the global context (Fan, 2012). This emphasis on the circulation of knowledge from the perspective of the global history of science has been reflected by various new concepts, including the notion of trade in physics, and the contact zones that link knowledge in a situation of asymmetrical power (Galison, 2010).

The second change in the approach to the history of science during the Cold War (including the atomic bomb programmes) is the discussion of the distinction and relationship between pure science, basic science and applied science, which has been neglected in policy studies but has been expounded in more recent literature, driven by the concept of historical legacy in the history of science. While the dichotomy between basic science and applied science or between basic research and applied research is no longer advocated in some fields of research, including STS (science and technology studies) and STI (science, technology and innovation), in which alternative notions such as transdisciplinarity and responsible research have been proposed in place of notions such as pure science and basic science, those concepts are still widely used in science policies and practices in different countries and even in public discourse (Schauz and Kaldewey, 2018). In contrast to STS researchers, historians and philosophers of science attempt to understand the meanings of those concepts and the relationship between contemplative and instrumental forms of knowledge as a pressing problem. What counts as purity in logic, in physics, in chemistry and in biology? How do pure science and applied science differentiate from each other? Does pure science equate to basic science? (Galison, 2008; Dear, 2012).

The distinction between these terms not only indicates the epistemological differences among the fields of science studies but is also closely related with the professional identity work of scientists, scientific institutions and the organizations conducting national research activities in different countries. Moreover, historians of science and STS researchers have also helped to highlight the importance of focusing not only on science policy but also on the characteristics of the evolution of science itself (Creager, 2013). Therefore, research on the history of science in different countries can shed valuable light on important concepts such as pure science, basic science and applied science and improve the discussion of the complex relationship between science and society.

While the global turn in the historiography of science offers a new conceptual framework for the history of science in national and regional contexts, it should be noted that the national or regional history of science remains confined to specific national or regional contexts and that, even though the global perspective on the history of science reveals the generation and circulation of knowledge, it cannot adequately reveal the underlying objects, organisms, texts, people and other targets (McCook, 2013).

Existing literature on the distinction between basic and applied research or pure and applied science has been mostly focused on countries such as the United States and the United Kingdom, and not much on China. In his paper on Chinese debates about basic research between 1949 and 1966, Wang (2018) interpreted China's science policy, analysed China's decision to launch the 'two bombs and one satellite' project and discussed basic research and exploratory research. He suggested that the impact of the successful Chinese atomic bomb test in 1964 on Chinese scientists and science policy deserves further examination.

In this study, I examine the chemists' work in preparing fuels and materials in China's 'two bombs and one satellite' project and their subsequent research after the success of the project in the light of the global history of science and the global circulation of scientific knowledge. In contrast to perspectives such as task-driven big-science organization and the relationship between science and politics, this study focuses on the scientific practice and concepts of the chemists. By analysing how the Chinese scientists engaged in the project understood the relationship between basic and applied research in their scientific practice and how they positioned themselves on issues of science policy, this article aims to offer different and shifting concepts of basic and applied research with cultural variation in the context of China.

2. Radiochemical research and the centralized training of new talent

The manufacture of atomic bombs, hydrogen bombs and missiles requires not only the expertise of physicists in fields such as nuclear reaction and nuclear decay, but also the expertise of chemists in the process of nuclear transformation, such as radioactivity and radioactive elements. The chemists' specific activities included the preparation, separation, purification and identification of radioactive elements, and the analysis of the properties and behaviours of nuclear transformation products.

The earliest participation by Chinese scientists in China's atomic energy research was in radiochemical research and the training of researchers.

In the spring of 1953, Qian Sanqiang, a nuclear physicist and then director of the Institute of Modern Physics of CAS, led a study mission on nuclear science research to the Soviet Union and exchanged views on expanding scientific cooperation between the two countries (Editorial Committee of Nuclear Industry of Contemporary China, 1987). In 1955, after the Soviet Union offered help to socialist countries in developing nuclear technology, China made a strategic decision to develop and establish the country's nuclear industry as soon as possible.

At that time, China did not have researchers engaged in radiochemical research directly, and a number of chemists specializing in structural chemistry and quantum chemistry joined the research on atomic energy. In 1950, the Institute of Modern Physics of CAS was established to focus on nuclear science research, and its main areas of research included experimental nuclear physics, cosmic rays and radiochemistry. Yang Chengzong and Guo Tingzhang, who were responsible for radiochemical and nuclear reactor materials, prepared gram-level uranium oxides with fairly high purity and studied the preparation of heavy water and graphite during China's first Five-Year Plan period (1953–1957), which paved the way for reactor construction. Guo was a radiochemist and theoretical chemist specializing in quantum chemistry and a pioneer in applying quantum mechanics and statistical mechanics to chemical research. He developed the absolute velocity theory and the effective structure theory of liquids, laying the foundation for the transitional state theory of chemical reactions. He had studied theoretical chemistry at Ohio State University and Utah State University before returning to China and joining the Institute of Physics of CAS in 1950.

Besides sending people to the Soviet Union to study reactor and accelerator technology, theoretical physics and experimental physics in 1955, the Ministry of Education set up a special nuclear education base with a radiochemical lab and a radiochemistry programme to train atomic energy researchers. In April 1955, after Qian Sanqiang returned home from a visit to the Soviet Union, the Ministry of Education appointed a team comprising nuclear physicists Hu Jimin, Yu Fuchun and Zhu Guangya from Zhejiang University, Peking University and Northeastern People's University (now Jilin University) to prepare for building an Institute of Physics at Peking University. The institute was the first organization dedicated to training nuclear technology talent in China. It was engaged in research and teaching in nuclear physics, making it the first nuclear education base in China as well.

In August 1955, according to the guidelines of the Central Committee of the Communist Party of China (CPC) and at the suggestion of Qian, the Institute of Physics was established at Peking University. It comprised professors from multiple universities and added a radiochemistry programme to the existing nuclear physics programme. Two years later, the Ministry of Education decided to cancel the institute, merge its nuclear physics programme into the Department of Physics and its radiochemistry programme into the Department of Chemistry, and establish the Teaching and Research Office of Radiochemistry (externally referred to as the 'Teaching and Research Office of the Structure of Matter') (Department of Technical Physics at Peking University, 1995). Guo Tingzhang concurrently served as deputy director of the Fifth Research Office of the Institute of Physics and director of Teaching and Research Office of Radiochemistry at Peking University (Qian et al., 1957).

In 1958, the two programmes began officially recruiting undergraduates in nuclear physics and radiochemistry. At the same time, chemists engaged in teaching and research on the structure of matter nationwide were transferred for teaching and research in radiochemistry; among them were Wu Zhengkai, Tang Aoqing and Lu Jiaxi. Wu was then directly transferred to the Ministry of Nuclear Industry to serve as chief engineer for the diffusive separation of uranium-235 and uranium-238. The Department of Atomic Energy at Peking University graduated its first class of radiochemistry students in 1957. In the autumn of 1958, it enrolled 93 students into its 5-year radiochemistry programme and 70 into its 4-year programme, in addition to selecting 70 top-performing junior students from different universities to study in the programme. In this way, China established its first higher education programme in radiochemistry at Peking University in 5 years from 1955 to 1960.

In 1958, after the passing away of Guo, Qian recommended Xu Guangxian for the position of director of the Teaching and Research Office of Radiochemistry after referring to the personnel archives of Peking University. Xu received his PhD in physical chemistry from Columbia University in 1951 and was engaged in quantum chemistry. Later, for the better management of confidential programmes, the CPC committee of Peking University demerged nuclear physics from the Department of Physics and radiochemistry from the Department of Chemistry to form the Department of Atomic Energy. In January 1959, Xu was appointed as deputy director of the department while concurrently serving as director of the Teaching and Research Office of Fuel Chemistry. In 1960, for reasons of secrecy, the Department of Atomic Energy was renamed as the Department of Technical Physics.

What did China do in the field of radiochemistry when it began its atomic energy research programme? Taking the Department of Atomic Energy/Technical Physics at Peking University as an example, Liu Yuanfang and others, under the guidance of associate professor Neferdorf (an expert from the Soviet Union), carried out research on hot atom chemistry and isotope exchange and actively prepared for teaching and experimental work in radiochemistry. Sun Yiliang and Zheng Shuhui conducted research on radioanalytical chemistry. Xiao Lun, a US-trained radiochemist, worked at the Atomic Energy Research Institute and spent a year teaching radiochemistry at Peking University.

Xu Guangxian's first task in the Department of Atomic Energy was to teach students an introductory course in nuclear physics. When he returned to China in 1951, he brought with him some books on radiochemistry and nuclear physics. Using those books as references, Xu prepared his lectures for the introductory course, covering radioactive decay and its laws, the composition and structure of the nucleus, reactors and accelerators, among other things (Xu, 1959). Gao Hongcheng, a professor in the Department of Technical Physics, recalled that Xu's teaching also included the laws of radioactive decay and new terms and concepts such as actinium, uranium, decay and fission, which took students into the world of radiochemistry.

In radiochemistry, although China received help from the Soviet Union, it was of not much use in China's nuclear research because it had little to do with applied research tasks such as the development of nuclear fuel, atomic bombs and nuclear reactors. The Soviet radiochemistry expert Neferdorf, in his communication with Chinese chemists, 'actually did not provide full information. What he focused on was hot-atom chemistry, an area of basic research of radiochemistry which has nothing to do with the atomic bomb' (Ye et al., 2013: 91). When Chinese scientists attended international academic conferences organized by the Joint Institute for Nuclear Research and visited the nuclear research base in Moscow, the Soviet side also closely guarded information related to atomic bomb development. Therefore, the Soviet Union did not offer much practical help. Chinese chemists realized that the effort to study radiochemistry and train urgently needed talent should focus on areas directly related to nuclear fuels such as uranium, thorium and plutonium (that is, nuclear fuel chemistry). As the extraction and preparation of nuclear fuels was the key to atomic energy, chemists devoted most of their attention to that work. At the same time, students of nuclear physics at Peking University studied not only the introductory course on nuclear physics but also principal chemistry courses, such as physical chemistry, complex chemistry and nuclear fuel extraction.

Overall, the radiochemical research work in China's 'two bombs and one satellite' project was carried out by chemists with physical chemistry and quantum chemistry backgrounds. They not only took it upon themselves to conduct research into nuclear fuel chemistry but also trained a number of researchers in the field. In other words, a lot of chemists had to change their research fields by entering a field they were less familiar with. When they had to make a choice between a national task and their personal interest in science, and between the autonomy of science research and service to the country, how did these chemists respond?

3. Theory attached to practice: The extraction and separation of nuclear fuel

Nuclear fuel extraction mainly involves three production lines: uranium, plutonium and thermonuclear fuels. The development of atomic energy, semiconductor and rocket technologies requires a large amount of nuclear fuel. The preparation of uranium, plutonium and thermonuclear fuels is the most basic and extremely important part in the development of atomic bombs, hydrogen bombs and missiles, and is also a huge project. The uranium and plutonium fuels for atomic bombs and the lithium-6 deuteride-based thermonuclear fuel for hydrogen bombs all require complicated processes involving ore smelting and the extraction and separation of radioisotopes. The content of uranium in natural ores that can be used to make atomic bombs is very low. Because of the very low levels of plutonium in uranium ores, plutonium also requires separation and purification by chemists before being used as nuclear fuel.

There are two routes for making atomic bombs, the first being fuelled by uranium. China's first atomic bomb was made of uranium-235. The first step to make a uranium bomb is to find uranium ores and extract uranium from them in a process called 'pretreatment'. Pure uranium thus extracted is 0.72% uranium-235 and 99.28% uranium-238. As uranium-235 used to make atomic bombs needs to have a concentration of 99%, it has to be separated from uranium-238. After the separation of the radioisotopes, it needs to be restored to metal, which is then used to make atomic bombs. China was not rich in uranium which occurred mostly in small and medium-sized mines with other elements such as phosphorus, sulphur, and non-ferrous and rare metals. Therefore, uranium had to be extracted from the natural ores and then purified to uranium-235. The chemists' work in this effort was to analyse the presence of uranium in ores, then extract uranium from the ores by pretreatment, and then separate uranium-235 from uranium-238 to serve as a raw material for atomic bombs. In addition, they needed to separate uranium, plutonium (or thorium) and other valuable elements in a process called 'post-treatment', which enables researchers to not only recover and reuse the remaining and newly generated fissile materials and thus improve the utilization of uranium resources but also to use newly generated fissile fuels: plutonium-239 and plutonium-241.

While the Soviet Union provided assistance in many important processes and shared valuable experience in nuclear weapon development, it withheld some key techniques. After the Soviet Union stopped its assistance in 1958, China had to entirely rely on itself for the extraction and preparation of nuclear fuels. In the production of uranium-235, for example, China could not make key equipment required for the fluorination of uranium and isotope separation, and lacked important techniques. The Soviet Union kept its diffusive separation technology for uranium and in many cases provided only process parameters, without explanation. For the production of plutonium-239, the Soviet Union stopped the supply of key components after the water treatment and fluorination of uranium ores. China could not make those components, and its post-treatment process was backward as well. Even the design of the factory conducting uranium–plutonium separation had not been completed (Liu et al., 2004: 193–194).

Chinese chemists began officially and comprehensively getting involved in the charging and preparation of nuclear fuels in 1958 after the Soviet Union stopped its aid to China in atomic energy. Five chemical research institutes of CAS, including the Institute of Organic Chemistry and the Institute of Chemistry, reached a collaborative agreement on atomic energy. The agreement identified priorities for systematic study, including uranium and thorium chemistry, organic extractants, ion-exchange resins and metal corrosion chemistry, which covered a number of chemical issues relating to the pretreatment and post-treatment of nuclear fuels and the separation and preparation of stable isotopes of lithium and borohydride. Chemists at Peking University and the Institute of Atomic Energy also joined the work on nuclear fuel preparation.

Mined uranium ores were subjected to a series of processes, including beneficiation, crushing, leaching, extraction, ion exchange and roasting to produce a product called 'yellowcake', which was then converted to uranium tetrafluoride and then to uranium hexafluoride through hydrofluorination or extraction. Uranium hexafluoride has a low boiling point and can be gasified and made into nuclear fuel through the diffusive separation and enrichment of uranium. The extraction and diffusive separation processes were developed mainly by chemists.

In 1960, the Institute of Organic Chemistry of CAS organized a team of more than 60 researchers and workers and began the extraction of nuclear fuel. Xu Guangxian of Peking University worked on the chemical separation and nuclear fuel separation of uranium-235 and uranium-238, and at the same time he taught the separation chemistry course for graduate and undergraduate students of the radiochemistry and inorganic chemistry programmes of the Department of Technical Physics at Peking University. At that time, extraction chemistry was not a well-established discipline. There were confusing explanations of the mechanisms of extraction, and there was no extraction chemistry textbook, either. More importantly, extraction chemistry at that time was only an analytical method for element separation. Although much progress was made internationally in the extraction of inorganic substances, there was a lack of systematic theorization for nuclear fuel extraction (Xu, 1962). Therefore, Xu initially worked on the extraction classification system and extraction mechanisms. On that base, he developed the separation method for uranium-235 and uranium-238 and explored the efficiency and mechanisms of the synergistic extraction of uranium and hafnium with different extraction agents.

The research team at the Institute of Organic Chemistry that was responsible for nuclear fuel extraction also started its work with a focus on the solvent extraction of uranium. In 1961, the team invited Xu to give lectures on the classification of organic extraction agents (Yuan, 1961). After that, the research team was divided into three groups tasked to prepare three kinds of extractants: acidic organophosphorus extractants, neutral organophosphorus extractants and amine extractants. In addition, another group was responsible for the performance of different extractants. Later on, the team was expanded to include graduates in specialties such as inorganic chemistry, analytical chemistry, radiochemistry and chemical engineering.

Among them, Lu Xiyan led the group for acidic organophosphorus extractants and improved the traditional method of alcoholysis of phosphorus pentoxide. Inspired by the phosphorylation reaction in nucleic acid synthesis discovered by Alexander Todd at the University of Cambridge, Lu and his team successfully synthesized the extractant P-204 with high purity (Zhu and Gao, 2018: 40). Xu Yuanyao and his amine extractants team not only prepared the extractant N-235 through a series of reactions such as ammonia solution, dehydration and ammonification based on mixed fatty acids, but also performed component analysis of the mixture. One year later, the team at the Institute of Organic Chemistry prepared the extractants P-204 and N-235 and successfully applied them to the preliminary extraction of uranium (Zhu and Gao, 2018: 37). Eventually, on 29 November 1963, the factory in Hengyang produced qualified uranium hexafluoride, providing a key raw material for uranium enrichment.

In the chemical pretreatment of uranium ores, the preparation of ammonium diuranate and the gaseous-diffusion-based enrichment of uranium were also important steps in extracting uranium. In order to precipitate ammonium diuranate without sulphate radicals from uranium sulphate solution, the Changchun Institute of Applied Chemistry systematically investigated the mechanism of sulphate radicals entering ammonium diuranate and the processing of amine ion exchange to produce sulphate-radical-free ammonium diuranate. In addition, the institute prepared uranium tetrafluoride from uranium dioxide using three methods by thermolysis-based purification of uranium and achieved a recovery rate comparable to the level reported at the second Geneva International Conference from May 1961 to July 1962 (Liu, 2019). They also prepared uranium hexafluoride by fluorination and submitted a crystallized sample of uranium hexafluoride to the Second Ministry of Machine-Building Industry, an administrative department for the bomb. The Institute of Chemistry carried out research on subjects including reaction dynamics, the sintering of uranium tetrafluoride and impurities in uranium tetrafluoride. Wu Zhengkai participated in gaseous-diffusion-based uranium enrichment in 1960 and 1961. He was responsible for the preparation of uranium hexoxide, including the engineering conditions for uranium enrichment. Cao Benxi, a chemist, in cooperation with Wu, made a special contribution to the chemical separation of uranium hexafluoride and plutonium.

At the time, plutonium provided a route to a fissile isotope without the energy-intensive requirement for high levels of isotopic enrichment that are essential with uranium. In fact, China initially considered plutonium for its nuclear programme but postponed the plutonium route and focused on uranium enrichment in the early 1960s when it experienced 3 years of famine. In contrast to uranium fuel, which involves a high raw-material separation cost, the preparation of plutonium fuel is much cheaper because plutonium-239 can be obtained through post-treatment from the solution in which uranium rods are dissolved in a reactor. Although technically it is easier to prepare plutonium than to prepare high-concentration uranium, the design of a plutonium bomb is more difficult than the design of a uranium bomb. Plutonium present in the world today is almost entirely synthetic in origin. The exceptions are trace amounts that occur occasionally together with uranium ores. It must therefore be produced in reactors. In order to separate the plutonium, the final product of the reactor must be chemically treated (that is, through post-treatment).

At that time, China had established the No. 404 factory for post-treatment. In assisting China, the Soviet Union introduced the precipitation method used in the post-treatment process, which involved precipitating one element while leaving the other element in the solution, thus separating uranium and plutonium. However, after precipitation, filtration was required, which would release a lot of radioactive wastewater, and refiltration was required if the filtered liquid was not clean enough, thus further increasing the amount of wastewater generated. The Second Ministry of Machine-Building Industry convened a top-secret meeting in Yan'er Island in Qingdao to discuss whether the project should continue to use the precipitation method or develop other methods. Both Xu Guangxian and the scientists at Tsinghua University strongly supported the extraction method. Xu had carried out research on the chemical extraction of nuclear fuels for 5 years, and the scientists at Tsinghua University also had filtration devices. The ministry eventually decided to adopt the extraction method and then build a post-treatment factory, headed by Hou Debang's student and chemical engineer Jiang Shengjie (Ye et al., 2013: 97). The ministry assigned the basic research tasks in the extraction-based separation of plutonium to Xu Guangxian and his colleagues. After the post-treatment factory was established, its processing not only substantially reduced waste but also significantly reduced costs in comparison with existing methods in foreign countries. China's second atomic bomb, which was successfully tested in December 1968, was made of plutonium.

In the preparation of thermonuclear fuel for hydrogen bombs, lithium-6 deuteride is an important material. In March 1967, the Institute of Organic Chemistry began examining a new process for the separation of lithium isotopes. More than 40 scientists and technicians, in collaboration with relevant factories ministered by the Second Ministry of Machine-Building Industry, in the course of several years and on the basis of a large amount of experimental research, synthesized a total of more than 200 extractants and identified extraction tasks with high extraction efficiency and practical value from thousands of extraction systems. In 1960, CAS also organized several chemistry institutes to solve multiple key analytical and testing problems relating to nuclear fuel extraction and preparation, nuclear testing and nuclear materials using a diversity of methods. They included, for example, the determination of several impurities in metal uranium and its compounds, the analysis of trace uranium in nuclear industrial wastewater, the analysis of various gases emitted from the production of uranium hexafluoride, and the analysis of ultrapure reagents in nuclear fuel processes.

The involvement of Chinese scientists in the nuclear weapon programme in the late 1954 would soon expand and have profound impacts on the debate over basic and applied research (Wang, 2018). After that, scientists had discussions about whether scientific research should be for science's sake or in the service of production. Some institutions, such as CAS and Tsinghua University, also had debates on those topics, while emphasizing planned scientific activity and calling for respect for and reliance on scientists in scientific decision-making.

In 1955, Guo Moruo, in his report to the conference on the establishment of the academic divisions of CAS, noted that the primary shortcoming of the academy's leadership work was the failure to seriously examine the practical needs of the country in forming its research plans, and he called for giving full scope to the initiative and creativity of scientists and relying on scientists to advance scientific work (Guo, 1955). In the discussion on the purpose of scientific research, Yan Jici, director of the Division of Technical Sciences of CAS, observed that, while transforming scientists, it was also important to respect scientists and believe in their ability to do well in their fields of research (Yan, 1957). Scientists interpreted 'attaching theory with practice' as 'starting out from practice, then theorizing, and then attaching the theory with the practice', which served as an important guideline for scientific research, and conveyed the message that theories could be advanced with practice.

After shifting to the practical work of nuclear fuel extraction and enrichment, chemists began adjusting 'theories' by identifying their areas of strength and using them in the service of national needs for example, Xu Guangxian leveraged his expertise in clathrate chemistry to find extraction methods suitable for nuclear fuel separation and laid the theoretical foundation for the preparation of extractants of nuclear fuel. Yuan Chengye, who had specialized in pharmaceutical chemistry and polypeptides, focused his research on amine extractants and led a group dedicated to research on the structures and functions of extractants. These practices also helped refine theories. Leveraging their scientific expertise and driven by their pursuit of scientific truth, the scientists advanced China's 'two bombs and one satellite' project and achieved success through their technological achievements, rather than recognition from the scientific community.

After the success of the project, the chemists turned to apply the technologies used in the project to serve civil society and broke new ground. Xu Guangxian applied extraction chemistry to the extraction and separation of rare-earth elements and then theoretically explored the electron structures, chemical bonds and clusters of rare-earth polynuclear complexes from the perspective of coordination chemistry and quantum chemistry. Yuan Chengye applied the extractants developed in the bomb project to the separation of rare-earth and nonferrous metals and conducted research on biologically active organophosphates based on neutral organophosphorus extractants.

4. Tasks leading disciplines: Fluorocarbon and fluorine materials

China's long-term national science and technology plan introduced in 1956 put forward the slogan 'tasks leading disciplines', which gave consideration to both applied research and basic research. The last of the 12 key tasks specified in the plan was 'investigations into some basic theoretical problems in the modern natural sciences'. After more scientists became involved in the nuclear programme in 1958, 'tasks leading disciplines' became a potent slogan encouraging chemists to shift their work areas to serving national tasks.

As I have mentioned, the extraction and enrichment of uranium for atomic bombs required the fluorination of uranium and uranium enrichment through gaseous diffusion, which involved processes that needed erosion- and radiation-resistant materials and special lubricants. Artificial satellites making also needed special materials for temperature control. All these needed support from fluorine chemistry and industry.

At that time, fluorine chemistry was not yet developed in China (few chemists were engaged in this field), and organic fluorine chemistry was an emerging discipline even globally. Recognition of organic fluorine chemistry as a large and important area of chemistry was only possible in the 1950s (Krespan, 1960). Moreover, due to the need for confidentiality, there was no open-source information internationally about the methods of preparation of new fluoride materials such as fluororubber and fluororesin.

It is a long way from basic research in fluorine chemistry to the production of fluororubber, which requires rigorous research and much effort, and this points to the outstanding success of China's national defence task at that time (Zhu and Huang, 2015: 113).

Jiang Xikui, a chemist at the Institute of Chemistry of CAS, who conducted some basic theoretical research on organic fluorine chemistry in the United States, served as the head of the fluororubber taskforce, and his team successfully prepared No. 1 fluororubber in September 1959. In the autumn of 1960, Chen Qingyun, who previously studied organic fluorine chemistry in the Soviet Union, joined the Institute of Chemistry and became a member of the fluororubber taskforce. The fluororubber had two components. One component required electrolysis and a very difficult process of preparation and could not be used for production. Therefore, the team had to shift to a different route of synthesis. After Chen Qingyun joined the team, he developed a new means of fluororubber preparation and eventually identified the best conditions for the preparation of hexafluoropropylene, providing a basis for the subsequent large-scale production of the substance in 3 years. Then the team successfully prepared fluororubber No. 2 and No. 3, which supported national defence projects. The new method that the team invented then is still used today worldwide, rather than the electrolysis method. Later, the Institute of Chemistry and the Shanghai Institute of Organic Chemistry ran research projects on fluoride materials. As the required materials were not available in Beijing but in Shanghai, CAS decided to transfer all related tasks of the Institute of Chemistry to Shanghai. As a result, Chen Qingyun followed the taskforce led by Jiang Xikui to the Shanghai Institute of Organic Chemistry.

As bromine and chlorine have isotopes and fluorine does not, turning uranium into uranium fluoride and separating uranium isotopes through gaseous diffusion based on uranium fluoride is the best way to obtain enriched uranium. This also represented the biggest challenge in making atomic bombs. The purpose of gaseous diffusion was to separate gaseous uranium hexafluoride through gaseous barrier diffusion. As one individual separation component had only a very limited separation capability, the entire system needed thousands of separation components.

The biggest problems relating to the diffusion process were erosion and clogging. For the entire project, infrastructure and equipment installation was only a small part of the work. Because uranium hexafluoride is highly corrosive, the lubricant used in the diffuser must have high corrosion resistance and be inflammable, despite high-speed friction. Therefore, the gaseous diffusion process required the equipment, especially the pumps, to be resistant to high temperatures and highly corrosive uranium hexafluoride. Traditional lubricants would combust under the heat generated by high-speed friction. At the time, there were new lubricants in the form of fluorocarbons that were both lubricating and inflammable. The properties of the fluorocarbons coincided with those required for materials used in handling uranium hexafluoride. However, when the Soviet Union withdrew its experts, they took away this lubricant as well. The search for better ways of synthesizing fluorocarbons had been pursued intensively during World War II (Krespan, 1960).

In November 1960, the Institute of Organic Chemistry was assigned the task of developing the lubricant. Huang Weiyuan, a chemist specializing in steroid chemistry, used his analytical expertise in organic compounds to analyse the structure of the lubricant with infrared spectrometers and eventually determined the appropriate conditions for the preparation of fluorocarbon. In addition, the institute also synthesized materials required to be corrosion and radiation resistant (those materials would be used in the diffusive separation equipment, including gaskets, spacers and valves) and constructed the production workshop.

The Changchun Institute of Applied Chemistry, based on its research on the preparation of fluorine at medium and high temperatures, completed the research on the phase equilibrium and best process conditions for the conversion from uranium difluoride to uranium tetrafluoride. In the production of uranium hexafluoride from uranium tetrafluoride using the low-temperature process designed by the Soviet Union, the fluoride of uranium experienced sintering. The Institute of Chemistry of CAS was tasked to address this issue and finally clarified the mechanism for the elimination of the sintering phenomenon.

Fluorine compounds, especially fluorine-containing polymers, have excellent thermal and chemical stability. These materials with special properties were used in various components, such as sealing sheets and temperature control coatings, in China's first artificial satellite. Temperature control of artificial satellites was an important emerging technology that required various new materials, including special temperature control coating. The Institute of Organic Chemistry developed a special organic coating, which was applied to the internal surfaces of artificial satellites for heat insulation. In addition, the institute was the only one capable of developing organic thermal control coating in China. Its organic coating was used in an experimental communications satellite successfully launched by China in 1984 and met the temperature control requirements for various parts of the satellite.

Scientific research has its intrinsic nature. Attaching theory with practice may not be a distinguishing strategy to achieve breakthroughs, especially in frontier and emerging technologies, which require comprehensive theoretical support as well as skills and experimental research. In exploring the conditions for preparing No. 1 fluororubber, Chen Qingyun leveraged his experience in making hexafluoroacetone, which played a key role in his effort to prepare hexafluoropropylene. On this basis, he kept on exploring and refining specific reactions.

Despite the strong support offered by the Institute of Chemistry to fluorine chemical research and the ample research force, fluorine chemistry still needed basic theories to make advances because it was a new area of chemical research. Thanks to the guideline of the strategy of 'tasks leading disciplines', China's chemists always conducted their practical work with an idea of developing fundamental theories as well. For example, Jiang Xikui and Chen Qingyun, in their research on fluororubber, also carried out research on related basic theories and discovered the halophilic reaction, which was one of the earliest reactions discovered by Chinese chemists.

After the completion of the 'two bombs and one satellite' project, the Institute of Organic Chemistry established a research lab for fluorine chemistry. In its effort to explore civilian applications of fluorine chemistry, the lab developed chromium fog inhibitors for electroplating factories. During this research, it discovered a fluorine ether group chain with a unique structure, which paved the way to the development of a series of reactions and reagents named with the family names of participating chemists. In the 1990s, those findings were collectively referred as ‘Shanghai fluorine chemistry’ by international chemistry community. This exemplary case of the transition from state-sponsored applied research to basic research was regarded as evidence of the success of the concept of tasks leading disciplines. In addition, in their subsequent research activities, the chemists at the Institute of Organic Chemistry were always thinking about how to combine basic research and applied research and make better use of fluorine chemistry.

5. Exploratory research: The development of high-energy fuels

Qian Sanqiang regarded basic research as ‘exploratory research’. Besides his belief that scientific research is the exploration of truth and that exploratory research holds an important position in technological innovation over the long term, he emphasized basic research’s precedence over technology. The theoretical research team of the Institute of Atomic Energy first explored and preliminarily researched the mechanism of the hydrogen bomb and its possible structures, which was considered to be an essential step in the early phase of the theoretical exploration of the hydrogen bomb.

What exploratory research did the chemists carry out? In August 1958, the Scientific Planning Committee of the State Council pointed out in its report on the implementation of the 12-year scientific plan that research on artificial satellites would accelerate a series of fields of research, including high-energy fuel. High-energy fuel and high-performance materials are essential to rockets, missiles and satellites. Qian Xuesen, a chief scientist of China’s missile programme, once vividly observed that ‘Everything is ready except the east wind’, in which ‘east wind’ was a metaphor for high-energy fuel. China’s missile development was driven by both basic research and applied research from the very start, and CAS led the ‘exploratory research’. CAS had to explore from scratch and focus on high-energy fuel instead of conventional fuels. All the four institutes of chemical research under CAS were assigned research tasks on high-energy fuel, and the two institutes in Shanghai and Dalian even set up experimental bases in mountainous areas.

What high-energy fuel uses as its raw material was part of the exploratory work of CAS. Qian Xuesen learned from US journals about boron hydride being used as a solid propellant with higher energy density than conventional fuels. However, boron hydride fuel was difficult to prepare and was an area rarely explored in China. Even the international academic community initially researched it mainly out of a theoretical interest. A greater difficulty came from the facts that the preparation of borane required a high-vacuum environment and the compounds were explosive, thus having very high requirements for experimental instruments and equipment. After a lot of effort, Huang Weiyuan and his colleagues successfully synthesized boron hydride in a remotely controlled glass device. However, the US announced that toxic boron hydride could not be directly used as high-energy fuel. Instead, a liquid fuel called helium fluorine was a prospective solution. After that, the Institute of Organic Chemistry made improvements based on boron hydride and eventually prepared helium fluorine fuel.

Along with exploratory research on the preparation of high-energy fuel, several institutes of chemical research under CAS developed a high-energy explosive to trigger the hydrogen bomb and also developed the cohesiveness of solid propellant and burning rate modifier. For example, the Institute of Applied Chemistry was assigned the task of developing liquid Thiokol, and the Lanzhou Institute of Chemical Physics put in place an entire research system covering a full range of subjects, including explosive synthesis, analysis and testing; moulding charges; amplification testing; and detonation theory. More than 150 researchers were transferred from other institutes to the Lanzhou Institute of Chemical Physics, accounting for 43% of its total staff. The institute’s research results were later used in China’s first hydrogen bomb.

The exploratory research conducted by chemists on high-energy fuel was basic research in a new field with the ultimate purpose of technological realization. Although the hydrogen bomb was successfully tested, significant resources and time were wasted by following the US route due to lack of experience. While some exploratory work achieved applications, the subsequent basic research did not follow up. In 1972, for example, the high-energy explosive unit of the Lanzhou Institute of Chemical Physics was merged into military production departments, including half of the institute's fixed assets and one-third of the institute's research personnel. Exploratory research results that were confidential were either eventually transferred to military production departments or left unpublished. Although the contributing chemists received recognition from the state in the form of accolades such as national defence medals, they did not receive wide acknowledgement from the scientific community, which was indeed regrettable.

Science has its own evolution. It is an investigative enterprise that requires inputs of technology, operations, experiments and apparatus as well as fundamental concepts and theoretical explanations. Viewing science as an investigative enterprise rather than an explanatory one is emphasized by scholars of the philosophy of scientific practice in their discussions on the structure of scientific development. The 'two bombs and one satellite' project is a case in point. Small factories were set up at research institutes because of the concept of 'institute–factory' advocated in the project for integrating scientific research, production and application. Those factories played a positive role in accelerating the independent development and design of raw materials and apparatus used in chemical research and chemical research's translation to chemical engineering.

6. Situated basic and applied research in the context of national tasks

The debate on whether there is a dichotomy between applied and basic research or a distinction between the internal and external development of science is not helpful in examining the structure of science. Science evolved in its practice. Understanding the meanings of the concepts of applied and basic research in both local and global contexts is a pressing problem to be addressed in the history and philosophy of science. The global turn in the history of science not only provides an expansion of geographical scope but also requires the exploration of the temporal-spatial and dynamic characteristics of the spread of science and placing national or regional science in the global context.

It should be noted that this study is not meant to be a comprehensive survey of the work of chemists in the 'two bombs and one satellite' project or a discussion of the relationship between ideology and science, but a case study on the neglected activities of chemists in a historically significant project. I focus on how those chemists both in academia and in the task-oriented national context have had to position themselves and their work in a complex field. In such cases, we need to examine how the chemists understand the relation between basic and applied research.

In the project, Chinese chemists shifted from their previous research to fields related to the project, especially radiochemistry, nuclear fuel chemistry, fluorine materials and high-energy fuel. That shift not only accelerated the circulation of related chemical knowledge worldwide but also created new fields of research and new scientific knowledge, such as extraction chemistry and fluorine chemistry. Robert Merton's account of the ethos of science is a sociological account consistent with the definition of scientific success as the locus of reliable knowledge of nature (Richardson, 2004). The social dimension of scientific knowledge does not disrupt the epistemic privilege of science. Disinterestedness and the universality of science are the foundation of scientific knowledge's global circulation. The work on the chemical reactions and theories of phosphorus chemistry and fluorine chemistry developed by Chinese chemists after the project showed its continuity on the basis of the principal theory, mechanism and techniques of nuclear fuel extraction. And the new chemical knowledge was circulated to other parts of the world after the recovery of China's international exchanges.

In his research on the social direction of science, Kitcher (2011: 260–264) argued that there is no absolute standard for the significance of research projects; nor is there any standard for 'good' research, apart from subjective preference. The only non-arbitrary approach to defend judgements concerning research agendas in the absence of absolute standards is to establish collective preferences democratically. However, his proposal was criticized for the excessive idealism of his well-ordered science. The government-regulated research in the project undoubtedly sacrificed the autonomy and subjectivity of scientists, but, on the other hand, the administrators and scientists had their own responses to that situation.

Promoting applied research through basic research and driving theoretical investigations through national tasks was a unique understanding of scientists in the 'two bombs and one satellite' project about the relationship between basic and applied research. They integrated those two sides in their scientific practice. Basic research as understood by the chemists was closer to theoretical research, while applied research referred to the specific programme tasks assigned by the country.

From attaching theory with practice to conducting exploratory research, the chemists were always looking for zones where basic research and applied research could be integrated. After their shift to 'practical' research work, they achieved their autonomy by regulating the 'theory' and working in areas where they had advantages. When working on technological realization, they remained committed to theoretical exploration. After the success of the project, the scientists, in their subsequent research, remained focused on how to integrate basic and applied research. In the fields of fluorine chemistry and extraction chemistry, for example, the chemists first explored how to put the research results developed in military programmes into civil uses. Even after they regained their autonomy in basic research in the 1980s, chemists were still committed to applying the high-efficiency chemical reactions developed in fluorine chemistry to the synthesis of new compounds that would benefit the world's well-being.

Mertonian norms of science offer a way to analyse how the chemists continuously regulated and handled the tension between planned research and the autonomy of science. Departing from the definition of the Mertonian norm of disinterestedness, the chemists understood the disinterestedness of research in terms of serving China's national interests. In contrast to recognition earned from the scientific community in pure science, technological realization served as an alternative recognition of the research work in the project. Despite this, the chemists always maintained the norm of universalism of pure science. During the 'Great Leap Forward' period (1958–1960), Xu Guangxian led the uranium separation work. In response to a reported extraordinary rise in uranium enrichment, he repeated the same experiments for more than 50 days to validate the results, despite the wishes of other team members to report the progress to the CPC Beijing municipal committee (Ye et al., 2013: 98–99). In addition, while technological realization itself was a form of recognition of scientists participating in the project, the scientists also valued recognition from the scientific community for their work. Therefore, the slogan 'tasks leading disciplines' was well received by the scientists because they found balance between working in planned research and pursuing science for science's sake. In 1959, the journal *Atomic Energy Science and Technology* was established, which not only promoted academic communication but also satisfied the wishes of the scientists to get recognition from the scientific community.

Therefore, revisiting the relation of basic and applied research in the context of China's 'two bombs and one satellite' project by focusing on the scientific practice of the chemists may offer a different understanding of the inherent tension between basic and applied science.

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References

Creager ANH (2013) *Life Atomic: A History of Radioisotopes in Science and Medicine*. Chicago, IL and London: University of Chicago Press.

Creager ANH and Santesmases MJ (2006) Radiobiology in the atomic age: Changing research practices and policies in comparative perspective. *Journal of the History of Biology* 39(4): 637–647.

Dear P (2012) Science is dead; Long live science. *Osiris* 27(1): 37–55.

Department of Technical Physics at Peking University (1995) *Cradle of Nuclear Scientists: The 40th Anniversary of the Department of Technical Physics, Peking University (1955–1995)*. Beijing: Department of Technical Physics, Peking University (in Chinese).

Editorial Committee of Nuclear Industry of Contemporary China (1987) *Nuclear Industry of Contemporary China*. Beijing: China Social Science Press (in Chinese).

Fan FT (2012) The global turn in the history of science. *East Asian Science, Technology and Society* 6: 249–258.

Galison P (2008) Ten problems in history and philosophy of science. *Isis* 99: 111–124.

Galison P (2010) Trading with the enemy. In: Gorman ME (ed.) *Trading Zones and Interactional Expertise: Creating New Kinds of Collaboration*. Cambridge: MIT Press, pp. 25–52.

Guo MR (1955) Report to the conference on the inauguration of the academic divisions of the Chinese Academy of Sciences. *People's Daily*, 12 June, p. 3 (in Chinese).

Kitcher P (2011) *Science in a Democratic Society*. New York: Prometheus Press.

Krespan CG (1960) Organic fluorine chemistry. *Science* 150(3692): 13–18.

Lewis JW and Xue LT (1991) *China Builds the Bomb*. Stanford: Stanford University Press.

Liu JF, Liu YQ and Xie HY (2004) *The Project of 'Two Bombs and One Satellite': A Model of Big Science*. Jinan: Shandong Education Press (in Chinese).

Liu YQ (2019) The Chinese Academy of Sciences and the 'two bombs and one satellite' project. *Journal of the Chinese Academy of Sciences* 34(9): 1003–1013 (in Chinese).

Manning P and Savelli M (2018) *Global Transformation in the Life Sciences, 1945–1980*. Pittsburgh: University of Pittsburgh Press.

McCook S (2013) Focus: global currents in national histories of science: the 'global turn' and the history of science in Latin America. *Isis* 104: 773–776.

Qian SQ, Deng JX and Li SZ (1957) In memory of Comrade Guo Tingzhang (1917–1957). *Science Bulletin* 8(14): 447 (in Chinese).

Richardson A (2004) Robert K. Merton and philosophy of science. *Social Studies of Science* 34(6): 855–858.

Schauz D and Kaldewey D (2018) Introduction. In: Kaldewey D and Schauz D (eds) *Basic and Applied Research: The Language of Science Policy in the Twentieth Century*. New York: Berghahn Books, pp. 4–6.

Van Dongen J, Hoeneveld F and Streefland A (2015) Introduction. In: Van Dongen J (ed) *Cold War Science and the Transatlantic Circulation of Knowledge*. Leiden/Boston: Brill, pp. 1–7.

Wang ZY (2018) Theory attached to practice: Chinese debates over basic research from thought remolding to the bomb, 1949–1966. In: Kaldewey D and Schauz D (eds) *Basic and Applied Research: The Language of Science Policy in the Twentieth Century*. New York: Berghahn Books, pp. 228–247.

Wu WQ and Shen JY (2018) Non-contractual social capital and outstanding scientists in the 'two bombs and one satellite' project: A concurrent discussion on China's contemporary science and technology innovation. *Studies in Philosophy of Science and Technology* 35(5): 124–128 (in Chinese).

Xu GX (1959) Lectures on introductory courses on nuclear physics. Manuscript collected in the database of the Archival Hall of the Data Collection Project (in Chinese).

Xu GX (1962) Outlook on the nuclear fuel extraction chemistry and suggestions on the classification of the extraction system. *Atomic Energy Science and Technology* 2(6): 412–424 (in Chinese).

Yan JC (1957) Transform scientists, respect scientists. *People's Daily*, 17 April, p. 7 (in Chinese).

Ye Q, Huang YH and Zhu J (2013) *Daunting Tasks, Great Missions: Biography of Xu Guangxian*. Beijing: China Science and Technology Press; Shanghai: Shanghai Jiao Tong University Press (in Chinese).

Yuan CY (1961) Work diaries of Yuan Chengye (July 1961–December 1961). Collected in the Archival Office of Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences (in Chinese).

Zhang H and Fu ZL (2017) Teacher–student relationship in engineering research: a case study on China's 'two bombs and one satellite' project. *Journal of Engineering Studies—Engineering from Interdisciplinary Perspective* 9(4): 400–407 (in Chinese).

Zhu J and Gao Y (2018) *All for Deeper Understanding and New Discoveries: Biography of Lu Xiyan*. Beijing: China Science and Technology Press; Shanghai: Shanghai Jiao Tong University Press (in Chinese).

Zhu J and Huang ZJ (2015) *Be Open-minded as a Valley: Biography of Huang Weiyuan*. Shanghai: Shanghai Jiao Tong University Press; Beijing: China Science and Technology Press (in Chinese).

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Article

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Science and national defence: Special editions on the National Defence Science Movement during the Anti-Japanese War

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Abstract

In 1941, Chiang Kai-shek put forward the proposition that 'National defence is built upon science and technology, and the strength of a country is secured by national defence', marking the official start of the National Defence Science Movement (国防科学运动). Attempting to answer the call, a number of journals and newspapers published special issues dedicated to the movement, including many contributions from senior political officials and technological influencers. The papers explored the meaning and role of science, scientific research, science popularization, science-related awards and similar topics. The writers underscored the value of science, publicized the idea of 'saving the country by means of science' (科学救国), highlighted the value of basic science and social science, and explained how different disciplines could play their part in national defence. They envisaged postwar reconstruction plans in fields as diverse as telecommunications and forestry and called on young people to study science and take the initiative by devoting themselves to scientific research. The publication of these special issues raised the status of science, especially the basic and social sciences, while playing a positive role in encouraging young people to engage in scientific research.

Keywords

National Defence Science Movement, Anti-Japanese War, science popularization, saving the country with science

The National Defence Science Movement was a campaign initiated by China's National Government during the Anti-Japanese War (1937–1945) to propagate and popularize scientific knowledge related to national defence. The movement was promoted mainly through scientific exhibitions, scientific performances, scientific paper competitions, the publication of special issues of magazines and newspapers discussing national defence science, the translation and introduction of new knowledge of national defence from Europe and America, and the establishment of national defence research awards. Compared with the Chinese Scientization Movement in the 1930s, the National Defence Science Movement focused on the dissemination of scientific knowledge as it related to national defence, stressing that science should serve national defence and encouraging young people to engage in scientific research for that purpose.

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In academic circles, previous research on science movements during the Republic of China era centred mainly on the Chinese Scientization Movement. Examples include Chen's doctoral thesis, '*Research on the Chinese Scientization Movement*' (2007); Li's master's thesis, '*Gu Yuxiu and the Chinese Scientization Movement*' (2012); Liu's 'A study on the Chinese Scientization Movement' (1987); Jia's 'Characteristics of "saving the country by means of science" and its modern value: Taking the scientization movement in the 1930s as an example' (2005) and 'The scientization movement from the perspective of *Ta Kung Pao*' (2003); and Peng's 'The establishment, activities and historical status of the Chinese Scientization Movement Association' (1992). Wang's master's thesis, '*Study on the Movement of Natural Science Popularization in the Shaan-Gan-Ning Border Region during the Anti-Japanese War*' (2019), covered science popularization activities in that region in the same period.

Given the complexity of the National Defence Science Movement, relevant academic research on it is scarce. This paper, taking several special issues published during the movement as research objects, analyses the content and authorship of the published articles in order to elaborate on the characteristics and value of those special issues.

1. The cause of the National Defence Science Movement

In 1936, feeling the pressure of Japan's incremental aggression, Chinese people in literary circles appealed for 'the establishment of national defence science'. They called for united efforts by Chinese scientific institutions and scientists and proposed three main tasks for national defence science: first, teaching national defence knowledge to the Chinese people; second, public education both to raise the public's awareness of national defence science and to cultivate national defence scientists; third, research on national defence science. They held that scientists and engineers must be brought together to study military chemistry, aviation, tanks, ammunition and other military factors, including the manufacture of gas masks, guns and bullets for civilian use during warfare and the improvement and invention of weapons and aircraft (Guang, 1936).

In 1937, the full-scale Anti-Japanese War broke out in China. Fully occupied with self-protection, the Kuomintang (KMT) Government had no time to engage in science and education. However, having suffered a serious defeat in the early stage of the war, China started to reflect on the cause of the defeat and appreciate the importance of science and technology in defence.

After 1939, the Anti-Japanese War entered a stage of strategic stalemate, and the situation in the rear areas gradually stabilized. Chiang Kai-shek (蒋介石) and the KMT Government now had time to contemplate the importance of science and technology in the war. In April 1939, the *Outline of Suggestions on the Coordination and Improvement of the Work of the National Spirit Mobilization Committee and the New Life Movement Promotion Council*, which was compiled by the New Life Movement Promotion Council, stated that one of the tasks of national spirit mobilization was to promote social science, national defence science and life modernization (Zheng and Huang, 2014). In November 1940, Qiu Guozhen (丘国珍), a KMT general trained in the Huangpu Military Academy and a veteran in the Battle of Songhu (淞沪会战), published an article titled 'From national defence science to comprehensive air defence', which stressed the importance of national defence science in modern warfare (Qiu, 1940).

On 7 February 1941, the Central Cultural Movement Committee under the Central Publicity Department of the KMT Government was established, with Zhang Daofan (张道藩) as its director and Hong Lanyou (洪兰友) and Pan Gongzhan (潘公展) as deputy directors (Editorial Department of *Guangxi Education Communication*, 1941). The purpose of this new institution was to 'strengthen national strength with cultural strength, promote national construction with cultural construction' and become the main force of the subsequent National Defence Science Movement.

On 12 March 1941, Chiang Kai-shek said in his radio address on the second anniversary of the National Spirit Mobilization Campaign, '[We] need to improve the scientific spirit, popularize science and technology, complete the industrial plan of our founding father, and promote national defence science. All national defence programmes must be guided by the highest scientific spirit and the highest level of science and technology . . . without science, there will be no national defence; without national defence, our country will be no more' (Chiang, 1941). The broadcast marked the beginning of the National Defence Science Movement.

On 5 May 1941, Cheng Siyuan (程思远), who was the Secretary of Bai Chongxi (白崇禧), Secretary of the Guangxi Branch of the KMT Youth League and Deputy Director of the Organization Department of the KMT Youth League Central Committee, made a speech titled 'Promoting the National Defence Science Movement' (Cheng, 1941c) on Guilin Radio, during which the term 'National Defence Science Movement' was promoted.

From 9 to 10 July 1941, in his speech to the joint meeting of the Executive Committee and Supervisory Committee of the KMT Youth League Central Committee, Chiang Kai-shek once again stated that the slogan 'Without science, there will be no national defence; and without national defence, our country will be no more' was not only the unanimous call of people around the country but also the irrefutable truth of the times (Chiang, 1942). Moreover, he offered a practical plan for the National Defence Science Movement, proposing concrete steps to promote national defence science in three aspects:

(1) Public education: honouring people who had made contributions to national defence, drawing diagrams and making models to introduce the progress of other countries in developing national defence science, and using all available opportunities to explain the subject to the people.
(2) School education: encouraging research on national defence science by college students and focusing all academic efforts on the construction of national defence; informing middle school students about the rapid progress of national defence science in modern countries and encouraging them to follow that example and catch up; requiring all primary school teachers to explain to their students that national defence science was an instrument that could save and build the country, so that the students would be able to appreciate, even during their childhoods, the honour of learning national defence science.
(3) The military: all the regiments must quickly come up with detailed methods and procedures for the science movement and make their best effort to find young people who were ready to serve national defence science, give them the necessary compliments and incentives, and spare no effort to help them make important achievements (Chiang, 1942).

Instructed by Chiang, the National Government officially started to promote the National Defence Science Movement.

We can see clearly that the National Defence Science Movement was a top-down science popularization movement promoted by the KMT Government. Chiang Kai-shek emphasized that 'it is true that this movement should focus on scientific theories, but it shall also prioritize the popularization of practical technology' (Chiang, 1942), which also foreshadowed that, during the movement, more importance was to be attached to applied science than to basic science.

2. The publication of special issues on the National Defence Science Movement

Following the mobilization of the government, celebrities, government officials, scientists and members of the public wrote articles to express their understanding of national defence science. To build momentum for the movement, many magazines and newspapers published special issues, included those described in this section.

2.1. Chinese Youth (Chongqing), 'National Defence Science Movement special edition' (1941)

Chinese Youth (Chongqing) was founded in July 1939. It was edited by staff of *Chinese Youth Monthly*, distributed by Youth Bookstore and published in Chongqing during the Anti-Japanese War. As a journal focusing on youth, its main policy was to 'encourage youth to join the war and inspire youth to build the country'. Its main content included expositions, translations, communications, literature

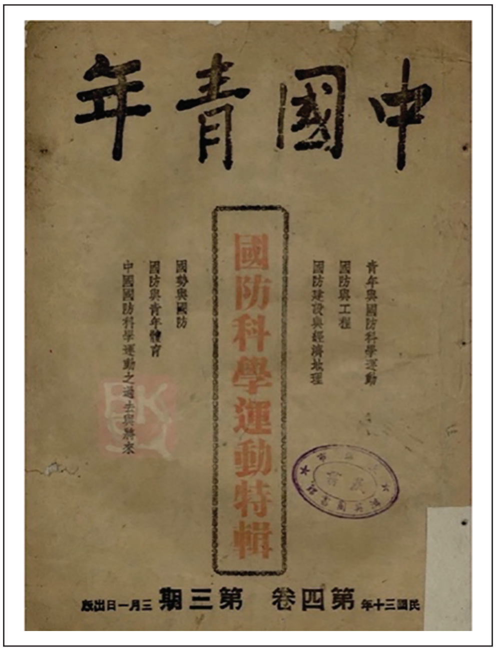

Figure 1. *Chinese Youth (Chongqing)*, volume 4, issue 3, on the National Defence Science Movement.

and art, and book introductions and reviews. Chiang Kai-shek and Chen Cheng (陈诚) were amongst the writers for the journal.

In March 1941, *Chinese Youth (Chongqing)*, volume 4, issue 3, which included a special section on the National Defence Science Movement, was published (Figure 1). The articles were written by government officials and scientists. The detailed contents are shown in Table 1.

Those who contributed to the special issue were all from Chongqing-based central government agencies or universities. The opening article was written by Zhang Zhizhong, who was the Secretary General of the Youth League of the Three Principles of the People. Taking the Anti-Japanese War in Wusong and Shanghai as an example, he encouraged young people to shoulder responsibilities for national defence. He held that there were two key points in the National Defence Science Movement: the first was to boost general scientific research; the second was to reinforce special scientific research on national defence, so as to underpin national defence. Gu Yuxiu (an electrical guru), Hu Huanyong and Li Xudan (geographers), and Cheng Dengke (a sports educator) discussed the relationship between their professional fields and national defence construction. In addition, Jian Guansan (an economist) reviewed the history of the National Defence Science Movement and set out his view of its prospects. Tan Pingshan probed China's economic policies from the perspectives of nationalism, civil rights and livelihoods, focusing less on science.

2.2. *Jiangxi Youth*, 'National Defence Science Movement special edition' (1941)

Founded in 1940, *Jiangxi Youth* was published in Ganxian County, Jiangxi Province, with Jiang Haidong (江海东) as the editor-in-chief. It was a political journal of the KMT supported by the Jiangxi branch of the KMT Youth League. It mainly published comment on current affairs, the economy, the military, politics, culture and the ideology and lives of young people. It reported on the status of young people around the country and included a small number of literary works and introductions to scientific knowledge.

Because the president of the journal was Chiang Ching-kuo (蒋经国), *Jiangxi Youth* was a leading magazine in the National Defence Science Movement. In June 1941, it issued a call for articles on the movement. On 10 July, volume 3, issue 2 included a special section (Figure 2). Most of the contributors were well known at that time (Table 2).

The authors of this special issue were all senior KMT officials. Zhu Jiahua and Weng Wenhao were geologists. In 1948, both of them were elected as academicians of the Academia Sinica (中央研究院). Cheng Shikui studied at the University of Chicago and Columbia University in the United States and obtained a master's degree. He served as a professor at the National Central University. Since this issue mostly targeted young people—the majority of the readers—these articles were oriented towards the responsibilities that youth should take in national defence and the National Defence Science Movement. For example, Zhu (1941) urged young people to value China's inherent morality as

Table 1. Articles published in *Chinese Youth (Chongqing)*, volume 4, issue 3, on the National Defence Science Movement.

Author	Author's title	Article title	Page
Zhang Zhizhong (张治中)	Minister of the Political Department of the Military Commission of the KMT Government and Secretary General of the Executive Committee of the KMT Youth League	Youth and the National Defence Science Movement	2–9, 23
Tan Pingshan (谭平山)	Member of the second National People's Consultative Conference	The national defence economy and the economic policy under the Three Principles of the People	10–22
Gu Yuxiu (顾毓秀)	Vice Minister of Education and member of the Resources Committee of the KMT Government	National defence and engineering	23–24
Hu Huanyong (胡焕庸)	Director of the Geographical Research Department of the Research Institute of the National Central University	National defence development and economic geography	25–27
Li Xudan (李旭旦)	Professor, Department of Geography, National Central University	National circumstances and national defence	28–32
Cheng Dengke (程登科)	Professor, Department of Physical Education, National Central University	National defence and youth sports	33–40
Jian Guansan (简贯三)	Member of the Central Library and Magazine Review Committee	China's National Defence Science Movement: Past and future	41–45, 53

well as physical fitness. Weng Wenhao was the only contributor who wrote about and shared his unique understanding of national defence science.

2.3. Chinese Youth, 'National Defence Science Movement special edition' (1941)

Chinese Youth, issue 3, which was published in 1941, included a special section on the National Defence Science Movement (Table 3).

This special issue discussed the National Defence Science Movement from a military perspective. Zhang's (1941b) article was the same as his article in the 'National Defence Science Movement special edition' of *Chinese Youth (Chongqing)*, except that the section in memory of the Battle of Songhu was deleted. Wang Shizhao discussed the establishment of national defence thought, national defence academic research and the creation of national defence science. Zhou Zhifeng reviewed the history of national defence science movements since the late Qing Dynasty. Guo (1941), Yu (1941) and Zhang (1941a) discussed the importance of, respectively, the air force, navy and army in national defence.

2.4. Xianyou Education, 'Perspectives of nine scientists on the National Defence Science Movement' (1942)

Founded in October 1941, *Xianyou Education* was a local education journal published in Xianyou, Fujian Province. The purpose of the journal was to study school education, adult education, children's education, public education, practical administrative issues, and so on. The main topics included expositions, special issues, education news, the introduction of teaching materials, education communication, teachers' garden, teaching discussions, teaching methods, education laws and regulations.

In February 1942, issues 4 and 5 of *Xianyou Education*, which can be seen as a special edition on the National Defence Science Movement, republished an article from the *Central Daily*, offering the perspectives of nine scientists on the movement (Table 4).

These articles, all of which were written by scientists, discussed the relationship between specific disciplines and national defence and the significant role that those disciplines could play in national defence development.

Figure 2. *Jiangxi Youth*, volume 3, issue 2, on the National Defence Science Movement.

2.5. 'National Defence Science Movement special edition' jointly published by the Central Daily and The Sweep (1942)

The *Central Daily* was the KMT's party newspaper. It was founded in Shanghai by the KMT Central Committee on 1 February 1928 and moved to Nanjing in 1929. In 1932, it adopted the presidential system under the auspices of the Publicity Department of the KMT Central Committee. In 1938, the KMT Government moved to Chongqing as a result of the Anti-Japanese War.

The Sweep was a newspaper of the KMT military system. Formerly known as the *Sweep Three-Day Journal*, it was founded in Nanchang in 1932 and moved to Hankou in 1935. It was published simultaneously in Guilin, Kunming and Chongqing during the Anti-Japanese War.

In 1942, to facilitate the activities of National Defence Science Movement Week, the *Central Daily* and *The Sweep* jointly published a special edition on the National Defence Science Movement on 10 October. The issue carried pieces by Bai Chongxi, Chen Shaokuan (陈绍宽), He Guoguang (贺国光), Ma Chaojun (马超俊) and others (Table 5).

The *Central Daily* and *The Sweep* had an important place in the propaganda work of the KMT, so the authors of this special issue were mostly senior officials of the National Government. Wang (1942) called for the popularization of the scientific spirit amongst the public. Sun (1942b) believed that people should seize the opportunity to carry out national defence development, starting with heavy industry, followed by the training of national defence scientists and the popularization of national defence science. Zhang (1942) explained the significance of the National Defence Science Movement from the perspective of scientific functions, suggesting that the National Defence Science Movement should include advanced scientific research and the popularization of scientific knowledge and that science was the only way to strengthen national defence. Gu (1942) put forward two tasks for the National Defence Science Movement: first, to make the youth and the public understand their own national defence responsibilities; second, to strengthen research on national defence science and technology. Wu (1942) called for a 'thorough' spirit in national defence science. Ji and Dai (1942) jointly wrote that heavy industry and transport were the foundation for national defence and that transportation was the prerequisite. Xiao (1942b), an expert on land issues, said that people, land, tasks and materials should be paid attention to in national defence development.

2.6. Zhejiang Youth (Jinhua), 'National Defence Science Movement special edition' (1943)

Zhejiang Youth (Jinhua) was a youth journal published monthly or bi-weekly. It was founded in January 1940, sponsored by the Zhejiang branch of the KMT Youth League and distributed by *Zhejiang Youth Bi-weekly*, with Wang Chuanben (王传本) as the editor-in-chief. The task of the journal was to explain the right approach to patriotism, help young people with their study and enhance their patriotic fervour. Its main contents included commentaries on

Table 2. Articles published in *Jiangxi Youth*, volume 3, issue 2, on the National Defence Science Movement.

Author	Author's title	Article title	Page
Pan Gongzhan (潘公展)	Deputy Minister of the Central Publicity Department of the KMT Government	Youth in the National Defence Science Movement	1–6
Weng Wenhao (翁文灏)	Minister of the Economy of the KMT Government	What is national defence science?	7
Zhu Jiahua (朱家骅)	Minister of the Central Organization Department of the KMT Government and Acting President of the Central Research Institute	Youth and national defence	8
Bai Chongxi (白崇禧)	Deputy Chief of the General Staff and Minister of Military Training of the Military Commission of the KMT Government	How to cultivate the voluntary spirit of young people	9–10
Huang Zhenqiu (黄镇球)	Air Defence Commissioner of the KMT Government	Modern youth and modern national defence	11–12
Cheng Shikui (程时煃)	Director of the Education Department and member of the Training Committee of the Party Affairs Department of Jiangxi Province	National defence modernization and the youth of our times	13–14

Table 3. Articles published in *Chinese Youth*, issue 3, 1941, on the National Defence Science Movement.

Author	Author's title	Article title	Page
Wang Shizhao (王世昭)	Chief Secretary of the General Command of the 16th Army Group, President of *Liuzhou Times Daily*, and Principal of Dadao Middle School	On the National Defence Science Movement	7
Zhang Zhizhong (张治中)	Minister of the Political Department of the Military Commission of the KMT Government and Secretary General of the Executive Committee of the KMT Youth League	Youth and the National Defence Science Movement	8–9
Zhou Zhifeng (周之风)	Member of the Field Mobilization Committee	China's National Defence Science Movement: Past review and future prospects	10–11
Guo Shizhen (郭世振)	Chief Correspondent of *National Defence Weekly*	The National Defence Science Movement and the development of China's new air force	12, 18
Yu Qijie (余祺节)		The navy and modern warfare (translation)	13
Zhang Xueyi (张学逸)	Commanding Officer (Lieutenant Colonel) of the Railway Corps of the Military Commission of the KMT Government	On the construction of national defence and railway forces	14–15

unreasonable social phenomena and articles on literature and science. The columns included brief comments, special issues, expositions, literary extracts, literature and art, science lectures, introductions to books and newspapers, youth news and a readers' mailbox.

On 4 April 1943, the first National Congress of the KMT Youth League was held in Chongqing. It adopted a 'resolution on mobilizing the youth to build a new China' that included five 'movements'. One of them was the National Defence Science Movement, requiring that the training of KMT Youth League members focus on national defence technology, and that each group should conduct at least one national defence research project, such as national defence chemistry or national defence

Table 4. Articles published in *Xianyou Education*, issues 4 and 5, on the National Defence Science Movement.

Author	Author's title	Article title	Page
Sun Guangyuan (孙光远)	Professor, Department of Mathematics, National Central University	Science and national defence	3
Gao Jiyu (高济宇)	Professor, Department of Chemistry, National Central University	Chemistry and national defence	4
Ouyang Zhu (欧阳翥)	Professor, Department of Biology, National Central University	Biology and national defence	4
Zhu Sen (朱森) and Zhang Geng (张更)	Director of Department of Geology, Chongqing University; Professor, Department of Geology, National Central University	Geology and national defence	4–5
Xiao Xiaorong (肖孝嵘)	Professor, Department of Psychology, National Central University	Psychology and national defence	5
Hu Huanyong (胡焕庸)	Professor, Department of Geography, National Central University	Geography and national defence	5–6
Pan Pu (潘璞)	Director of the Department of Mathematics and Physics, Chongqing University	Astronomy and national defence	6
Feng Jian (冯简)	Professor, Engineering College, Chongqing University	Underground antennas	7

Table 5. Articles published in the *Central Daily* and *The Sweep* on the National Defence Science Movement in 1942.

Author	Author's title	Article title	Page
Wang Chonghui (王宠惠)	Secretary General of the Supreme Council of National Defence	National defence development and scientific spirit	6
Sun Ke (孙科)	President of the Legislative Yuan of the KMT Government	Promoting national defence science and national defence development	6
Zhang Daofan (张道藩)	Chairman of the Cultural Movement Committee of the KMT Central Committee	The significance of the National Defence Science Movement	6
Zhou Ziya (周子亚)	Professor, Department of Law and Department of Foreign Languages, National Political University	The National Defence Science Movement: Past and future	6
Gu Yuxiu (顾毓秀)	Vice Minister of Education of the KMT Government	The National Defence Science Movement and national defence development	6
Wu Tiecheng (吴铁城)	Minister of the Overseas Affairs Department of the KMT Government	Promoting the spirit of national defence science	7
Ji Yuanpu (季源溥) and Dai Juntao (戴钧陶)	Chief of the Labour Division of the Ministry of Railways; Chairman of the Party Department of Hunan–Guangxi–Guizhou Railway, Wartime Labour Association of China Labour Association	The preconditions for the development of national defence science	7
Xiao Zheng (肖铮)	President of China Land Survey Association	A basic condition for national defence development	7
Hong Lanyou (洪兰友)	Vice Chairman of the Cultural Movement Committee of the KMT Central Committee	National defence science and the spirit of 'rule of law'	7

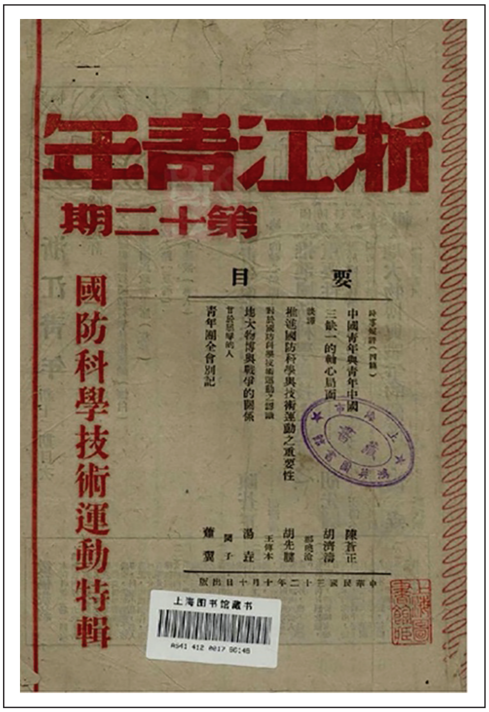

Figure 3. *Zhejiang Youth (Jinhua)*, issue 12, on the National Defence Science Movement.

industrial science, and master one national defence skill, such as in parachuting, gliding, boating, swimming, riding and shooting, detection, measurement, radio, photography, driving or grenade throwing (Chongqing Archives, 1943). Against such a background, *Zhejiang Youth (Jinhua)*, issue 12 (Figure 3), published in Jinhua in 1943, included a special section on the movement (Table 6).

All the authors of this special issue except Hu Xiansu worked in Zhenjiang. Wang Chuanben stressed the importance of science and technology to national defence. He suggested the development of national defence science and encouraged young people to shoulder the responsibility of building the nation. Both Hu Xiansu and Zhu Kezhen emphasized that national defence science should include not only applied sciences but also basic sciences. Tang Miao's article was a condensed version of his speech at a cadre training meeting for Zhejiang Province in which he discussed the advantages and disadvantages of China's vast landscape and abundant resources from a military perspective. In his article, Zou Maotong introduced a vision for telecommunications development during postwar reconstruction.

2.7. Culture Pioneer, 'national defence science special edition' (1944)

Culture Pioneer was founded in September 1942, with Li Chendong (李辰冬) as the editor-in-chief, and distributed by the Culture Pioneer Society of the Cultural Movement Committee of the KMT Central Committee. As a comprehensive journal, it carried political, economic, legal, cultural, educational and philosophical works and translations, as well as natural science articles, literary works, book reviews and reports on cultural news. It also contained articles that slandered the Communist Party.

On 10 October 1944, under the auspices of the Cultural Movement Committee of the KMT Central Committee, an activity related to the National Defence Science Movement was held in Chongqing, the second capital of China at that time. To facilitate that activity, a 'national defence science special edition' was published in volume 4, issue 7 (issue 82 in total) of *Culture Pioneer* (Editorial Department of *Culture Pioneer*, 1944) (Figure 4 and Table 7).

At the time of publication of the *Culture Pioneer* special edition, the National Defence Science Movement had entered its fourth year. The articles in this period no longer appealed to the public to join the movement, but instead focused on special academic reviews and popular science discussions, as well as suggestions for postwar reconstruction.

After China's victory in the Anti-Japanese War, the National Defence Science Movement gradually lost traction. The National Day national defence science exhibition, national defence science speech and other activities continued, but no more 'National Defence Science Movement' special editions were published.

Three of the seven special issues were published in 1941, two in 1942, one in 1943 and one in 1944, indicating a dwindling trend. For the special issues published in 1941 and 1942, most of the authors were high-ranking KMT officials, while some were technological experts; for those published in 1943

Table 6. Articles published in *Zhejiang Youth (Jinhua)*, issue 12, on the National Defence Science Movement.

Author	Author's title	Article title	Page
Hu Xiansu (胡先骕)	Vice President of the International Science Church, member of the Central Research Institute, President of the National Chung Cheng University	The importance of promoting the National Defence Science Movement	14–15
Wang Chuanben (王传本)	Editor-in-chief of *Zhejiang Youth (Jinhua)*	Understanding the National Defence Science Movement	15–17
Zhu Kezhen (竺可桢)	President of the National Zhejiang University[a]	Science and national defence	18–19
Tang Miao (汤淼)	Chief of Staff of the General Command of the 32nd Army Group	The relationship between a vast land with abundant resources and warfare	20–26
Zou Maotong (邹茂桐)	Director General of the Zhejiang Telecommunications Administration Bureau	National defence and telecommunications	27–29

[a]Now Zhejiang University.

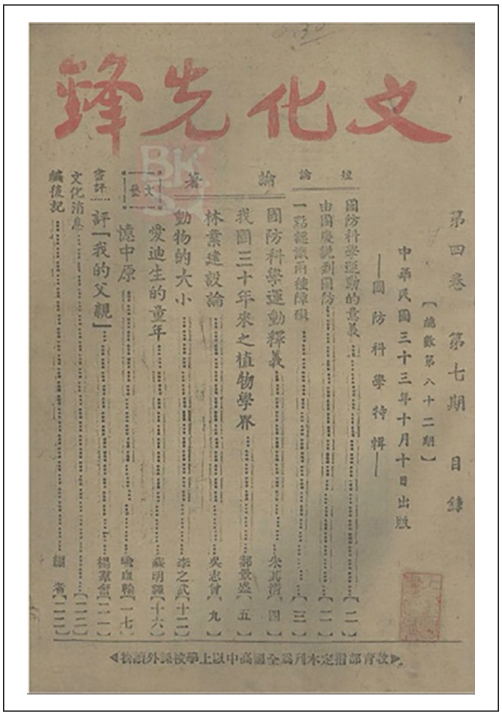
文化先鋒
第四卷 第七期 目錄
（總數第八十二期）
中華民國三十三年十月十日出版
—國防科學特輯—
國防科學運動的意義……（二）
由國慶說到國防……（二）
一點經驗兩種障碍……（三）
國防科學運動釋義……（四）
我國三十年來之植物學界……（五）
林業建設論……（九）
動物的大小……（十二）
愛迪生的童年……（十六）
憶中原……（一七）
書評 評「我的父親」……（二一）
文化消息……（二三）
編後記……編者（二三）
教育部指定本刊為全國高中以上學校課外讀物

Figure 4. Contents of *Culture Pioneer*, volume 4, issue 7.

and 1944, the authors were mainly scientists, and government officials were in the minority. Judging from the titles of the articles, those written by government officials were more macroscopic, whereas those written by scientists often focused on specific sciences and addressed specific issues in depth. In their content, the early articles generally called on all sectors of society to stress science and on young people to delve into the sciences, while the later articles principally explored specific scientific knowledge and reviewed academic history.

The campaign initiated by the top leaders of the National Government began with vigour and vitality, endorsed by the heads of various government departments, who wrote copious articles. However, with the passage of time, the number of special issues declined; fewer articles were contributed by senior officials, and most of the authors were technological experts. The enthusiasm of the movement also cooled down. We can see that the formal movement failed to take root amongst the people, which made it harder to accomplish the goal of the movement as proposed by Chiang.

3. Scientific topics in the special issues on the National Defence Science Movement

The articles in the special issues on the National Defence Science Movement mainly discussed topics such as the meaning and role of science; scientific research; the popularization of science; and science and technology awards.

Table 7. Articles published in *Culture Pioneer*, volume 4, issue 7, on national defence science.

Author	Author's title	Article title	Page
Zhu Qiqing (朱其清)	Special Committee Member of the National Resources Committee	Explaining the National Defence Science Movement	4
Hao Jingsheng (郝景盛)	President of the Institute of Botany, Peking Academy	A thirty-year history of the botanical circle in China	5
Wu Zhizeng (吴志曾)	Researcher at the Central Agricultural Laboratory	On forestry development	9–11
Li Zhiwu (李之武)	Researcher at the National Jiangsu Medical College[a]	The size of animals	12–15

[a]Now Nanjing Medical University.

3.1. Discussing the meaning and role of science

Giving the definition of science. Pan's (1941) article pointed out that 'science is systematic knowledge' and that 'science is what's summarized into principles and becomes systematic knowledge by analysing and proving the causal relationship of all phenomena in the universe based on facts'.

Promoting the role of science. The positive role of science was affirmed. For example, mathematician Sun (1942a) stated in 'Science and national defence' that scientific development had a direct impact on modern warfare, such as by increasing traffic and transportation capacity, enhancing military contact capability and increasing the destructive capacity of weapons. Scientific methods could improve productivity and work efficiency and avoid waste when managing manpower and material resources with science and technology. At the same time, science also had some negative effects and was regarded as a double-edged sword. Zhang (1942) mentioned in his article that science was not only an instrument to save people, but also a tool to kill people.

3.2. Advocating scientific research

The value of scientific research in national defence was affirmed. Zhang (1942) believed that there were two key points in developing the National Defence Science Movement. The first was to develop advanced scientific research. To that end, it required experts and scholars to take great pains with in-depth scientific research 'in order to obtain unique specialties and inventions with outstanding achievements in theory and practice'. Using the vivid example of the Japanese attack on Shanghai on 28 January 1932, Zhang (1941c) warned young people that science, not iron and blood, was what Chinese people should rely on to safeguard their homeland. In order to enhance national defence, the key point was to improve scientific research. Wang (1942) also emphasized that national defence and science were inseparable. In 'Explaining the National Defence Science Movement', Zhu (1944) stressed that the purpose of the National Defence Science Movement was not to reveal national defence secrets but to strengthen research on national defence science. In 'The National Defence Science Movement and national defence development', Gu (1942) pointed out that an important task of the National Defence Science Movement was to strengthen research on national defence science and technology.

3.3. Emphasizing the popularization of science

Many scholars believed that one way to carry out the National Defence Science Movement was to promote the popularization of science. In 1942, when Li Siguang broadcast 'On scientific national defence' on Guilin radio station, he stated that the 'scientific process of national defence means to make the national society more scientific' so that people could understand the great power of science (see Li, 1942). Zhang (1942) wrote that there were two points to develop the National Defence Science Movement, one of which was spreading scientific knowledge amongst the people so as to motivate them to learn and apply science. Wang (1942) also stated that the construction of national defence was a comprehensive work; that is, it was necessary to promote the scientific spirit amongst the Chinese people.

3.4. Calling for the establishment of science and technology awards

The importance of establishing science and technology awards was emphasized. For example, the editorial of *Guilin Li Bao* on 10 October 1942 provided three specific suggestions for promoting the National Defence Science Movement (see Li, 1942). The first one was to respect scientific researchers, which could be achieved by government rewards and funds to support researchers and by setting up research institutes and providing regular funding. Only when scientific researchers had stable lives and experimental tools could their research be facilitated. In 'Science and national defence', Zhu (1943) wrote that, in order to consolidate national defence, the government should reward not only research in applied science but also research in natural science. He noted the value of natural science research to national defence and called for establishing awards for scientific research as soon as possible.

In 1943, responding to appeals from the scientific community, the National Defence Science and Technology Promotion Committee offered a reward of 1 million yuan to address the need for national defence and resolve technical difficulties. It looked for answers to 10 major questions: methods for direct nickel plating of steel; the recovery of rubber from used tires; synthetic rubber and rubber substitutes; the manufacturing of steel wheels for railway locomotives; high-temperature cylinder oil; large-scale urea extraction; gasoline concentrates; fireproof coatings; alcohol-resistant coatings; and welding rods (Anonymous, 1943). The 10 special research fields involved the chemical and energy industries, which were both extremely important in wartime. In 1944, the Central Cultural Movement Committee set up the award to honour people making contributions to national defence science. Shan Zongsu (单宗肃), an associate engineer of the No. 2 Factory of the Central Electrical Equipment Factory, who invented the 3Ca3-type electron tube, and Tang Jiazhen (汤家桢), an apprentice from the No. 4 Factory of Kunming, who designed a coiler for square copper wire, won the certificates (Editorial Department of *Electrical Communication*, 1944).

3.5. Introducing knowledge of science and the history of science

Articles published in the 1943 and 1944 special issues began to spread scientific knowledge. 'The size of animals' by Li (1944) was written to popularize science. It mainly discussed the size of animals' bodies and the impacts of various natural forces on creatures of different sizes. Li concluded that every animal with a certain shape has a most appropriate size, which is determined by physical factors and limited by the animal's biological cycle and natural environment, and noted that the natural conditions and social systems of a country make an impact on its development.

Some articles also attempted to introduce knowledge of the history of science. In 'A thirty-year history of the botanical circle in China', Hao (1944) discussed the history of botanical research in China. He first introduced the practice of botanical research in ancient China, and then divided the history of botanical science during the Republic of China into four stages: the period of translation and assimilation from 1911 to 1918, the period from 1919 to 1929, the period of research and creation from 1930 to June 1937 and the period of suffering from July 1937 to 1944. Hao also listed the leading botanical research institutions, publications and botanists in China.

4. The value of the special issues on the National Defence Science Movement

The publication of the special issues on the National Defence Science Movement had great value in various aspects.

4.1. Emphasizing the value of science and publicizing the idea of 'saving the country through science'

The disparity in military strength between China and Japan in the early and middle period of the Anti-Japanese War made people aware of the backwardness of China's military as well as its science and technology. In view of that, many authors emphasized the importance of science with indisputable facts and then called on the government to promote the popularization of science and establish awards for scientific research. They believed that science was the only way to save the nation. Cheng (1941b), who assisted Hu Xiansu in founding Chung Cheng University at that time, published 'National defence modernization and the youth of our times'. He noted that the National Defence Science Movement was not only an urgent requirement at that time but also the fundamental basis for China to survive and be independent afterwards. He believed that 'science is the key factor that truly makes the nation self-reliant, independent and free'.

4.2. Encouraging young people to study science and engage in scientific research

Chinese Youth (Chongqing), Jiangxi Youth, Chinese Youth, Xianyou Education and *Zhejiang Youth (Jinhua)* all regarded young people as their main readers. Those journals' special issues on the National Defence Science Movement emphasized the role of science in saving the nation in the war against Japanese aggression, encouraged young people to study science and actively engage in scientific research, and pointed out the direction for enthusiastic young people in the Anti-Japanese War.

Bai (1941) believed that young people at that time had two tasks: on the one hand, they should fulfil their duty as Chinese citizens in the Anti-Japanese War; on the other hand, they should study and work hard on national defence science to prepare for shouldering heavy responsibilities in the future.

Huang (1941), known as the founder of air defence in China, wrote in 'Modern youth and modern national defence' that 'what China lacks most at present is science, and young people, as the middle force of the country, should aim to do great things rather than pursue high posts. It is best for them to become scientists and shoulder the responsibility of building a new China.'

Cheng (1941b) required young people to re-understand the world and develop a correct attitude towards science. He encouraged youths to change their traditional view of science and intensify their learning of scientific knowledge and skills. He hoped that young people could promote science amongst the public through propaganda speeches.

In 'The National Defence Science Movement and national defence development', Gu (1942) stated that an important task of the National Defence Science Movement was to encourage the youth of the whole country to participate jointly in national defence construction.

In 'Explaining the National Defence Science Movement', Zhu (1944) encouraged young people to engage in scientific research and strengthen their technical skills. Jian (1941) pointed out that, in order to make China a country with modern national defence, Chinese youth must study basic science, including mathematics, physics and chemistry. Zhou (1941) also reminded young people of the significance of national defence science. In 'The importance of promoting the National Defence Science Movement', Hu (1943) advocated that young students be mobilized to study national defence science in order to train a large number of talented people in the fields of national defence science and technology.

In addition to the special issues on the National Defence Science Movement, ordinary youth publications also encouraged young people to engage in scientific research. For example, *Chinese Youth (Chongqing)*, volume 4, issue 6, 1941, illustrated four life paths that Chinese youth should choose, one of which was to become a person immersed in national defence science (Figure 5).

4.3. Emphasizing the importance of basic science and social science in national defence construction

In the National Defence Science Movement, many exhibitions of national defence science were held in

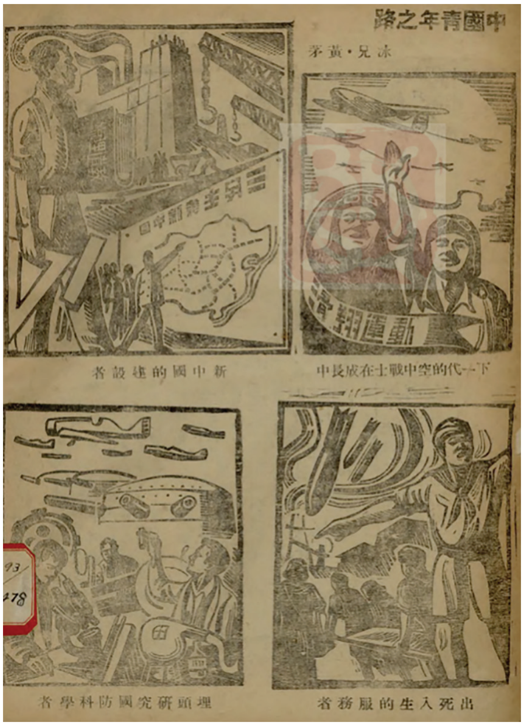

Figure 5. 'Four life paths of Chinese youth', page 4 of *Chinese Youth (Chongqing)*, volume 4, issue 6, 1941.

many provinces and cities across China, with a focus on displaying weapons, military machinery and communication equipment. The exhibitions promoted people's understanding of the importance of 'hard' sciences, such as mechanical engineering, electronics and communications. However, in the special issues on the National Defence Science Movement, a number of scientists wrote articles on the importance of basic science, social science and even art in the war and national defence.

As the backbone of the Chinese Scientization Movement, Gu (1941) pointed out in 'Youth participating in the National Defence Science Movement' that researchers in natural sciences could concentrate on inventing new weapons, while those in social science could use their strengths in the areas of organization and efficiency. Natural scientists were responsible for instrumentalization, while social scientists were responsible for application. Those who studied literature and art could also contribute to national defence by using their strengths scientifically.

Geologist Weng (1941) showed his profound understanding of national defence science and emphasized the importance of pure science as basic science in 'What is national defence science?'. He believed that the science of manufacturing weapons was related to national defence and that administrative institutions, people training, financial policies and financial schemes were indispensable for national construction, along with mechanical engineering, chemical engineering and military manufacturing research. He concluded that all sciences were related to national defence, including basic applied science, pure science and social science.

Wang (1941) held that national defence science should be divided into general national defence science and special national defence science. The research on the former involved multiple topics, such as literature, history, geography, population, economics, industry, transportation, national spirit, international science, politics and propaganda, while studies on the latter involved the national defence characteristics of various regions and countries in the world.

Zhou (1942) wrote that national defence science was the foundation of sound national defence and could be divided into spiritual national defence science, such as philosophy, and material national defence science, which was based mainly on natural science. Spiritual national defence science took national will as its backbone, and the government should carry out spiritual mobilization, promote national education and enhance people's levels in that regard.

Hong (1942) also stressed that only the development of science could guarantee the survival of the country. China should develop not only natural sciences such as mechanical engineering, electrical engineering and mining science, but also social sciences such as law, politics and economics. Only with sound politics could the country develop national defence.

Hu (1943) advocated that, in order to study national defence science, people should engage in national defence science in a broad sense by learning not only aviation and mechanics but also mathematical physics and chemistry. Young students were encouraged to study national defence science and also learn science indirectly related to national defence science, such as agricultural science, engineering, geology, meteorology, mining, metallurgy, nutrition, national defence geography, economic geography and so on.

Tang (1943) wrote about the characteristics of modern warfare in 'The relationship between a vast land with abundant resources and warfare' and emphasized the important role of social science in developing military tactics.

4.4. Explaining the role of various disciplines in the construction of national defence

Against the background of the National Defence Science Movement's advocacy of applied science, many scientists engaged in basic science wrote articles to emphasize the values of their disciplines and make the public aware of the role of basic science in the construction of national defence.

For example, in 'Science and national defence', Zhu (1943) listed the values of various natural science researchers to national defence: mathematicians could use analytical geometry to determine the position of shells in flight; physicists could track German submarines through the vibrations of quartz plates; chemists invented mustard gas and substitutes for rubber used in war; biologists refined the nutrients and medicines needed by people in war; geologists searched for and developed minerals and energy sources needed in war; meteorologists predicted weather; and so on.

The role of geography. Geographer Hu's 'National defence development and economic geography' (1941) listed three important elements in economic geography (rice and food; cotton and clothing; coal and industry), illustrating the importance of economic geography in the construction of national defence. In 'Geography and national defence', Hu (1942) pointed out that geographical knowledge, especially knowledge of frontier geography, was needed in the building of national defence facilities, economic construction, industrial and mining development, agriculture, forestry, aquaculture, commercial distribution and population surveys, and that geographical knowledge would also affect international issues and foreign policies.

Geographer Li (1941) indicated in 'National circumstances and national defence' that the situation of a country should include two parts: the innate conditions of a country, including its location, area, shape, topography, climate and minerals; and its acquired elements, including its population, nationality and national organizational ability. The enhancement of national strength equalled the strengthening of national defence.

The role of geology. Geologists Zhu and Zhang (1942) jointly wrote 'Geology and national defence', which listed the minerals needed in national defence and emphasized the importance of geology. They stressed that a country rich in minerals is bound to be prosperous and strong and suggested opening up mines as early as possible in order to make the best use of China's minerals and win victory in the Anti-Japanese War.

The role of chemistry. In 'Chemistry and national defence', chemist Gao (1942) listed the chemicals used in the war, pointed out that 'there would be no national defence without chemistry', and stressed the influence of chemistry on national defence.

The role of biology. In 'Biology and national defence', biologist Ouyang (1942) divided science into two parts (theoretical science and applied science) that were equally important to national defence. Biology was a basic science, the importance of which in national defence had long been ignored. Ouyang also outlined the role of science in treating wounded soldiers, improving soldiers' nutrition and enhancing their combat effectiveness and called on people to recognize the value of biology.

The role of psychology. In 'Psychology and national defence', psychologist Xiao (1942a) highlighted the importance of psychology to national defence, mainly in three aspects: choosing military personnel, improving training and increasing publicity.

The role of astronomy. In ‘Astronomy and national defence’, astronomer Pan (1942) argued that, although astronomy is a pure science, its role in the Anti-Japanese War should not be ignored. For example, astronomy could be used in military navigation and positioning, precise timing, predictions of the impacts of solar activity on military radio, the impact of tides on terrain, and the impact of moon phase changes on night marching operations, all of which proved the value of astronomy in national defence.

The role of sport education. In ‘National defence and youth sports’, sports educator Cheng (1941a) introduced the relationship between youth sports training and military training, and between national defence and nationality. He put forward the principles and policies of sports education in the context of national defence, summarized the content of sports teaching materials for national defence purposes with diagrams and charts, and cited the examples of throwing, climbing, crawling, rolling, long jump, high jump, sandbag, swimming, and other sports. Towards the end of the article, he also underscored the importance of sports in the Anti-Japanese War.

4.5. Looking forward to postwar reconstruction and providing reconstruction proposals

In the special issues published in 1943 and 1944, some scholars began to consider postwar reconstruction.

Zou Maotong graduated from Shanghai Jiaotong University and later studied at the Marconi Radio School in the United Kingdom. In 1943, Zou, who was then the Director General of Zhejiang Telecommunications Administration Bureau, introduced the important role of telecommunications in peacetime and wartime (Zou, 1943). He reviewed the 60-year history of China’s telecommunications industry and assessed the serious damage to China’s telecommunications facilities and shortage of telecommunications specialists caused by the Anti-Japanese war. He called on the country to redouble efforts in postwar reconstruction to develop a sound civilian telecommunications industry based on the construction of the military telecommunications network.

In ‘On forestry development’, Wu (1944) discussed the importance of forests to the country’s prosperity and strength, presented data on the situation of China’s forest resources and proposed concrete means to promote forestry development in China. The basic principles included focusing on national defence and people’s livelihoods, putting the economy and rapid development first and pooling research resources and talent. The specific methods included comprehensive afforestation, strict management, technology-based operation and industrialized utilization. The key policies included expanding forestry education, fostering the research spirit and perfecting the administrative system. Wu also reviewed forestry development in the Republic of China period and made some forecasts.

5. Conclusion

The seven special issues of journals and newspapers on the National Defence Scientific Movement took national defence construction as a turning point, set great store on science in modern national defence and national construction, and propagated the idea of ‘saving the country by means of science’. In a context in which applied science was valued but basic science was undervalued, the articles reiterated the significance of ‘soft’ sciences such as basic sciences and social sciences and explained how different disciplines functioned in national defence construction. They also envisaged postwar reconstruction plans in telecommunications, forestry and other industries and encouraged young people to study scientific knowledge, actively engage in scientific research and take action to implement the concept of ‘saving the country by means of science’. The publication of the special issues raised the status of science to some degree, especially the status of basic disciplines and social sciences, and thus played a positive role in encouraging young people to devote themselves to scientific research.

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References

Anonymous (1943) National Defence Science and Technology Promotion Committee call for answers. *Xinhua Daily*, 26 September (in Chinese).

Bai CX (1941) How to cultivate the voluntary spirit of young people. *Jiangxi Youth* 3(2): 9–10 (in Chinese).

Chen S (2007) *Research on the Chinese Scientization Movement*. PhD Thesis, Peking University, China (in Chinese).

Cheng DK (1941a) National defence and youth sports. *Chinese Youth (Chongqing)* 4(3): 33–40 (in Chinese).

Cheng SK (1941b) National defence modernization and the youth of our times. *Jiangxi Youth* 3(2): 13–14 (in Chinese).

Cheng SY (1941c) Promoting the National Defence Science Movement (Speech on Guilin Radio on 5 May 1941). *Southwest Youth* 2(6): 4–6 (in Chinese).

Chiang K (1941) How to make the whole country a strong fighting machine (Radio address on the second anniversary of the National Spirit Mobilization Campaign on 12 March 1941). *Military Monthly* 3(5): 3–6 (in Chinese).

Chiang K (1942) On the National Defence Science Movement. *National Defence Weekly* 4(8): 2 (in Chinese).

Chongqing Archives (1943) Resolution on mobilizing the youth to build a new China. In: The Minutes of the First National Congress of the KMT Youth League, file no. 0093-0002-00189, pp. 224–231 (in Chinese).

Editorial Department of *Culture Pioneer* (1944) Postscript. *Culture Pioneer* 4(7): 22 (in Chinese).

Editorial Department of *Electrical Communication* (1944) Shan Zongsu and Tang Jiazhen won the national defence science award. *Electrical Communication* (32): 5 (in Chinese).

Editorial Department of *Guangxi Education Communication* (1941) The Central Publicity Department establishes Cultural Movement Committee. *Guangxi Education Communication* 3(3–4): 44–45 (in Chinese).

Gao JY (1942) Chemistry and national defence. *Xianyou Education* (4–5): 4 (in Chinese).

Gu YX (1941) Youth participating in the National Defence Science Movement. *Friends of Students* 2(1): 7 (in Chinese).

Gu YX (1942) The National Defence Science Movement and national defence development. *Central Daily and The Sweep*, 10 October, p. 6 (in Chinese).

Guang H (1936) Establishing national defence science: The responsibility of scientists. *Popular Culture: Politics, Economy, Science, Engineering Semi-Monthly* 4(4): 16–17 (in Chinese).

Guo SZ (1941) The National Defence Science Movement and the development of China's new air force. *Chinese Youth* (3): 12, 18 (in Chinese).

Hao JS (1944) A thirty-year history of the botanical circle in China. *Culture Pioneer* 4(7): 5 (in Chinese).

Hong LY (1942) National defence science and the spirit of 'rule of law'. *Central Daily and The Sweep*, 10 October, p. 7 (in Chinese).

Hu HY (1941) National defence development and economic geography. *Chinese Youth (Chongqing)* 4(3): 25–27 (in Chinese).

Hu HY (1942) Geography and national defence. *Xianyou Education* (4–5): 5–6 (in Chinese).

Hu XS (1943) The importance of promoting the National Defence Science Movement. *Zhejiang Youth (Jinhua)* (12): 14–15 (in Chinese).

Huang ZQ (1941) Modern youth and modern national defence. *Jiangxi Youth* 3(2): 11–12 (in Chinese).

Ji YP and Dai JT (1942) The preconditions for the development of national defence science. *Central Daily and The Sweep*, 10 October, p. 7 (in Chinese).

Jia XH (2003) The scientization movement from the perspective of the *Ta Kung Pao*. *Journal of Dialectics of Nature* 25(3): 26–30, 109 (in Chinese).

Jia XH (2005) Characteristics of 'saving the country by means of science' and its modern value: Taking the scientization movement in the 1930s as an example. *Science, Technology and Dialectics* 20(1): 91–97 (in Chinese).

Jian GS (1941) China's National Defence Science Movement: Past and future. *Chinese Youth (Chongqing)* 4(3): 53 (in Chinese).

Li W (1942) The National Defence Science Movement. *Analysis of Current Affairs* (51): 27–30 (in Chinese).

Li XD (1941) National circumstances and national defence. *Chinese Youth (Chongqing)* 4(3): 28–32 (in Chinese).

Li ZF (2012) *Gu Yuxiu and the Chinese Scientization Movement*. Master's Thesis, Central China Normal University, China (in Chinese).

Li ZW (1944) The size of animals. *Culture Pioneer* 4(7): 12–15 (in Chinese).

Liu XM (1987) A study on the Chinese Scientization Movement. *The Chinese Journal for the History of Science and Technology* 8(2): 21–29 (in Chinese).

Ouyang Z (1942) Biology and national defence. *Xianyou Education* (4–5): 4 (in Chinese).

Pan GZ (1941) Youth in the National Defence Science Movement. *Jiangxi Youth* 3(2): 1–6 (in Chinese).

Pan P (1942) Astronomy and national defence. *Xianyou Education* (4–5): 6 (in Chinese).

Peng GH (1992) The establishment, activities and historical status of the Chinese Scientization Movement Association. *The Chinese Journal for the History of Science and Technology* 13(1): 60–72 (in Chinese).

Qiu GZ (1940) *From National Defence Science to Comprehensive Air Defence*. Special issue in commemoration of the Air Defence Festival, edited by Inspectorate of Air Defence, Aviation Committee. Lihuang: Anhui Printing Bureau, pp. 72–75 (in Chinese).

Sun GY (1942a) Science and national defence. *Xianyou Education* (4–5): 3–7 (in Chinese).

Sun K (1942b) Promoting national defence science and national defence development. *Central Daily and The Sweep*, 10 October, p. 6 (in Chinese).

Tang M (1943) The relationship between a vast land with abundant resources and warfare. *Zhejiang Youth (Jinhua)* (12): 20–26 (in Chinese).

Wang B (2019) *Study on the Movement of Natural Science Popularization in the Shaan-Gan-Ning border region during the Anti-Japanese War*. Master's Thesis, Northwest University, China (in Chinese).

Wang CH (1942) National defence development and scientific spirit. *Central Daily and The Sweep*, 10 October, p. 6 (in Chinese).

Wang SZ (1941) On the National Defence Science Movement. *Chinese Youth* (3): 7 (in Chinese).

Weng WH (1941) What is national defence science. *Jiangxi Youth* 3(2): 7 (in Chinese).

Wu TC (1942) Promoting the spirit of national defence science. *Central Daily and The Sweep*, 10 October, p. 7 (in Chinese).

Wu ZZ (1944) On forestry development. *Culture Pioneer* 4(7): 9–11 (in Chinese).

Xiao XR (1942a) Psychology and national defence. *Xianyou Education* (4–5): 5 (in Chinese).

Xiao Z (1942b) A basic condition for national defence development. *Central Daily and The Sweep*, 10 October, p. 7 (in Chinese).

Yu QJ (1941) The navy and modern warfare. *Chinese Youth* (3): 13 (in Chinese).

Zhang DF (1942) The significance of the National Defence Science Movement. *Central Daily and The Sweep*, 10 October, p. 6 (in Chinese).

Zhang XY (1941a) On the construction of national defence and railway forces. *Chinese Youth* (3): 14–15 (in Chinese).

Zhang ZZ (1941b) The youth and the National Defence Science Movement. *Chinese Youth* (3): 8–9 (in Chinese).

Zhang ZZ (1941c) The youth and the National Defence Science Movement. *Chinese Youth (Chongqing)* 4(3): 2–9, 23 (in Chinese).

Zheng HQ and Huang LR (2014) *China Wartime Capital Archives: Wartime Movement (I)*, edited by Tang RM. Chongqing: Chongqing Press, pp. 315–320 (in Chinese).

Zhou ZF (1941) China's National Defence Science Movement: Past review and future prospects. *Chinese Youth* (3): 10–11 (in Chinese).

Zhou ZY (1942) National Defence Science Movement: Past and future. *Central Daily and The Sweep*, 10 October, p. 7 (in Chinese).

Zhu JH (1941) The youth and national defence. *Jiangxi Youth* 3(2): 8 (in Chinese).

Zhu KZ (1943) Science and national defence. *Zhejiang Youth (Jinhua)* (12): 18–19 (in Chinese).

Zhu QQ (1944) Explaining the National Defence Science Movement. *Culture Pioneer* 4(7): 4 (in Chinese).

Zhu S and Zhang G (1942) Geology and national defence. *Xianyou Education* (4–5): 5–6 (in Chinese).

Zou MT (1943) National defence and telecommunications. *Zhejiang Youth (Jinhua)* (12): 27–29 (in Chinese).

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Article

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Born to do science? A case study of family factors in the academic lives of the Chinese scientific elite

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Abstract

Primarily based on data collected by the Project for Collecting Historic Data of Scientists' Academic Life, this paper sets out to analyse the cultural and social role of family factors in the academic lives of three prominent scientists: He Zehui, Wang Shouwu and Wang Shoujue. It was found that, while providing economic support, in the cultural dimension, their family conveyed the idea of saving the nation through science and industry, offered guidance on research career planning and cultivated the concept of feminism; in the social dimension, the three scientists clearly benefited from the academic power and social networks of their family members. This case study of a Chinese scientific family reveals an integration between Western scientific culture and Chinese family culture, and extracts some family factors that have great influence on the academic lives of the scientific elite.

Keywords

He Zehui, Wang Shouwu, Wang Shoujue, family factors, Chinese scientific elite

In the study of the scientific community, sociologists of science have paid attention to the influence of the family in the academic lives of the scientific elite. With regard to financial conditions, researchers have pointed out that in the United States, as well as in China before the war against Japan, a good family income provided a relatively good start for children to engage in scientific research, but that such influence weakened in China once the war began (Andreas, 2009: 22; Bai, 2007: 13–25; Cao, 2004: 77–83; Zukerman, 1977: 63–68). Bourdieu (1986) divided a family's education capital into economic, cultural and social capital. It is the task of historians of science to show how the cultural and social capital of families affects the academic lives of outstanding scientists. In answering that question, one dilemma lies in the fact that it is often difficult to clearly distinguish the influence of family factors from the influence of other factors when tracing the academic life of an individual scientist. As a result, the role of the family may be easily exaggerated or ignored. To address this deficiency, one possible approach is to explore what elite scientists from the same family, namely the scientific family, have in common in their access to family cultural and social capital.

During the development of modern science in China, several scientific families that reconciled the characteristics of the traditional Chinese family under the imperial civil examination system and the Western scientific family emerged. In this

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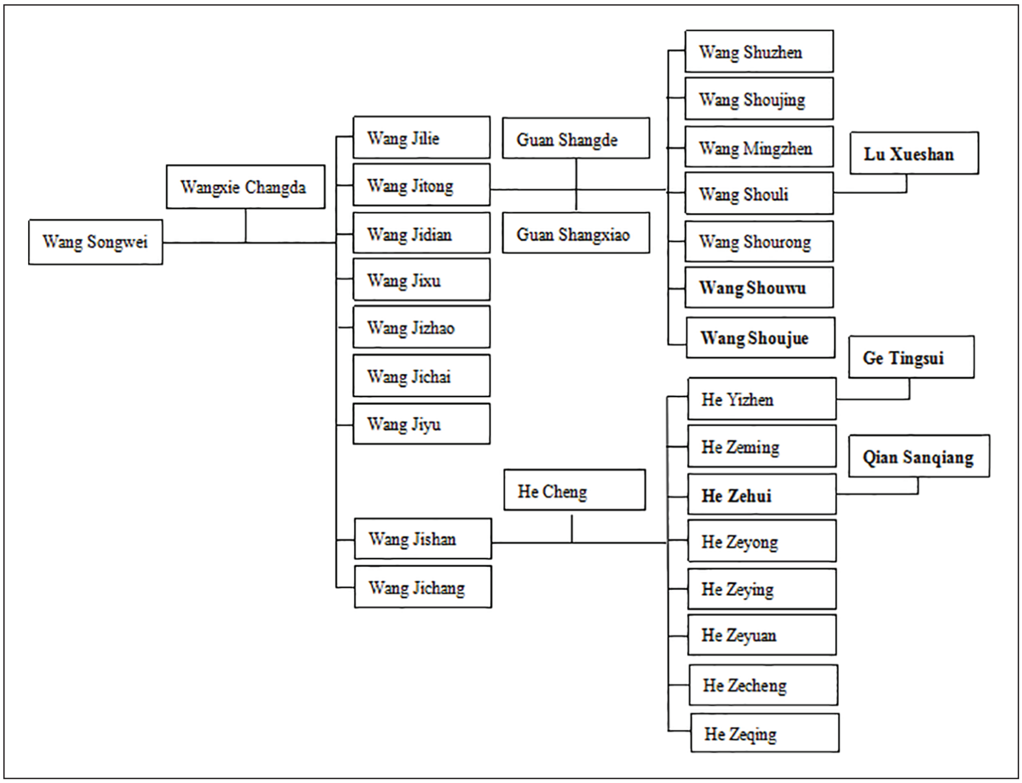


Figure 1. Positions of He Zehui, Wang Shouwu and Wang Shoujue in their family pedigree (names in bold are CAS members).

paper, I have selected the Wang–He family (Figures 1 and 2), the largest scientific family in China, for a case study. The core members of the family were in the lineage of Wang Jitong, son of Wang Songwei, and the lineage of Wang Jishan, daughter of Wang Songwei. Among Wang Jitong's children, Wang Shouwu, Wang Shoujue and Wang Shouli's husband Lu Xueshan were all members of the Chinese Academy of Sciences (CAS); among Wang Jishan's children, He Zehui and her husband Qian Sanqiang and He Yizhen's husband Ge Tingsui were CAS members. Based on oral history, letters, manuscripts and other forms of data on He Zehui[1], Wang Shouwu[2] and Wang Shoujue[3] from the Project for Collecting Historic Data of Scientists' Academic Life (PCDS), this research analyses family influences on these three scientists and sheds light on the cultural and social role of the family in the lives the scientific elite.

1. Cultivation of the idea of saving the country through science

After inductive science was introduced into China in the 19th century, local actors in China's scientific development often took a strong patriotic and collectivist stance (Wang, 2019a). In the specific case of He Zehui, before she and her husband returned to China to devote themselves to science and technology for national defence, she had shown her determination to fight against Japanese aggression using her knowledge of ballistics.[4] Naturally, this could be attributed to the wider idea of 'scientific nationalism' (Wang, 2002), especially the idea of 'studying hard to save the country', which she accepted at Tsinghua University (Peng et al., 1994). However, we should not ignore that she had already displayed a rational tendency to patriotism before entering university. When the Japanese marine corps landed in neighbouring Shanghai in 1931, there

Figure 2. A group photo of the Wang–He family in 1931, showing Wangxie Changda (in the middle); Wang Shouwu (second from left), Wang Shoujue (third from left) and Wang Shourong (third from right) in the front row; and He Zehui (first from left), He Yizhen (third from left), Guan Shangxiao (fourth from left), Wang Shouli (fifth from left), He Cheng (second from right), Wang Jitong (third from right), Wang Shoujing (fifth from right), Wang Jishan (sixth from right) and Wang Jiyu (seventh from right) in the back row (Source: PCDS).

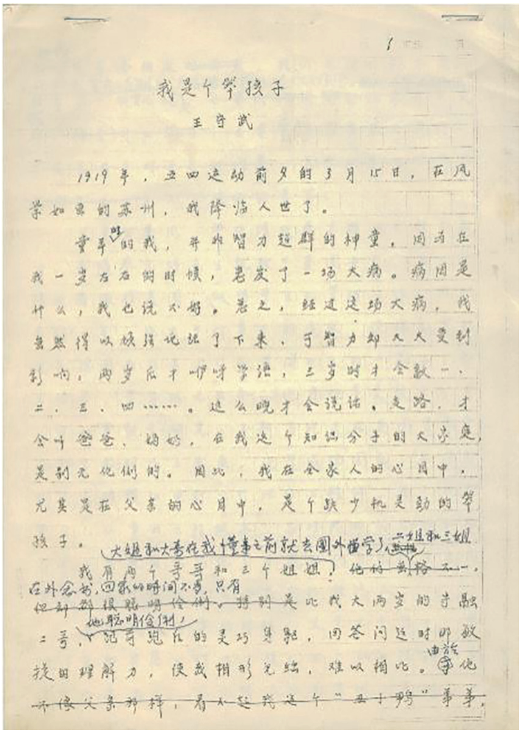
were some pessimistic voices in Suzhou. But Zehui wrote that such pessimism was useless and that people should instead 'think of ways to save our country and compatriots' (He, 1931).

Before going to university in 1932, Zehui had studied in Zhenhua Girls' School in Suzhou, which was founded by her maternal grandmother, Wangxie Changda and headed by her aunt, Wang Jiyu. As a result, her thoughts were deeply affected by family culture via both family and school education. Her maternal grandfather, Wang Songwei advocated fighting against foreign aggression in the late Qing Dynasty and died in sorrow after China's defeat in the First Sino-Japanese War.[5] Her father, He Cheng, an early member of the Chinese Revolutionary League, once studied in Japan and had a strong sense of national salvation. Members of Zehui's family generally had high levels of education. Meanwhile, her aunts – Wang Jizhao, Wang Jichai and Wang Jiyu – all went to study in the United States. Among them, Wang Jichai was the first Chinese female doctor in chemistry (Kang and Li, 2012). Before Zehui went to university, her eldest sister, He Yizhen, had already graduated from Ginling College in 1930 and went to study in the United States. Given that Zehui grew up in a family with both scientific and national salvation traditions, it comes as no surprise that she believed in saving the country through science.

Unlike He Zehui, Wang Shouwu and Wang Shoujue lived in Shanghai with their parents during their childhood. Their scientific enlightenment came mainly from their father, Wang Jitong, who was fond of mathematics when he was studying at the School of Combined Learning. Jitong visited the United Kingdom and later participated in the founding of the Academia Sinica. He was accomplished in mathematics and mechatronics and once bought an old hand-held calculator to teach his children mathematics (Wang, 2009). Influenced by the idea of national salvation through industry, the family attached importance to practical activities, and offered 'all kinds of practical facilities to let children play by themselves'. For example, the Wang children used the chime clock at home to understand the operating principle of time telling and made toys and locks with tools and materials that their father brought home from his factory.[6]

One most typical example was light-bulb repair by Shouwu, who was in the fourth grade, and his elder brother Shourong. When they found that a bulb did not work because the filament was broken, they carefully broke the bulb glass and reconnected the filament. However, not only did the bulb fail to work, but all the lights in the house didn't light up. Seeing what had happened, their father explained to them that the lights could not work because the fuse was broken and then told them about the principle of fuses. For Shouwu, this series of exercises and training improved his hands-on ability in scientific research: 'The scientific atmosphere of my family contributed to my interest in natural science, and my knowledgeable father was the person who led me to the world of science' (Figure 3).[7]

As a result, the idea of national salvation through industry was put into practice in the careers of the Wang children. For example, Wang Shoujing, the eldest son, obtained a PhD in physics from Columbia



我是个笨孩子

王守武

1919年，五四运动前夕的3月15日，在风景如画的苏州，我降临人世了。

童年时的我，并非智力超群的神童，因为在我一岁左右的时候，患发了一场大病。病因是什么，我也说不好。总之，经过这场大病，我虽然得以侥幸地活了下来，可智力却大大受到影响，两岁后才咿呀学语，三岁时才会数一、二、三、四……。这么晚才会说话、走路，才会叫爸爸、妈妈，在我这个知识分子的大家庭，是别无他例的。因此，我在全家人的心目中，尤其是在父亲的心目中，是个缺少机灵劲的笨孩子。

我有两个哥哥和三个姐姐，大姐和大哥在我懂事之前就去国外留学了，二姐和三姐在外念书，回家的时间不多，只有~~他们的性格不一，但都很聪明伶俐，特别是~~比我大两岁的守融二哥，他聪明伶俐，[illegible]的灵巧劲，回答问题时的敏捷的理解力，使我相形见绌，难以相比。由于他~~不像父亲那样，看不起我这个"丑小鸭"弟弟，~~

Figure 3. Wang Shouwu's 'I am a silly boy' manuscript (Source: PCDS).

University. He served as Chairman of the Department of Physics of Peking University and participated in preparations to found the Chinese Physics Society. Later, his interest turned to 'work that can make practical contributions to the country' (Wu, 2005), and he also served as the director of the Central Machinery Factory of the Resources Committee of the National Government. Wang Shouwu participated in the preparation of the No. 109 Factory of CAS in the 1950s and had been its director since 1980. Wang Shoujue also worked at the Shanghai Xincheng Electric Appliances Factory in the 1950s.

2. Motivation of feminist consciousness

Another influence of the family culture on He Zehui was the feminist idea of pursuing equality between males and females. It is true that science takes the principle of universalism as its value norm and rejects any restriction on science for any reason other than lack of competence (Merton, 1973: 272). However, obstacles generally exist for females entering, remaining in and advancing in science. Compared with the latter two aspects (the 'pipeline' and 'ceiling' metaphors), the issue of entering science has received less attention but puzzled Zehui and her contemporary Chinese girls.

Take Wang Mingzhen, Zehui's cousin, as an example. Mingzhen's father, Wang Jitong, became a talented scientist through self-study, so he took a position of neither supporting nor opposing his children going to university, while her stepmother refused to pay for her university tuition. When Mingzhen was preparing to cancel a marriage arranged by her stepmother in order to study abroad, her father threatened to break their father–daughter relationship until her elder sister, Wang Shuzhen, came forward to persuade their father. Mingzhen won the first place in the examination of the board of the British Boxer Indemnity Scholarship, but Wu Youxun, who was the director of the question-setting team, considered it a waste of money to send girls to study physics abroad. Consequently, he replaced the first-placed Mingzhen with the second-placed male student. On learning of this, Mingzhen dared not protest, 'because I know that they would not change the list of admitted students . . . they have the power, and I have to accept it' (Wang, 2006). Fortunately, Mingzhen was awarded a Barbour Scholarship to study at the University of Michigan, and her joint paper (with her supervisor) on Brownian motion had a great impact.

By contrast, He Zehui had a keen awareness of gender discrimination at an early stage and resisted it through concrete actions. After Zehui was admitted to the Department of Physics of Tsinghua University, Ye Qisun, the departmental head, who was of the 'old feudal guard' in the eyes of Zehui, at first refused to accept female students and only changed that position because of a hard struggle by Zehui and her classmates (Zhang, 2006). After that, Zehui proved herself through outstanding study and research performance. Recalling Zehui's significant scientific discoveries, Qian Sanqiang repeatedly

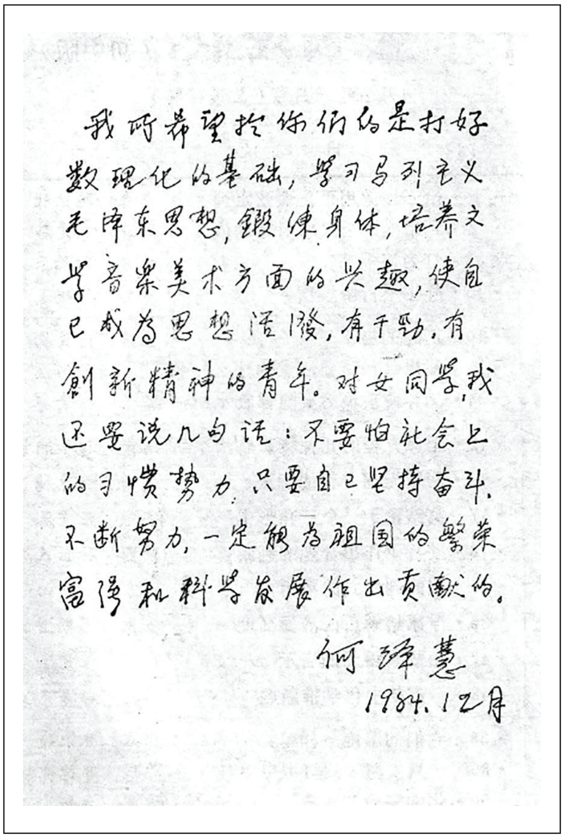

我所希望於你们的是打好
数理化的基础，学习马列主义
毛泽东思想，鍛煉身体，培养文
学音乐美术方面的兴趣，使自
已成为思想活潑，有干勁，有
創新精神的青年。对女同学，我
还要说几句话：不要怕社会上
的习惯势力，只要自己坚持奋斗，
不断努力，一定能为祖国的繁荣
富强和科学发展作出贡献的。
何泽慧
1984.12月

Figure 4. Manuscript of He Zehui's message to teenagers (Source: PCDS).

praised her 'keen and meticulous observation ability, exploration spirit of not letting go of any abnormal signs in scientific experiments, and skills in making correct analyses of new phenomena' (Qian, 1989: 44, 58). In one message she wrote to teenagers in her later years, Zehui especially reminded them that female students 'should not be afraid of the habitual forces in society' (Figure 4).[8]

There is no doubt that Zehui and Mingzhen both had outstanding research capabilities, but they still needed the support of their family to engage in scientific research. Today, when people talk about Zehui's feminist stance, they often associate it with her maternal grandmother, Wangxie Changda, and her Suzhou Zhenhua Girls' School. After the death of her husband, Wangxie Changda moved the whole family to Suzhou, organized a free-the-feet association in Suzhou to lead female opposition to foot-binding, and opened Zhenhua Girls' School to provide education opportunities for girls. However, Mingzhen also benefited from her grandmother Wangxie Changda and Zhenhua Girls' School: when Wangxie Changda saw the 10-year-old Mingzhen dressing her younger brother at home, she asked Mingzhen's stepmother, 'Mingzhen should go to school at this age. How could you leave her at home as a maid?' As a result of such interventions, Mingzhen entered Zhenhua Girls' School (Wang, 2006). From a comparison of the family education of Zehui and Mingzhen, we can conclude that, in addition to the influence of her maternal grandmother and Zhenhua Girls' School, Zehui's awareness of gender equality was inseparable from or, even more importantly, strongly influenced by the support of her parents and aunts.

3. Guidance on research career planning

One important aspect of the Whig history of science in research on elite scientists is the 'deification' of their personalities and the linearization of their academic growth, while ignoring their basic attributes as laymen in the early stages of their careers. In fact, they faced some common problems, such as difficult choices of universities and majors and confusion over the direction of their postgraduate careers. Whether or not their families could offer guidance made a big difference. In Wang Shouli's view, one characteristic of the higher education of the Wang brothers and sisters was unity and mutual assistance: 'the elderly ones help the younger' (Wang, 2009). According to Wang Shoujue's recollection, when he and Wang Shouwu chose their undergraduate university, they were influenced by Wang Shoujing, their eldest brother, who had returned home from a trip to Germany, so they both chose the German-influenced Tongji University.[9]

He Zehui also received guidance from her family. She asked her eldest sister, He Yizhen, who was 4 years older than her, many times for advice on choosing and changing her major subjects. Although

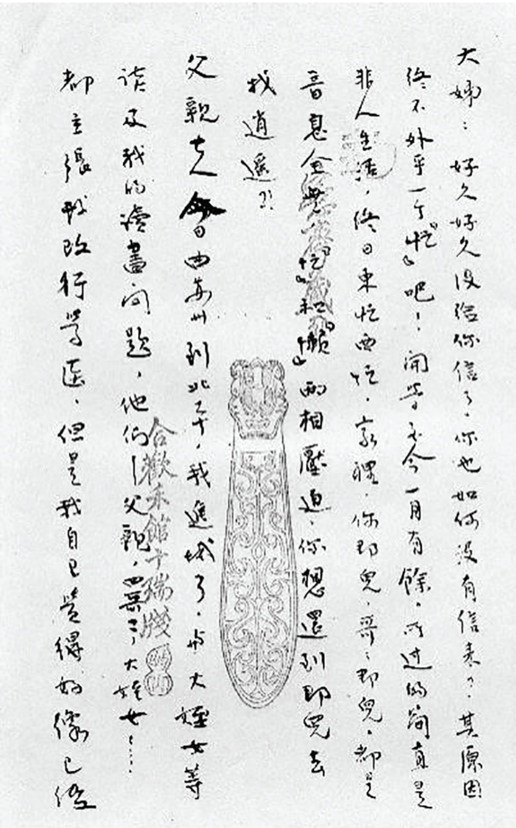

大姊：好久好久沒給你信了，你也如何沒有信來？其原因
終不外乎一个忙吧！開學至今一月有餘，所过的簡直是
非人生活，終日東忙西忙，[illegible]，[illegible]，[illegible]，[illegible]，都是
音息全無，[illegible]而相壓迫，你想還到[illegible]去
找逍遥?!
父親七舍由[illegible]到北平，我進城了，與大姪女等
談及我的讀書問題，他們父親，四哥，大姪女……
都主張我改行学医，但是我自己覺得好像已經

Figure 5. He Zehui's letter to her eldest sister in 1934 (Source: PCDS).

we do not know what advice Zehui got from Yizhen, it is not difficult to understand the importance that Zehui attached to Yizhen's views, given that they both graduated from Zhenhua Girls' School and thus had a similar educational background. For example, Zehui wrote in 1934 (Figure 5):

> My father, fourth eldest brother and eldest niece were of the view that I should change to study medicine, but I think it's too late to do so. What do you think if I change now? . . . If I choose to study medicine, I have to spend at least two more years in university and then take the exam for Peking Union Medical College or other. What do you think of this? I really don't know what to do now. Be **quick** to give me an instruction! Be **quick** to make a decision for me! Anyway, I have wasted this year. If I decide to study medicine, I should work hard on biology and chemistry right away, right?! Now I think that I really should learn medicine. Why haven't I woken up earlier?! Why do I only think of it now?! I've deselected advanced calculus and other courses today and attended the biology course. Don't you think it is not worth it for me? I have wasted two whole years! Please be honest and tell me the truth, **be quick, be quick**.[10]

Of course, Zehui, who came from a highly educated family, also occasionally received advice from family elders with different opinions. In another letter to Yizhen in 1934, she mentioned that her eldest and third eldest aunts both believed that, if she would change her major, that should be done after graduation so as not to affect her subsequent study for a master's degree and PhD. However, Zehui considered that to be an 'absolutely wrong' view, not only because a 'paper diploma' was nothing beneficial to the country, but also because it got the purpose of education 'totally wrong' by seeing getting a degree as the only aim. In her view, the purpose of higher education was not merely to obtain a diploma, but first and foremost to achieve personal development and meet the needs of the country (Wang, 2019b).

We can see that Zehui had begun to accept the opinions of her elders in a rational and critical way. In fact, her aunts, whom she questioned, were already innovators of their times. However, as young people received further modern education, especially scientific education, they challenged the ideas of older generations. In one sense, this also reflected the free and democratic style of Zehui's family education, which left space for revolutionary ideas.

4. Support of academic power and social resources

From her years at Tsinghua onwards, in addition to receiving guidance and advice from her family, Zehui began to benefit from her family's social network. At the Department of Physics of Tsinghua University, Professor Zhou Peiyuan, who had a good personal relationship with Zehui's cousin, Wang Shoujing, treated Zehui 'as his younger sister' and chatted in Suzhou dialect when they met (Peng et al., 1994). When Zehui was preparing to study abroad, her father, He Cheng, counted on his personal friendship with Shanxi governor Yan Xishan to secure a scholarship for her as a female student of Shanxi origin, probably at double the usual value (Liu, 2013: 65). When Yizhen went to visit Zehui in Germany in 1937, she called upon Professor Friedrich Paschen, the teacher of her supervisor (Yin and Li, 2016). Professor Paschen not only invited Zehui to live in his house but also, based on a comprehensive consideration of the war situation in Berlin and the prospect of nuclear physics, introduced her to Professor Walther Bothe of the Kaiser Wilhelm Society in Heidelberg (Liu, 2013: 69–83). At that time, Professor Bothe had established the Institute of Physics under the Medical Research Institute of the Kaiser Wilhelm Society and served as its director. He also built the first particle accelerator in Germany together with Wolfgang Gentner.[11] It was at that time that Zehui began her research in nuclear physics.

Zehui's subsequent academic life was connected with her husband Qian Sanqiang's academic network. After establishing their relationship through letters, Zehui, who was then in Germany, shared with Sanqiang her research on the elastic positron–electron collision phenomenon. In 1945, Sanqiang used the opportunity of resumed scientific exchanges between Britain and France after World War II to introduce Zehui's discovery, which was then billed as 'scientific treasure' by *Nature*, at the British–French Conference on Cosmic Rays. The following year, Zehui's research was read out by Sanqiang at the Royal Society's conference to celebrate the 300th anniversary of Isaac Newton's birth.

In 1946, Zehui married Sanqiang and joined her husband's research group at Collège de France (Figure 6). At the time, Sanqiang was conducting research under the guidance of Irène Joliot-Curie (daughter of Madame Curie) and her husband Jean Frédéric Joliot-Curie. The joint discovery of the quaternary fission of the uranium nucleus by Zehui and Sanqiang was reported by Jean Frédéric Joliot-Curie at a meeting of the college (Qian, 1989: 41–45).

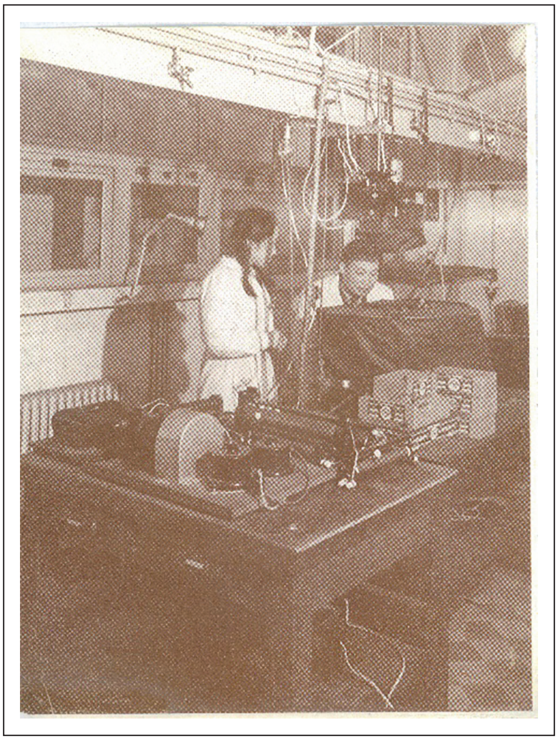


Figure 6. He Zehui and Qian Sanqiang doing experiments at Collège de France (Source: PCDS).

Before Zehui and her husband returned to China in 1948, Sanqiang attracted the interest of Peking University, Tsinghua University, the National Academy of Peiping and other institutions. After consultation between the President of Tsinghua University, Mei Yiqi, and the Vice President of the National Academy of Peiping, Li Shuhua, Sanqiang joined Tsinghua while concurrently serving as director of the newly established Institute of Atomics of the National Academy of Peiping, and Zehui went to the institute as a researcher.[12]

In their academic lives, the Wang brothers also received support from their family members. When the Wang family moved back to Suzhou from Shanghai, it was Wang Jishan, who was then headmaster of Zhenhua Girls' School, who introduced Wang Shouwu to study at Suzhou Middle School. After graduating from Tongji University, Shouwu worked in the Kunming-based Central Machinery Factory where his

Figure 7. Wang Shouwu (right) and Wang Shoujue together at work (Source: PCDS).

eldest brother, Shoujing, was director and his second eldest brother, Shourong, was the sub-factory director. After receiving his PhD in the United States, Shouwu failed to get a university position in China and then joined the Institute of Applied Physics of CAS, where his brother-in-law, Lu Xueshan, was deputy director.[13] Also thanks to Xueshan, the younger brother, Shoujue, was able to work under the guidance of Xueshan in the Crystallography Research Division of the Institute of Physics of the National Academy of Peiping before graduating.[14]

As the Institute of Physics of the Academia Sinica and the Institute of Physics of the National Academy of Peiping were merged into the Institute of Applied Physics of CAS, the Crystallography Research Division moved to Beijing, but Shoujue resigned and stayed in Shanghai. In 1956, Shoujue was transferred back to the Institute of Applied Physics, and then remained in a subordinate relationship with Shouwu: when Shouwu was head of the Semiconductor Research Division, Shoujue was the leader of the semiconductor device group; after the Institute of Semiconductors was established, Shouwu was deputy director for research and Shoujue was head of the Device Research Division (Figure 7).[15]

5. Conclusion

There is undoubtedly randomness in the emergence of scientific families, but their histories nevertheless provide a starting point for observing the influence of the family on scientists. We can see that the elite scientists of the Wang–He family might not have been ‘born to do science’, but they definitely benefited from family support, including but not limited to the economic support, on their way to major scientific achievements (Figure 8). At the cultural level, He Zehui was influenced by the idea of saving the country by science and the idea of feminism, while the Wang brothers cultivated their father’s idea of saving the country through industry and attention to practice. In their educational and research experiences, all three scientists received advice from their family. At the social level, family members fully mobilized their contact networks inside and outside the scientific community when educational and scientific research resources were extremely limited and provided powerful support for them at many key points. These findings have become potential indicators for analysing the family factors of Chinese scientific elites.

The Wang–He family epitomized the naturalization of Western science and culture and the modernization of Chinese family culture. While depending on the family’s atmosphere and social thoughts, the elite scientists could be more independent in their thinking. They would not blindly follow the opinions of their elders, but maintain a sceptically critical attitude towards them. At the same time, females began to pursue the right to equal access to education and research, which could be regarded as a transformation of Chinese family culture under the influence of Western science and culture. In return, given its Chinese context, the social network of family members played a powerful role in the process of individuals’ development, thus naturalizing Western science and culture.

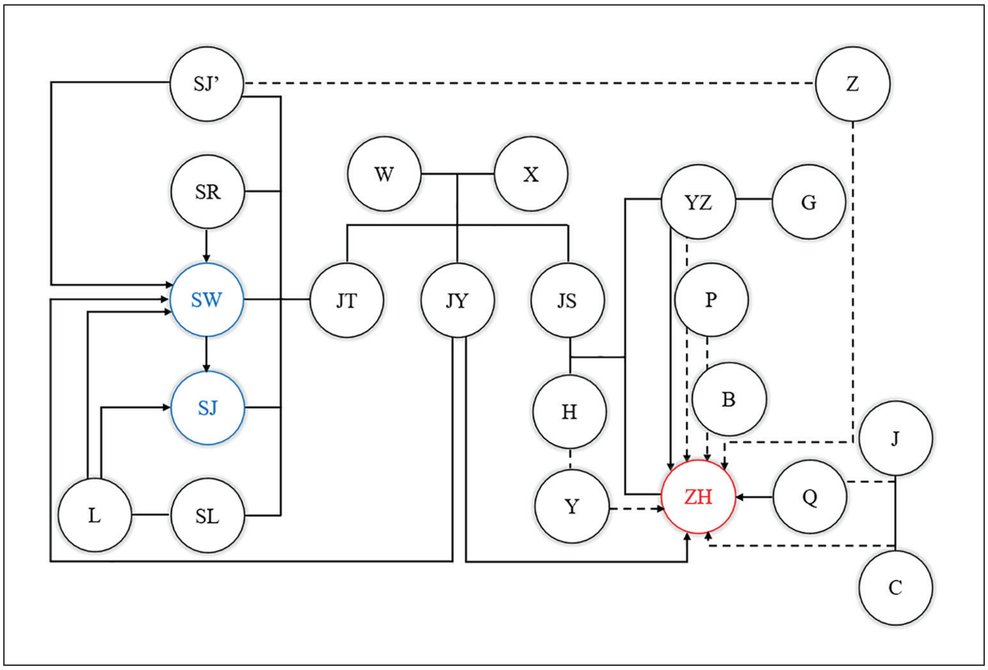


Figure 8. Scientific capital that He Zehui, Wang Shouwu and Wang Shoujue received from their family.
—— Family network - - - - Social network → Scientific capital.
W: Wang Songwei; X: Wangxie Changda; JT: Wang Jitong; JY: Wang Jiyu; JS: Wang Jishan; SJ': Wang Shoujing; SR: Wang Shourong; SW: Wang Shouwu; SJ: Wang Shoujue; SL: Wang Shouli; L: Lu Xueshan; H: He Cheng; Y: Yan Xishan; YZ: He Yizhen; G: Ge Tingsui; ZH: He Zehui; Q: Qian Sanqiang; P: Friedrich Paschen; B: Walther Bothe; J: Irène Joliot-Curie; C: Jean Frédéric Joliot-Curie; Z: Zhou Peiyuan.

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Notes

1. He Zehui (1914–2011), a nuclear physicist, was elected as a CAS member in 1980. Born in Suzhou, Jiangsu Province (native place: Lingshi, Shanxi Province), she studied ballistics at Technische Hochschule Berlin (now Technische Universität Berlin) after graduating from the Department of Physics of Tsinghua University in China in 1936. After receiving a PhD in engineering in 1940, she discovered and studied the elastic electron–positron collision phenomenon at the Medical Institute of the Kaiser Wilhelm Society, Germany. At Collège de France, she and her husband, Qian Sanqiang, jointly discovered and studied the phenomena of ternary and quaternary fission of the uranium nucleus. In 1948, she returned to China and participated in the establishment of the Institute of Atomics of the National Academy of Peiping. In the 1950s, she successfully developed a nuclear emulsion that reached the international advanced level. She served as deputy director of the Institute

of High Energy Physics of CAS. Her husband, Qian Sanqiang (1913–1992), who was also a nuclear physicist, was elected as a CAS member in 1955. He was Vice Minister of the Second Ministry of Mechanical Industry, Vice President of CAS and a recipient of the Two Bombs and One Satellite Meritorious Service Medal. He Zehui's brother-in-law, Ge Tingsui (1913–2000), was a metal physicist who was also elected as a CAS member in 1955. He served as deputy director of the Institute of Metal Research and the Institute of Solid State Physics of CAS.

2. Wang Shouwu (1919–2014), a semiconductor device physicist, was elected as a CAS member in 1980. Born in Suzhou, Jiangsu Province, he graduated from Tongji University in 1941 and received his master's and PhD degrees from Purdue University in 1946 and 1949, respectively. After returning to China in 1950, he served as director of the Semiconductor Division of the Institute of Applied Physics and deputy director for Research of the Institute of Semiconductors of CAS. He was involved in preparations for building China's first transistor factory and led research on the dynamics of high field domains in gallium arsenide and the transient and photoelectric properties of PNPN negative resistance lasers to improve the yield of large-scale integrated circuit chips. Lu Xueshan (1905–1981), brother-in-law of both Wang Shouwu and Wang Shoujue, was a crystallographer who was elected as a CAS member in 1955 and served as acting director of the Institute of Applied Physics of CAS.
3. Wang Shoujue (1925–2016), a semiconductor electronics scientist, was elected as a CAS member in 1980. Born in Shanghai, he graduated from Tongji University in 1949 and worked at the Institute of Radium of the National Academy of Peiping, the Institute of Applied Physics and the Institute of Semiconductors of CAS. In 1957, he was sent to the Lebedev Physical Institute of the Soviet Academy of Sciences for further study. He successfully developed China's first germanium alloy diffusion high-frequency transistor, which was used on transistorized high-speed computers. He also developed silicon plane technology and devices, which served China's 'two bombs and one satellite' project. Wang Shoujue was the first to publish a paper on the multi-logic circuit, which is a kind of circuit integrated with high-speed fuzzy logic.
4. According to He Zehui, 'Studying ballistics, I may be asked to return to China to work for the Military Industry Department. Armed with my calculation, Chinese soldiers must shoot accurately. Had they asked me earlier, Japanese soldiers would have already retreated' (Wang and Zhang, 2017: 33).
5. From an interview with Wang Shoujue by Li Yanping, Liu Xiao and Zhang Chenghua on 31 March 2011 in Suzhou, collected by PCDS.
6. From an interview with Wang Shoujue by Yin Xiaodong on 21 September 2011 in Beijing, collected by PCDS.
7. From Wang Shouwu's manuscript titled 'I am a silly boy', collected by PCDS.
8. From He Zehui's manuscript in 1984, collected by PCDS.
9. From an interview with Wang Shoujue by Yin Xiaodong on 21 September 2011 in Beijing, collected by PCDS.
10. From He Zehui's letter to He Yizhen in 1934, collected by PCDS. Words in bold were stressed by Zehui in her letter.
11. From the website of the Max-Planck-Institut für Kernphysik; see Max-Planck-Institut für Kernphysik, Von Kernphysik und Kosmochemie zu Quantendynamik und Astroteilchenphysik [From nuclear physics and cosmochemistry to quantum dynamics and astroparticle physics], https://www.mpi-hd.mpg.de/mpi/fileadmin/files-mpi/Broschueren/Geschichte.pdf (accessed 6 March 2019) (in German).
12. From Mei Yiqi's letter to Qian Sanqiang in 1947, collected by PCDS.
13. From an interview with Wang Shouwu by Wang Yige on 3 January 2011 in the United States, collected by PCDS.
14. From an interview with Wang Shoujue by Li Yanping, Liu Xiao and Zhang Chenghua on 31 March 2011 in Suzhou, collected by PCDS.
15. From an interview with Wang Shoujue by He Chunfan in 2009 in Beijing, collected by PCDS.

References

Andreas J (2009) *Rise of the Red Engineers: The Cultural Revolution and the Origins of China's New Class*. Stanford: Stanford University Press.

Bai CL (ed.) (2007) *Becoming Science and Technology Talents: Mechanism for the Growth of Science and Technology Talents in the Chinese Academy of Sciences*. Beijing: Science Press (in Chinese).

Bourdieu P (1986) The forms of capital. In: Richardson JG (ed.) *Handbook of Theory and Research for the Sociology of Education*. Translated by R Nice. New York: Greenwood Press, pp. 241–258.

Cao C (2004) *China's Scientific Elite*. New York: Routledge.

He ZH (1931) What should we think if Japanese marines reach Suzhou. *Magazine of Suzhou Girls' School of Revitalizing China* 26–27 (in Chinese).

Kang J and Li YP (2012) The first female Chinese PhD in chemistry – Wang Chi Che. *The Chinese Journal for the History of Science and Technology* 33(2): 167–175 (in Chinese).

Liu X (2013) *Biography of He Zehui*. Beijing: China Press for Science and Technology (in Chinese).

Merton RK (1973) *The Sociology of Science: Theoretical and Empirical Investigation*. Chicago: The University of Chicago Press.

Peng HW, He ZH and Wang DH (1994) Recalling our teacher Zhou Peiyuan. *Physics* 23(3): 188–189 (in Chinese).

Qian SQ (1989) *Discovery of the Phenomenon of Ternary and Quaternary Fission of the Nucleus*. Beijing: Scientific and Technical Documentation Press (in Chinese).

Wang Z (2002) Saving China through science: The Science Society of China, scientific nationalism, and civil society in Republican China. *Osiris* 17: 291–322.

Wang MZ (2006) My ninety years. *Physics* 35 (3): 174–182 (in Chinese).

Wang SL (2009) On Wang Jitong and his sons and daughters. In: Wang ST, et al. (eds) *Electromechanical Technology during the era of the Republic of China*. Changsha: Hunan Education Publishing House, pp. 70–72 (in Chinese).

Wang HB (2019a) Between collectivism and individualism: Chinese scientists' choice. In: Liu X (ed.) *Science and You: Proceedings of the 2018 Science & You International Symposium and Summit on Culture of Science*. Beijing: Tsinghua University Press, pp. 183–186.

Wang HB (2019b) He Zehui's individual academic growth in her family network. *Modern Science* (2): 14–18 (in Chinese).

Wang CF and Zhang L (eds) (2017) *Scientific Dream, Chinese Dream: Album of the Exhibition on Chinese Modern Scientists*. Beijing: China Press for Science and Technology (in Chinese).

Wu DY (2005) Memory of early development of Chinese physics (III). *Physics* 34(6): 399–404 (in Chinese).

Yin XD and Li R (2016) The Barbour Scholarship and eight Chinese female physicists. *The Chinese Journal for the History of Science and Technology* 37(3): 313–326 (in Chinese).

Zhang L (2006) Interview with He Zehui. 12 April. Available at: http://www.cctv.com/program/dajia/20060412/101593.shtml (accessed 21 November 2018) (in Chinese).

Zukerman H (1977) *Scientific Elite: Nobel Laureates in the United States*. New Brunswick: Transaction Publishers.

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Article

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Collecting and compiling the oral accounts of Chinese scientists trained in the Soviet Union in the 1950s and 1960s: Practice and reflection

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Abstract
In recent years, the recovery and compilation of the oral histories of scientists has attracted increasing attention. The focus of the research has also expanded from individual experiences to collective experience. As part of the Project on Collecting the Historical Data of Chinese Scientists' Academic Life, and following the norms of historiography, I and other team members compiled oral interviews and accounts of Chinese scientists trained in the Soviet Union in the 1950s and 1960s. Through the procedures of data collection, candidate selection, framework construction and detailed presentation, I compiled the oral accounts of 16 Soviet-educated Chinese scientists, supplemented by photos, annotations and other information. These materials describe the lived circumstances and feelings of those scientists in the early days of the People's Republic of China and recreate the collective experience of this generation of scientists from multiple angles.

Keywords
Scientists, oral history, Project on Collecting the Historical Data of Chinese Scientists' Academic Life, studying in the Soviet Union

1. The oral history of scientists: From individual experiences to collective experience

Scientists are regarded as part of a social elite due to their knowledge and contribution to society. Yet, at the same time, because of their dedication to academic research and the complexity and sometimes confidentiality of their studies, they have often kept out of the public eye. Even in academic circles, the study of their academic records and life experiences from the perspective of historical studies and social development is a relatively new practice.

The American Institute of Physics was one of the first international organizations to conduct oral interviews with scientists. After the death of Albert Einstein and Niels Bohr in the 1950s and 1960s, the

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institute found that the memories and personal accounts left by those great scientists were very limited, so it began work to 'rescue' oral histories of scientists (Good, 2017). The British Library also launched an oral history of British science project in 2009. At that time, it found that, since 2000, 27 world-leading British scientists, including seven Nobel laureates, had left little or no personal record of their life and career experiences (British Library, 2018).

Since the 1980s, some researchers have conducted research on oral interviews with Chinese scientists (Zhang, 2010). That work has involved Chen Xingshen (see Tian, 2000), Huang Zongzhen (see Fan et al., 2000), Shi Zhongci (see Wang, 2001) and other important scientists. Those studies are of high historical value because they have recreated historical details that are little known to the public and used different ways to present the oral histories of scientists.

One of the best works is the *Oral History of Chinese Science in the 20th Century* book series edited by Fan Hongye. The series was launched in 2006 with the purpose of rescuing the precious historical literature of Chinese science and technology in the 20th century. By 2018, the accounts of 400 scientists and scientific workers on the front line had been collected. Based on their accounts and summaries by the interviewers, 56 books, using 54 different types of accounts, were produced. The series is divided into four categories: transcripts of the interviews; oral autobiographies compiled by the interviewers based on the accounts of the interviewees; autobiographies written by the interviewees; and records of group interviews on the topics of major events, achievements, academic disciplines and institutions. The first three categories aim to recreate the development of various disciplines and their social backgrounds based on the career experiences of individual scientists (Shen, 2009; Xu, 2009; Yuan, 2010). The fourth category records the collective memories and experiences of scientists who were involved in major scientific events (Fang et al., 2014; Sun et al., 2010).

In 2010, the China Association for Science and Technology, together with 11 ministries and commissions, including the Organization Department of the Central Committee of the Communist Party of China, the Ministry of Education, the Ministry of Science and Technology, the Chinese Academy of Sciences (CAS) and the Chinese Academy of Engineering (CAE), jointly launched and implemented the Project on Collecting the Historical Data of Chinese Scientists' Academic Life (PCDS). The main subjects of the project are CAS and CAE academicians who are over 80 years old and have rich academic experience and old scientific and technological workers who, although without the title of CAS or CAE academician, have made outstanding contributions to the development of science and technology in China.

With the academic experiences of these scientists as the main theme, the PCDS focuses on collecting and categorizing oral historical data that reflects the academic experiences, achievements and landmark events of the scientists, as well as physical objects and images that can truly demonstrate how they generated, developed and updated their thinking, views and concepts.[1] So far, it is the largest project of its kind in China. By the end of 2018, 512 specific tasks of data collection had been carried out across the nation, collecting and transcribing many audio and video files of interviews with scientists and others.

One important feature of the PCDS is that it is focused on people. This 'people-centred' approach is manifested in two aspects. First, the subjects are mostly individual scientists, plus a small number of scientist groups. Second, the main subject is the life experiences of the scientists, which are used to mirror changes over time and the advance of science and technology. Because of its focus on people, the most outstanding achievements of the PCDS so far are research works such as biographies and oral accounts of older scientists, which focus on their personal experiences and life stories.[2]

The PCDS presents typical cases in the construction of the modern Chinese scientific community and the development of science and technology in China. At the same time, summarizing common features from personal materials and answering specific questions about the history of science in China are priorities for further research. In particular, in the scientific and technological history of China, many scientists have planned and modified their academic paths and restructured their research careers according to the country's development needs. Through their collective efforts, many breakthroughs have been achieved. Their similar life trajectories and intragenerational characteristics have also contributed to their common way of thinking. Exploring their shared academic paths during the founding and construction of the People's Republic of China, as well as their relations with the external environment, by revisiting historical scenes and digging into important historical events that they experienced during a specific historical period is an important field of research.

2. Oral accounts of Soviet-educated scientists involved in the PCDS

In the 1950s and 1960s, more than 16,000 university students, postgraduates, researchers and interns were sent by the Chinese Government to the Soviet Union to take part in specialized courses and further education programmes (Li, 2016: 175–177). Most were involved in science and technology. Some of them, after returning to China, made important contributions to the development of their disciplines and the economic and social development of the country. In December 2007, there were 100 CAS academicians and 109 CAE academicians who had educational experience in the Soviet Union (Li, 2016: 209–219).

Research on their education in the Soviet Union in the 1950s and 1960s has produced many summaries and statistics based on official documents and historical literature (see Li, 2010, 2016; Zhou et al., 2012). However, on the lived experience of the scientists, such as how they were selected for the programme and the details of their training and overseas studies, researchers have repeatedly quoted a few available memoirs, interviews and oral accounts, so many details need to be further clarified (see Shan and Wang, 2007; Soviet Union and CIS Branch, Western Returned Scholars Association, 2000; Zhu, 1997, 2003).

In 2016, the number of Soviet-educated scientists covered in the PCDS reached 78. Exploring and summarizing their oral accounts and other materials can help to enrich the empirical evidence on their research, recreate their experiences and enable us to re-evaluate and reconsider the value of this historical phenomenon and the people involved in it.

Following the norms of historical study (Fan, 2009), and based on my experience and inspiration gained from the PCDS and my research on the oral histories of scientists, I summarized the collected data, with a focus on the history of Soviet-educated scientists. This has included several different steps, such as data collection, candidate selection, framework construction and detailed presentation.

My work is based on adequate access to research materials. By reviewing the personal information of 395 scientists collected from 2010 to 2015 by the PCDS and checking the PCDS database, I obtained archives, photos and certificates of 55 scientists relating to their Soviet educational experience, as well as audio and video recordings and transcripts about this particular experience given by themselves or others. My aim was to establish the historical circumstances of China's policy of sending students to the Soviet Union based on the memories of the scientists among them. Therefore, when selecting oral accounts, I gave priority to those materials with relatively complete and substantial information about their experiences in the Soviet Union. I did not include records from scientists who had since died or who could give only fragmented accounts due to their age or for reasons of confidentiality. Based on those principles, I chose 16 scientists.[3]

A central task of my work is to present the oral accounts of the 16 Soviet-educated scientists in a proper structure. It is not enough to simply sort out and list all the collected materials; it is necessary to establish a clear structure based on existing research and the available historical data as well as an in-depth consideration of the relevant historical issues.

2.1. Organization of structure

For structure, I followed the steps that scientists went through for study in the Soviet Union and divided the oral accounts of the scientists into three stages:

- pre-study period: selection and training before going to the Soviet Union

- study period: study and life in the Soviet Union
- post-study period: activities after returning home.

The scientist's pre-study and post-study experiences are presented in a group mode; that is, the oral memories of the group are about a shared experience. For the study period, the scientists are divided into three groups based on the types of higher learning institutions they attended: comprehensive universities, engineering colleges and scientific research institutes. In each group, the oral memories of the scientists are described, and each scientist's memories are structured and presented.

(1) Scientists who studied in comprehensive universities in the Soviet Union

Wu Yangjie studied organic chemistry at Moscow University as a postgraduate from 1954 to 1958 and graduated with a doctoral degree.

Hu Hongwen studied organic chemistry at Moscow University as a trainee teacher from 1957 to 1959 and graduated with a doctoral degree.

Zhou Yulin studied partial differential equations at Moscow University as a postgraduate from 1954 to 1957 and graduated with a doctoral degree.

Yang Fuyu studied biochemistry at Moscow University as a postgraduate from 1956 to 1960 and graduated with a doctoral degree.

Zhang Siying studied mechanics and mathematics at Moscow University as a trainee teacher from 1957 to 1959 and graduated with a doctoral degree.

Yang Fuqing studied program design at the Computing Centre of the Academy of Sciences of the Soviet Union as a trainee teacher from 1957 to 1958 and at the Department of Mathematical Mechanics of Moscow University from April 1958 to October 1959.

(2) Scientists who studied in engineering colleges in the Soviet Union

Xu Zhifang studied water conservancy and soil improvement at the Moscow Institute of Water Engineering as a postgraduate from 1951 to 1955 and graduated with a doctoral degree.

Chen Houqun studied hydropower at the Moscow Institute of Dynamics as a college student from 1952 to 1958 and graduated with an engineering degree.

Guo Shangping studied oilfield development at the Moscow Petroleum Institute as a postgraduate from 1953 to 1957 and graduated with a doctoral degree.

Zhou Yaohe studied metallurgy at the Moscow Iron and Steel Institute as a postgraduate from 1953 to 1957 and graduated with a doctoral degree.

Jiang Yiyuan studied agricultural machinery at Leningrad Agricultural College as a trainee teacher from 1957 to 1959.

Chen Shilu studied aerodynamics at the Moscow Institute of Aeronautics as a trainee teacher from 1956 to 1958 and graduated with a doctoral degree.

(3) Scientists who studied in scientific research institutes in the Soviet Union

Yuan Chengye studied pharmaceutical chemistry at the Soviet Institute of Pharmaceutical Chemistry as a postgraduate from 1951 to 1955 and graduated with a doctoral degree.

Xie Yuyuan studied pharmaceutical chemistry at the Institute of Natural Organic Compound Chemistry of the Academy of Sciences of the Soviet Union as a postgraduate from 1951 to 1955 and graduated with a doctoral degree.

Chen Yushu studied mechanical nonlinear vibration at the Institute of Mechanics of the Academy of Sciences of the Soviet Union as a postgraduate from 1959 to 1963 and graduated with a doctoral degree.

Tang Xiaowei worked as a nuclear physics researcher at the Joint Institutes for Nuclear Research in Dubna from 1956 to 1960.

2.2. Presentation of source material

I organized the texts to present them in the first person. This method of writing is based mainly on the oral accounts of the scientists involved in the PCDS and an assessment of the targeted readers. The oral materials are sincere and detailed, so using the first-person narrative form helps to maintain the individuality of the scientists and their experiences. The intended readership includes both professional and other readers. For professionals, relatively complete accounts will help them get a better picture of the information and use the information in future research. For other readers, first-person accounts can help them associate more closely with the personal experiences and life inspirations of the scientists, as if reading a story.

The PCDS emphasizes the academic use of the oral accounts, pictures and background materials of the scientists. Given the diverse types of material, many details deserve special attention during the sorting process. In choosing material, I mainly used transcripts of recordings of interviews of the scientists collected by the PCDS teams. Before I began sorting the material, most of the transcripts had been checked only for fluency and the content had not been restructured. Speaking of their experiences in the Soviet Union, each scientist did not necessarily give a full account in one interview but spoke about it in multiple interviews, so some content overlapped. In sorting the material, I put the statements of the same scientist about different stages of the Soviet education into different parts and put the statements of different scientists about the same stage together in chronological order. For a relatively complete description of a scientist's experience, I retained the scientists' own narrative content and logic, making only appropriate inductions and classifications, and thus retaining the original oral characteristics of the scientists and the vividness of the narration.

In addition, I enriched the information as much as possible by comparing different oral statements about the same experiences and by consulting various historical documents. I used annotations to expand information when the statements involved historical background, some organizations, other scholars and other important content. In order to further describe the historical situation of the scientists' stay in the Soviet Union, I used contemporary photos of them and their study notes, published papers, degree certificates and other materials.

3. Case analysis: Activating the oral materials with questions

Sorting academic interviews is not just about checking for fluency, but about restructuring those accounts based on existing research, with specific questions in mind and from an observer's perspective. It is particularly important to highlight the historical background and significance of the experiences of the scientists through academic annotation.

At present, research on the sending of students to the Soviet Union in the 1950s and 1960s focuses mainly on analyses of official policies and archives, the collection of the memories of people who lived through that period, and summarizing the achievements of some scientists. Based on intensive research on the history of student education in the Soviet Union, the PCDS aims to explain how the policy was adopted and implemented by the selecting bodies and the selected individuals by studying the detailed behaviour of both individual scientists and groups of scientists. Through the vivid and concrete presentation of individual oral accounts, the project has recreated the life experiences of the scientists sent to the Soviet Union during that period, including their selection and training in China; their experiences of study, life, international exchange and political activities in the Soviet Union, especially their academic training and interactions with their Soviet tutors; their work after they returned home; and the application of their Soviet-acquired knowledge in their new posts.

The scientists included men and women who went to and returned from the Soviet Union in different years and had different educational backgrounds (undergraduate students, postgraduate students, trainee teachers). They attended different educational institutions and experienced different training methods.

The following are three examples of how I restructured the oral accounts of the Soviet-educated scientists, with some consideration of relevant academic issues.

3.1. Case 1: Oral accounts of the selection and training of students to be sent to the Soviet Union

Existing research on the selection and training of those who went to the Soviet Union has made full use of the relevant archives of the Ministry of Education and Beijing Foreign Studies University (Li, 2016).

However, those studies have often focused only on the relevant state policies and how the policies were implemented in the cases of individuals, including their feelings and reactions. Due to the lack of experience-based material, there is still great space for further research.

Sorting through the oral accounts of the Soviet-educated scientists, I started with the pre-study selection and training stage. I gathered the oral accounts of the 16 scientists, which tell us how these people from different regions, posts, universities and professions were gathered together for the national mission of studying in the Soviet Union, and how, after a series of training sessions, they had set out on their journeys.

I started with an introduction to and analysis of the selection policy and its formulation based on historical archives and then examined the information extracted from the oral accounts of the scientists about their selection and training. The candidate selection process was presented with the oral accounts of Xu Zhifang and three other scientists; the examination process was presented with the oral accounts of Guo Shangping and two other scientists; and the selection of trainee teachers was presented with the oral accounts of Zhang Siying and two other scientists. On the scientists' preparatory training before going to the Soviet Union, the oral accounts of several scientists recorded their personal experience of Russian-language study, political study, physical exercise, qualification reviews and final preparations.

Through these accounts, readers will get a general picture of the policy of sending students to the Soviet Union and its development during this period, as well as the various steps of the selection and training process and the personal experiences of the scientists.

3.2. Case 2: Oral account of Yang Fuqing from the perspective of history and gender research

The first group of scientists all studied at Moscow University, which is a comprehensive university. Yang Fuqing was a female scientist and an early participant in computational mathematics in China. Her study in the Soviet Union was a typical example. I use her case to introduce the steps in the restructuring of oral accounts and the value of those accounts.

After preliminary screening, I found that Yang talked about her experience of studying in the Soviet Union in two interviews. Another two interviews with Xu Jiafu – her fellow postgraduate student in the Soviet Union – also mentioned this. With Yang's personal accounts as the main body of the oral materials, I structured her story in three parts: 'My first year at the Academy of Sciences of the Soviet Union', 'Entering Moscow University' and 'Extracurricular life at Moscow University'. I also included photos of Yang operating a computer, taking classes together with her classmates in the tutor's office, performing at a party and attending activities of the Communist Youth League to create a lifelike scene.

Yang studied computer programming at the Computing Centre of the Academy of Sciences of the Soviet Union and Moscow University. The background to her study was the Chinese Government's formulation of the *Outline of the Long-term Plan for the Development of Science and Technology 1956–1967* in 1956, which stressed the importance of developing new disciplines such as computer science. Yang and Xu were among the first batch of scholars sent to study computational mathematics abroad. Their experience in the Soviet Union is of great significance in the study of the history of science and technology and the history of computational mathematics of the People's Republic of China. The oral materials include Yang's personal accounts of her studies in computer science and computer programming and her memories of other schoolmates, plus annotations on the Mathematics Department of Peking University (her alma mater) and Xu's oral accounts, thus presenting readers with the overseas studies experience of the pioneers of computational mathematics in China during that period. In addition, when compared with the memories of the other 15 scientists, Yang's oral accounts demonstrated the unique experiences and perspective of female scientists. For example, her detailed accounts of participating in art performances and cooking at school fully showcased her lively and optimistic character and her exciting life in the Soviet Union.

3.3. Case 3: Zhou Yaohe's oral account, which highlights the role of national needs in shaping the academic paths of individual scientists

Zhou Yaohe mentioned his experience in the Soviet Union three times in his oral accounts. I included his personal accounts in the group who attended engineering colleges and divided them into four parts: 'Entering the field of metallurgy', 'Life at the Central Institute of Mechanical Technology and Manufacturing of the Soviet Union', 'Conducting research and obtaining patents' and 'Life in spare time'. His group photo with experts and colleagues in the Soviet Union and photos of his patent certificate and the certificate for his doctoral degree were also included.

Zhou graduated from Tsinghua University, majoring in mechanical manufacturing. When he was chosen to study in the Soviet Union, he was sent to study metallurgy at the Moscow Iron and Steel Institute. In his personal accounts, Zhou talked about the training methods used by Soviet engineering colleges, which placed more emphasis on the practical skills of students. He also shared his study and life experiences in the Soviet Union and the psychological transition he went through when changing his subject of study from machinery to metallurgy. He believed that he was assigned to his course for two reasons: the country needed metallurgical research professionals during that period; and he had attended an optional course on casting during his undergraduate studies. Zhou went through a period of anxiety after entering the field of metallurgy in the Soviet Union. Yet, with the guidance of the Soviet teachers and by his own efforts, he developed an independent research capability and obtained patents for his research. By studying in the Soviet Union, he linked his academic pursuit with the development needs of the country and dedicated his knowledge to serving the country. His experience epitomized the life experience of Chinese scientists in that specific historical period.

4. Conclusion

Summarizing the oral accounts of Soviet-educated scientists is a process that ranges from collecting the accounts to recreating the growth and history of a particular group. The experience of the group was deeply related to specific historical background and events. The scientists faced similar objective conditions and shared similar subjective feelings, such as pre-study selection and training and post-study distribution in the scientific and academic professions, and similar mental states. When examining the oral accounts of the whole group, I observed their similar experiences and the factors behind their choices and actions. I think this is an event-oriented oral history narration, but we cannot deny that individual oral accounts can show more details, so the main part of my compilation work is the stories of the 16 scientists. I believe that readers can understand the group more deeply by reading the stories of each scientist, but I just talked about the experiences of individual scientists in a specific historical period by using their oral accounts about particular events. Their other oral accounts of other times in their lives were not involved in the compilation. I think those are suitable for a person-oriented mode of narration.

Based on the collected and compiled oral accounts of Soviet-educated scientists, some new research tasks involving this group can be undertaken. First, we can use these materials to discuss the relationship between the Soviet-educated scientists and the establishment of some new disciplines in China in that period, as well as the changes they brought about in some traditional subjects. Second, the methods adopted in this study can be used to find other oral materials of scientists who had similar experiences, and some scientists can be interviewed on related topics for more information. I have provided some ways to deal with the oral history materials of different scientists speaking about the same event and have tried to combine different oral accounts and other historical materials, such as pictures, into an effective narrative frame.

Now the rescue of the oral histories of scientists – from filling in the blanks in their life records to studying the historical process behind collective events and to exploring their external environment and internal motivations – is attracting more and more attention from researchers, and the factors involved are also getting more complicated. We can never predict what results we will get in the next oral interview; only by constantly learning about the scientists and adding new perspectives can we raise valuable questions and obtain meaningful information so that the oral histories of scientists can truly become the oral history about 'scientists', capturing the extraordinary features of this unique profession.

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Notes

1. The Implementation Plan for the Project of Collecting Historical Data of Scientists' Academic life, 2010.
2. See for example, Fan et al. (2015), Han (2015) and the Oral History Special published in *Chinese Journal for the History of Science and Technology*, 2011, issue 2.
3. The 16 scientists include Wu Yangjie, Hu Hongwen, Zhou Yulin, Yang Fuyu, Zhang Siying, Yang Fuqing, Xu Zhifang, Chen Houqun, Guo Shangping, Zhou Yaohe, Jiang Yiyuan, Chen Shilu, Yuan Chengye, Xie Yuyuan, Chen Yushu and Tang Xiaowei. Materials used in this study are all from transcriptions of oral interviews with these scientists, which are collected in the PCDS database.

References

British Library (2018) An oral history of British science: A new national life stories interview programme. Available at: https://www.bl.uk/.

Fan HY (2009) Reflections on the oral history of Chinese science in the 20th century: speech at the symposium on the oral history of Chinese science in contemporary times. *Chinese Journal for the History of Science and Technology* 3: 269–276 (in Chinese).

Fan HY, Chen DH and Chen DD (eds) (2015) *My Meteorological Career: Oral Account of Chen Xuerong*. Beijing: China Science and Technology Press (in Chinese).

Fan HY, Wang DL and Wei HN (2000) Interview with Huang Zongzhen. *Chinese Journal for the History of Science and Technology* 4: 316–323 (in Chinese).

Fang ZZ, Lin CL, Wu YW, et al. (2014) *Witness the Detonation of China's Atomic Bomb*. Interviewed and edited by Hou YB. Changsha: Hunan Education Press (in Chinese).

Good GA (2017) Gathering the human stories of science. *Physics Today* 70(5): 74–75.

Han F (ed.) (2015) *My Education Life: Oral Account of Shen Panwen*. Beijing: China Science and Technology Press (in Chinese).

Li XS (ed.) (2010) *Chinese History of Overseas Education, New China Volume*. Guangzhou: Guangdong Education Press (in Chinese).

Li P (2016) *Overseas Studies and Nation Building: A Study on Chinese Students' Education in the Soviet Union in the Early Years of the People's Republic of China*. Shanghai: Shanghai Jiao Tong University Press (in Chinese).

Shan G and Wang YH (2007) *A Documentary of Chinese Students in the Soviet Union*. Beijing: Central Compilation and Translation Press (in Chinese).

Shen SJ (2009) *Autobiography of Shen Shanjiong*. Edited by Xiong WM. Changsha: Hunan Education Press (in Chinese).

Soviet Union and CIS Branch, Western Returned Scholars Association (ed.) (2000) *The Road of Students: The Footprints of Chinese Students in the Soviet Union in the Early Days of the People's Republic*. Beijing: China Youth Press (in Chinese).

Sun HL, Wen SX, Pan YS, et al. (2010) *Interview Record of Scientific Expedition in Qinghai–Tibet Plateau (1973–1992)*. Interviewed and edited by Wen J. Changsha: Hunan Education Press (in Chinese).

Tian M (2000) Interview with Chen Xingshen. *Chinese Journal for the History of Science and Technology* 2: 117–127 (in Chinese).

Wang XQ (2001) Interview with Shi Zhongci. *Chinese Journal for the History of Science and Technology* 1: 48–55 (in Chinese).

Xu LZ (2009) *Interviews with Xu Lizhi*. Interviewed and edited by Yuan XD and Guo JH. Changsha: Hunan Education Press (in Chinese).

Yuan LP (2010) *Yuan Longping's Oral Autobiography*. Interviewed and edited by Xin YY. Changsha: Hunan Education Press (in Chinese).

Zhang L (2010) An overview of research progress on the oral history of Chinese science in recent years. In: *Academic Seminar on Inheritance and Innovation in Research on Doctors' Biographies*, Jiangxi, China, 22–26 July (in Chinese).

Zhou SW, Li P and Hao YQ (2012) *Record and Reflection of the Trend of Overseas Studies in the Soviet Union in the Early Years of the People's Republic of China*. Shanghai: East China Normal University Press (in Chinese).

Zhu X (ed.) (1997) *You Are the Hope: Memory of the Years of Studying in the Soviet Union*. Beijing: China Youth Press (in Chinese).

Zhu X (ed.) (2003) *You Are the Hope: The Unforgettable and Extraordinary Years*. Beijing: China Metrology Press (in Chinese).

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Article

From 'the mind isolated with the body' to 'the mind being embodied': Contemporary approaches to the philosophy of the body

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Abstract

In the interpretation of the body in the 20th century, philosophy placed less emphasis than before on its natural composition and sought to integrate value judgements from different perspectives. The philosophy of the body addresses the deepest essential problems of human society and culture, it generates a uniquely detailed analysis of human nature and its various roles and performances in social operations, and it reveals contemporary society's operating mechanisms and deep internal contradictions. Accordingly, philosophy no longer gives the mind any priority or superiority in terms of cognition, and the focus of research has moved away from pure consciousness and towards the body. Contemporary philosophical exploration of the body covers both the concept of belongingness and the feasibility of bodily freedom. It not only foregrounds the impossibility of viewing the body and the mind as separate entities but also leads us to examine the connections between humans and the world, taking meaning, reason and the body as their basis. This paper explores the connections between body and thought in modern philosophy, traces the development of philosophy's increasing concern with the body, elucidates the main contributions of representative figures in the field of philosophy of the body, and analyses the methodological significance and influence of the philosophy of the body as a contemporary philosophical trend.

Keywords

Body, thought, embodied mind, world, identity

Since the ancient Greeks, a binary opposition between the body and the soul has been a basic framework of Western philosophy. People tend to consider their bodies as matter without thoughts and as fundamentally different from their souls and minds. No matter what else 'body' might mean, it refers principally to a thing without comprehension, choice or judgement, contrary to self-determination and free will (Walter, 2011: 138). According to René Descartes, although there is a close interaction between the mind and the body, they are two beings with different essences. The body stands for sensibility, contingency and uncertainty, whereas the mind represents sense, truth, stability and certainty. Thus, for much of the history of Western thought, the body has been in a hidden and obscure state.

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Nevertheless, in the 19th century, Nietzsche not only treated reason, emotion, thought and will in a new way but also re-explored the relationship between the human body and spirit. He analysed the operation of power, especially power that produces knowledge and subjectivity by taking the body as an object. Subsequently, philosophers started to focus on the hidden ties between body and thought; they began to use the term 'body' to resist the arbitrariness of the philosophy of consciousness, and they contributed to a philosophical movement that was increasingly concerned about the body.

In the second half of the 20th century, the body became a popular research topic, as scholars moved away from the examined object and towards the subject of thoughts and behaviours. The body has since been a focus of sustained attention in the humanities and social sciences and a major topic in discussions about contemporary politics and culture (Slatman, 2014: 15–21).

1. The body, social symbols and value signs

Since Friedrich Nietzsche, the body has occupied an important position in philosophy. Although various theories have been advanced, their common focus is the inherent materiality of the body, by which it reaches a certain level of social practice; in this way, they combine the body and society and take the body as the starting point of the world. The disenchantment and secularization of the body runs throughout modern Western history, affecting considerations of how individuals make choices in the physical development strategies of life planning and who determines the disposition of the body's products and parts. The body as an aspect of nature has been seen as a carrier of social and political significance. Gradually subjected to human interference or even domination, it has become a site of interaction, possession, repossession and linking of systematic expert knowledge. Comparing society to a body (unlike comparing it to a family) makes the authoritative order of society more inevitable and irreplaceable, and thus the body becomes a source of acute contradictions in ideology.

Most of Michel Foucault's works are closely related to the body, which has long been a focus for examinations of phenomena such as psychosis, clinical medicine and prison systems. Foucault recognized that these issues, in order to become objects of study, must manifest themselves and that they can do that only in the human body. In his work on the archaeology of knowledge and the genealogy of power, Foucault attributed a variety of social events in different social and historical periods to the continuous process of reconstructing fractured relational networks based on differences in power, instead of to a specific, fixed historical structure. He believed that any original and continuous reconstruction process was closely related to the body in the flesh. None of these historical processes, no matter how brief, can be separated from the existence and operation of the body:

> The flesh—and all the things embedding into it including food, climates and earth—is where the source is: just as the body generates desires, weaknesses, and faults . . . all the events in the past . . . are also linked in the flesh, and sometimes jostle against one another in the flesh. They would also dissolve, fight, and vanish with each other, and pursue the insurmountable conflicts . . . Therefore, genealogy, as the stream analysis, is in the link between the body and history. (Foucault, 2004a: 152–153)

The historical shaping of the body is both the physical archive of historical events and the material witness of those events.

However, the functions and operations of each part of the body have been affected and limited by sociocultural environments, and its modes of activity and the effects of its actions are presented in those environments directly. Accordingly, Foucault did not restrict himself to general discussions of the relationships between the body, the mind and thought. Instead, he explored how personal body conditions and modes of activity have been limited by social systems and regulations in different historical eras, how the body and social systems and regulations interact during the process of production, and how the functions of each part of the body are fulfilled through the relation between social normalization and personal subjectivation. He went on to explain how the demand and desire that are necessary for personal life are related to the maintenance and operation of the entire social system in terms of the fundamental functions of the body, such as the basic operations of the digestive system and the sexual organs. Those functions appear to belong to the physical processes of life, but in fact they possess social morality and great cultural significance and in different eras have been socialized rigidly and symbolized culturally through institutions and rituals.

The purpose of Foucault's research was to explain how power mechanisms relate directly to the human body, its many functions, and its physiological processes, feelings and enjoyment; far from obscuring the human body, those functions enable it to take its place in such an analysis. The relationship between biological nature and social nature becomes increasingly complex with the development of modern technologies of power, as opposed to being connected one after another, as depicted in traditional theories of sociology. Therefore, it is not the 'spiritual history' that attaches importance to the body in terms of how people endow it with significance and values but 'the history of the body itself' and the history of the methods that people use to surround physical and energetic things in bodies (Foucault, 2004b: 383).

Like Nietzsche, Gilles Deleuze regarded the body as an active, rising and positive productive force. Deleuze interpreted Nietzsche's philosophy of the body in detail and developed it further, abstracting the body as a productive force or a huge desire machine. According to Deleuze, the body as desire is capable of growing, evolving and venturing forth endlessly. The production of desire is a contradictory process that has been suppressed both internally (a body without organs) and externally (society). A body without organs in this sense is not a *soma* without organs but a body without organization, an antistructural body, a generative and variable body:

> . . . a state that gets rid of its social connection, discipline, symbolism, and subjectivity, so as to become a body that is unrelated to, separated from, and decomposed of the society, therefore, . . . is able to be reconstructed in a new way. (Best and Kellner, 2011: 118)

A body without organs performs internal or external resistance in the form of persecution of organs internally or of agents externally (Deleuze, 2011: 112). Desire is interpreted as decentralized, fragmented and dynamic in nature. The movement of desire is not to find objects that it lacks and that can satisfy it but to seek new links and representations within the drive of its abundant energy. In short, the pursuit of desire stands for a trend in subjective theory that keeps modernity at a distance.

This change of attitude towards the body reflects the secularization of Western values. Whereas traditional Western values focused on abstinence and self-control, the consumer culture and fashion industry that arose in the 20th century emphasized control of the body's surface. The recurrence and interpretative schema of realistic rationalism are regarded as frozen, rigidly coercive objects that impede creativity. 'Culture' in modern society has become a synonym of and figure for a series of operations of commercialized symbols. In this context, contrary to the traditional ethic of 'the body serving the individual', the modern ethic of 'enabling the individual to serve his/her own body' takes priority:

> Its 'rediscovery', in a spirit of physical and sexual liberation, after a millennial age of puritanism; its omnipresence (specifically the omnipresence of the female body, a fact we shall have to try to explain) in advertising, fashion and mass culture; the hygienic, dietetic, therapeutic cult which surrounds it, the obsession with youth, elegance, virility/femininity, treatments and regimes, and the sacrificial practices attaching to it all bear witness to the fact that the body has today become an object of salvation. It has literally taken over that moral and ideological function from the soul. (Baudrillard, 1998: 130)

In other words, the body takes the place of the soul completely.

With the spread of consumerism, people have increasingly focused on the aesthetic qualities of the body. Body capital has become a standard of taste. Nevertheless, the basis for the body's being occupied again is not the independent goal of the subject but a standardized principle of entertainment and hedonistic utility, a utilitarian constraint directly associated with a social coding rule for production and directed consumption. The 'liberated body' is therefore a representation, indicating only that an ideology regarding souls has been replaced by a more functional ideology – that is, a spontaneous performance of the body has taken the place of the transcendence of the (completely internal) soul. However, this manifestation is false, as it takes the role of privileged spiritual pillar away from the soul only to give it to the body instead. Currently, the body has penetrated into production as its economic pillar, guiding psychological principles and political strategies that can be controlled; it has been reduced to an object of investment projects. The effects of such projects are even more profound than the alienation of the body in labour.

The body's occupation of this central position in daily life is particularly evident in the importance of 'habits', since the impressions caused by body posture concern the external expressions that one is least likely to change deliberately. Pierre Bourdieu developed his view that the body accumulates differences between social power and social inequality on the basis of his study of the social habits of professional groups. The body, as a symbolic sign, is capital in itself. It can usually be displaced as economic capital and converted into cultural capital, the conversion being accomplished by particular practices of the body. Habits, or practical senses, are the 'quasi somatization' of the world. A practical belief is a physical state, not a psychological state or a belief in institutionalized doctrines and creeds determined by spiritual freedom; the original acquisition regards the body as a memorandum and as the place where the greatest value is stored (Bourdieu, 2012: 88, 101, 212). For instance, people attach importance to certain major collective ceremonies not only because ceremonious presentation is central to the style and features of a group but also for a less overt reason: it is through strict arrangement of practical activities and regular governance of the body, and especially bodily expression of emotions (such as laughter or tears), that thoughts are organized and emotions produced. Habits, as a kind of knowledge, are the memory of hands and bodies; when we cultivate habits, it is our bodies that 'understand'. The body thus combines consciousness of social structures and world structures. The world structure enters the body through internalization, and body and mind are unified there. In this sense, practical sense is body sense.

2. Body, world and embodied mind

In the second half of the 20th century, all kinds of influences promoted the development from phenomenology to psychology. Maurice Merleau-Ponty's phenomenology of the body was a psychology established on the basis of a philosophy in which Descartes's *cogito* was replaced by the perceptual body-subject. The Cartesian definition of perception as the internal performance of given objects of the external world results in a dualism of subject/object and of all the relevant philosophical questions. According to Merleau-Ponty, such questions cannot be fully addressed within the framework of Cartesianism/mentalism, and perception must therefore be reconsidered in a fundamental way. This insight was the starting point of his analysis of the embodiedness of perception and the intentionality of the body.

Merleau-Ponty's exposition and examination of issues such as time, space, the other, the natural world, freedom and intersubjectivity were all conducted through discussion of the body. In this approach, the body is the possessor of vision and touch, not merely their means; 'eyes' are visible 'bodies' and 'minds' are invisible 'spirit'. The body provides conditions of conscious objects and meanings from perception. It watches everything and is able to watch itself. It is the visible and sensible object for itself. Since the body and everything else are made of the same materials, the vision of the body is formed in everything in a certain way, and the public visibility of things produces a secret visibility in the body (Merleau-Ponty, 2007: 36–37, 39). The body and the world are coexisting relations, and the world is presented to a person with all the parts of his or her body through a connection similar to that which exists between each part of the body. This is a living connection rather than a 'natural geometry'. Understanding of the world starts from the understanding of the body, since the world is not an objective existence and cannot be exhausted by rational knowledge. Access to the world is experiencing and perceiving through the body. Merleau-Ponty's later ontology, and in particular the system he began to develop in *The Visible and the Invisible*, can be conceived of as a form of radical enactive cognition (Zavota, 2016).

This idea of perceiving the world through the body was further developed by George Lakoff and Mark Johnson at the end of the 20th century. They began by criticizing a range of erroneous objectivist claims about thinking that ignore an important feature of human cognition: namely, that the physiological structure and physical experience of humans have played a key role in the process of forming meaningful concepts and reasoning. On this basis, they claimed that the formation of the concept of space derives from our continuous spatial experience; this most fundamental concept results from the interaction between individuals and their natural environment (Lakoff and Johnson, 2015: 57–58). Cognition or mind is inseparable from direct physical experience, which is not simple but is obtained under the premise of a certain extensive and profound culture. Cultural assumptions, values and attitudes are not conceptual coverings that we can choose to impose (or not impose) on experience. Culture is implied in each experience itself as the way we experience the world that we live in. Through natural dimensions, our bodies and the essence of our natural and cultural environments give structure to our experience. Recurring experience leads to the creation of categories, which are experiential ‘gestalts’ with natural dimensions. Those gestalts define the coherence of experience. We understand experience directly when we depend on experience gestalts obtained directly from ourselves, our environment and our interaction in the environment, and when we believe that experience has coherent structures; we understand experience metaphorically when we use a gestalt of one domain of experience to structure our experience of another domain (Lakoff and Johnson, 2015: 201).

Merleau-Ponty’s writings have been cited as the theoretical foundation of embodied cognition theory, and in *Structure of Behaviors* he examined mutual regulations and choices between organisms and their environments:

> . . . all the movements of [the] organism have always been restricted by external influences, if we are willing to, we can totally take actions as a result of the environment. But likewise, just as all the stimulation obtained by the organism can only be achieved by means of their previous movements (they are achieved by exposing sensory organs to external influences), we can say that behaviors are primary reasons of all the stimulation. The form of such stimulation is created by inherent methods of organism itself, presented to external functions . . . [The] body selects the stimulation it wants to feel in the physical world, according to the nature of the receptor, the thresholds of its nerve center and the movements of its organization. (Merleau-Ponty, 2010: 27–28)

Inspired by this, embodied cognition theory has advanced the following propositions: 1) cognition depends on types of experience that come from bodies with various sensory movements; and 2) the perception movement abilities of individuals are embedded in a broader biological, psychological and cultural context. Those propositions emphasize that perception and movement processes, and consciousness and action in nature, are inseparable in cognition because they are linked in the individual not purely or accidentally but through evolution and integration (Varela et al., 2017: 173).

A growing body of evidence confirms that cognition is embodied and grounded. Nonetheless, abstract concepts remain a significant theoretical challenge. Dove (2018) has argued that a successful account of how language augments cognition must emphasize its symbolic properties and incorporate a view of embodiment that recognizes the flexible, multimodal and task-related nature of action, emotion and perception systems. Allen and Friston (2018) have illustrated how the free energy principle can dissolve tensions between internalist and externalist accounts of cognition by providing a formal synthetic account of how internal representations arise from autopoietic self-organization. The free energy principle thus furnishes empirically productive process theories for guiding discovery through formal modelling of the embodied mind. As an alternative to representational approaches to the imagination, Medina (2013) has articulated an enactivist approach to examining how the enactive imagination works in animal cooperative behaviour and in animal communication. His approach indicates that an enactive imagination is a key component in a person’s cognitive, affective and moral learning. A question remains as to how, if at all, emotions and subcortical contributions fit into this emerging picture. In this connection, Miller and Clark (2018) have proposed a tightly coordinated process of continuous reciprocal causation that weaves together bodily information and ‘top-down’ predictions, thereby generating a unified sense of what is out there and why it matters.

In the exploration of cognition, we cannot avoid such logical implications, as any scientific description (of either biological or mental phenomena) must be a product of the structure of our cognitive system. We necessarily implement such reflective behaviours against the given background of biological, social and cultural beliefs and practices. Our assumptions about that background are simply the things that we do, and we adopt the schema as a whole, including the background we are exposed to. The basic cyclical shaft is the embodiment of experience and cognition, including the active body both as a structure of experience and as a cognitive mechanism. Understanding is not a state inside the head but one that criss-crosses brain, body and world. In this regard, extended cognition can be regarded as emphasizing the crucial role played in our cognitive processes by tools, material representations and the wider environment (Toon, 2015). Bodily interaction with the world and the accompanying subconscious processing can change subjects’ dispositions to apply their concepts in ways that are not rationally accessible to them (even given a complete description of that interaction), and it does not constitute a change in the content of the concepts involved (Rupert, 2016).

Embodied cognition research draws on phenomenology’s elimination of both entity dualism and attribute dualism. If the mind is not an independent entity separated from the body, and if it is not an epiphenomenon unrelated to behaviour, then can we establish a theoretical conception of ‘the mind in the body’? The core conception of the mind in the body is that the mind is not merely an entity or attribute that is separate from the body but is essentially an act or physical activity, and any mental activity is rooted in physical activity. If we can refer to the mind governed by dualism as the mind of entity and of epiphenomenon, then we can refer to the mind in the body as the body–mind of embodied mind, or simply as physical mind.

The concept of body–mind does not consist of two related entities or properties of the body and the mind. The purpose of connecting the words ‘body’ and ‘mind’ with a dash is to show that the mind is the body and that they are integral and inseparable. However, the integration of the body and the mind is not equivalent to the reduction of traditional psychosomatic theory to physical and physiological states of the brain in which the mind is equal to the active body. Indeed, a large body of evidence suggests that our concepts are often embodied and grounded in sensorimotor systems, and this speaks against standard forms of the phenomenal concept strategy (PCS). According to the PCS, thinking about the connection between mental facts and physical facts involves the exercise of both physical and phenomenal concepts. Nevertheless, it is possible to formulate a new version of the PCS that is more in keeping with embodied cognition, focuses on the features of physical concepts and adequately explains the appearance of contingency (Dove and Elpidorou, 2016).

In the process of exploring the mind and of criticizing Cartesian dualism, the philosophy of the body denies the supposed priority and superiority of the mind in cognition. That denial has moved the focus of research away from consciousness and towards the body, and subsequent explorations take account of both the concept of belongingness and the feasibility of bodily freedom. This leads us to recognize not only the impossibility of regarding the body and mind as separate entities but also the real associations between people and the world, with meaning, sense and the body as their basis. This reconstruction of cognitive activities and reinterpretation of the idea of the mind open up a wide expanse of road to us, even if we have so far taken only our first few steps along it.

3. Resorting to the ‘embodied mind’

In the 1970s, following these developments in psychology, the cognitivist or symbolic approach dominated research into cognition, particularly in the form of connectionism, which took neural network processing as its theoretical basis, supposing it to be analogous to human cognitive activities through the biological activities of the brain. In the AI (artificial intelligence) community, consciousness is regarded as a method of information processing in the human brain. This raises the question of how the brain represents and processes information, for which there are two main proposals: module theory, which implies a transcendental viewpoint, and distribution theory, which is more or less empirical.

In terms of modules (analogies of ontology and faith), symbolism regards human brains as symbolic operation systems and human thinking as essentially a form of symbolic processing; in this view, intelligence can be modelled by static, sequential digital calculation models. In connectionism, the cognitive functions and features of human brains are integrated on the basis of neurophysiology, in that information is converted and sub-symbols are parallel-processed by means of digital features (instead of logical rules) (Garnham, 2009: 99–110). Undistributed systems are often directed by a single command, and commands are published centrally. Each network layer consists of a serial relationship, while the distributed system has multiple organizations to issue commands. (Since no unified command organization behaves asynchronously, asynchronous contents are obviously included here.) The distributed system is therefore characterized by good levels of fault tolerance, self-learning abilities, the generation of associations and speed.

It should be noted that the elements in the pattern of intense excitement that characterizes consciousness usually occur one at a time. In other words, consciousness activities are serial, but the brain is a parallel information-processing system. Understanding this requires an acknowledgement that consciousness reflects the most important event being processed by the brain at any given time. A variety of conscious and unconscious neural activities take place in the brain, which is a parallel information-processing system that takes consciousness as its serial centre (Sharkey and Sharkey, 2009: 180–191). The module theory and the distribution theory, as two paradigms of mutual opposition and competition, can explain some of the existing findings. The module theory is effective in illustrating phenomena such as interference, generalization and ratings in the process of cognition psychology; for example, some types of language failures in patients with brain injuries support the module theory of language structures, and parallel calculation is widespread in the nervous system. In contrast, the distributed theory is more successful in simulating relatively simple cognitive processes.

With its rich experimental results, cognitive psychology has changed the face of psychology, but it has also been heavily criticized, not least at the level of methodology. Research in cognitive psychology has focused on individual cognitive phenomena to the neglect of interactions between individuals, interactions between individuals and culture, and the essence of social structures in which individuals are members. Traditionally, cognitive psychologists adopted computer metaphors to explain mental activities. Programmers, on this analogy, do not need to know about hardware, and cognitive psychologists therefore work at the level of behavioural analysis. Nowadays, however, a growing number of psychologists acknowledge that the role of human information processing in almost every important aspect of its functioning is importantly different from that of a standard digital computer.

The basis of contemporary cognitive psychology is mental representation and computation theory. Representation theory regards cognition as reproduction of the object world, whereas computation theory regards it as a process of computing information or manipulating symbols according to limited formal systems or algorithmic rules. Either way, what is revealed is the computational mind, which is at a considerable distance from the experiential mind, although complete human cognition must include both aspects at the same time (Jackendoff, 2002). The riddle of consciousness has not been solved, but at least we have gained the methodological insight that the solution will require the integration of multiple disciplines. Over the past 30 years, a welcome trend in cognitive psychology has been a focus on the occurrence and development of psychological phenomena in daily life, in an attempt to establish a cognitive model that is consistent with the human experience of consciousness and that will reveal cognitive activities through the characteristics of human intuitive experience.

Since the results of quantitative research on psychological phenomena are specific and precise, theories in almost all fields of modern cognition can be tested under standard laboratory conditions. However, there are many respects in which laboratory studies do not adequately represent the realities of daily life. In a psychological experiment, the response of the subject is not caused by the stimulation directly but by the stimulation as a clue to the experimenter's subjective response. This interference with independent variables may affect the subject's understanding of the experimental scenario and their own role within it, and the motivational directions taken by the subject. In other words, subjects tend to behave according to the so-called Hawthorn effect, presenting demand characteristics in response to the experimenter's assumptions (Pickel, 2008: 441). The existence of such experimental effects is enough to show that there is a difference between the experimental scenario and the 'real' world; because the former is a transient, artificial and abnormal situation formed by interaction between subjects and experimenters, extending the results of any experiment to a larger group is problematic.

Another prominent aspect of laboratory research is the so-called decoupling problem. With the development of research expertise, it has been noted that the scope of experimental methods is very limited. Research into interests, necessities, emotions and hopes involves a large number of unrelated variables, and experimental methods are often unsuited to controlling them. The unnatural environment of the experiment therefore affects the individual's psychological and behavioural responses, bringing the validity of the test into question. For moral reasons, some studies do not control subjects, instead tailoring the study environment to the individual. In this connection, Neisser (1999: 255–256) has noted that the study of information-processing approaches has yet to explore any aspect of human nature beyond laboratory limitations, and its basic assumptions have not gone beyond the computer models on which it relies. The human mind is not a general-purpose computer, and it is only the organ that is very sensitive to external stimulation. Eysenck and Keane's (2010: 4–5) warning is therefore unsurprising:

> . . . from the perspective that the discovery of new phenomena leads to a surprising number of related sub-phenomena, the more scientific the study of memories, the further it is away from the goals it should have.

Although that view is somewhat pessimistic, it is useful to remain alert to the qualitative impacts of changes in motivation and mood in internal cognitive activity. A focus on inner psychological processes under strict control that fails to take account of the main features of perception and memory that occur in daily life will lead cognitive psychology to repeat the mistakes of behaviourism, thus becoming a narrow and specialized field without broader significance.

These considerations are not intended to illustrate that purely descriptive scientific concepts and methods should not be applied in psychology; nor do they deny the importance of distinguishing between purely physical experience and spiritual matters. For present purposes, it is important to maintain a critical awareness of the preconceptions of the physics of modern psychology. On the one hand, it criticizes the use of empirical concepts to guide description when those concepts have not been analysed sufficiently carefully; on the other hand, it criticizes the way in which descriptive and explanatory sciences are juxtaposed and regarded as similar interpretations.

Phenomenology examines people's sense of reality (the way the world presents itself to the individual). For the phenomenologist, human psychology is dominated by subjective feelings rather than by the objective world. What we perceive is not necessarily the same as the objective existence of the outside world, and our behaviour depends on how the objective object appears. Edmund Husserl believed that feelings brought us direct knowledge about the world in its original appearance but that the purpose of our perception can distort that authenticity. The distortion can take many forms, from simple visual illusion to racial prejudice. Perception is often distorted because our minds are mixtures of opinions, assumptions and expectations:

> . . . it is impossible for the science of the mind to act according to the natural sciences, to learn from natural science in method, even in the schema where description is opposed to explanation . . . only derived from the intuitiveness given by reality itself . . . from the experience of the original living world . . . from the inherent nature of mental things. (Husserl, 2001: 190–191, 268)

According to psychology, the mind is revealed by what it does; according to phenomenology, the mind is revealed in the way it feels.

Scholars who emphasize the importance of phenomenology in psychology argue that scientific research requires supplementation by detailed phenomenological research from human experience. The basis of their argument is that psychology is very different from the natural or biological sciences in that it studies people, who are self-conscious and thus different from other organisms. Human experience is alive and can be expressed clearly in the first person, and consciousness is a uniquely important thing that psychologists care about. This concern requires special research techniques different from those used in traditional science, which are more appropriate for behavioural research (Zahavi, 2009: 247–262). Phenomenology has provided psychologists with a way to solve a series of special problems. 'Phenomenological suspension' can be seen as a move away from reflection on inner intentionality towards explanations of the inner process that are free of artificial restrictions.

Some common themes have emerged from research in this area. First, psychologists should be concerned with the functioning of the entire person instead of considering people in terms of isolated processes (such as learning and memory). Second, within certain limits, people have freedom to choose what to do; consciousness is the basic process of human beings, and research into consciousness is inseparable from the study of human beings. Third, psychologists should be concerned with the needs and problems of real life and people's motivations, not just with what is under study in the laboratory. Given the uniqueness of their subject matter, psychologists should design methods that are appropriate for that subject matter; simple reliance on traditional scientific techniques amounts to an evasion of the responsibility to make meaningful judgements. Finally, psychologists should concern themselves with helping people to understand themselves, rather than simply predicting and controlling human behaviours (Smith, 2016: 15–33).

4. Ecological validity and mind evolution

Experimental psychologists have focused on understanding phenomena such as memory and forgetting and have sought a fundamental understanding of brains and sensory organs, which they regard as systems capable of selecting, organizing, storing and retrieving information. They believe that this understanding must be based on experiments under simulated conditions that are designed to provide a high degree of control. Thus, during memory experiments, subjects are usually presented with two groups of materials: oral and non-oral. The oral materials may consist of a series of proper nouns, adjectives, verbs, fragments of prose, poetry and stories; the non-verbal materials generally include geometric figures, pictures of people, still lifes and landscapes. In order to describe and classify the performances of their subjects, cognitive psychologists place them in an experimental context with the aim of eliminating specific cultural content. Their research emphasizes and explores the existence and universality of basic cognitive structures. They seek to identify 'infrastructure', 'initial processes', 'general phenomena' and the universal mental functions that are indispensable to human nature.

In contrast, the ecological paradigm of cognitive research emphasizes that cognitive activities are rooted in cultural backgrounds. We acknowledge, for example, that in most cultures the memories of men and women will be different because of education and career differences; similarly, we observe that witnesses from very different cultural backgrounds have different recollections of the same events, especially complex events that are recounted orally.

Over the past two decades, ecological validity has attracted increasing attention, winning wide acceptance from psychologists and becoming an important reference point for experimental research and design. Ecological validity is the extent to which the results of psychological research extend to real-life situations. This concept emphasizes research on naturally occurring psychological processes and psychological phenomena with functional significance. It is used to evaluate whether a theory or an experimental result is of practical value, and it sees applicability to different groups of people, tasks and stimulations as a prerequisite of external validity (Galotti, 2008: 19, 29–30). In other words, if a study lacks ecological validity, it yields only the psychological and behavioural responses of the subjects in the particular study, not their actual representation in daily life.

Take memory studies as an example. The early cognitive psychologist Hermann Ebbinghaus used meaningless syllables as memory materials in order to simplify the stimuli and isolate responses. As a result, he arrived at the well-known Ebbinghaus memory curve. This kind of formalized research seldom involves behaviour with daily significance. Nevertheless, it has a number of advantages. It is based in the daily lives of its subjects; it shows that the memory materials for descriptive recall patterns are different from those for meaningless syllables; it requires no special observation or recall methods; and it dispenses with time limits.

In the middle of the 20th century, Frederic Bartlett realized that the development of psychological theory depends on research that solves practical problems. His work narrowed the gap between basic psychology and practical psychology, providing psychological research with a more realistic focus. He rejected Ebbinghaus's use of meaningless syllables divorced from reality and began to study memory in environments similar to real life. His materials were pictures and stories connected to everyday experience, incorporated into what he characterized as the descriptive method, the hieroglyph method, the series reproduction method and the diary method, and he used them to examine the whole process of memory, as well as to study his own autobiographical memory.

In Bartlett's (1932: 227–238) view, mental processes tend to be contained in memory terms in a realistic way; that is, as they actually occur in a normal individual, within or outside a social group. The purpose of his methods, in addition to considering the correctness of the recall, was to analyse the free descriptions of the subjects and their thoughts when answering the experimenters' test questions, thus examining the naturally occurring behaviours of the subjects rather than the behaviours prompted by the psychologists. Although Bartlett's theory contains many speculative components and never gained wide acceptance, his research prompted many people to think about the nature and dynamics of memories from a completely different perspective.

Until recently, cognitive research has been dominated by the computational-representational understanding of mind (CRUM). In CRUM terms, representation is the way that information is presented and recorded in the human brain. Cognitivism and connectionism both regard cognition as representations; cognitivism regards symbol processing as the appropriate carrier of representation, whereas connectionism regards the entire emergent representation as the representation of the world (Thagard, 2012: 11–13). The concept of representations is based in part on foundationalism and essentialism – the view that information and significance (or the essence, law or truth of things) are expressed through phenomena and that symbols are carriers for revealing information or significance.

The generative view refuses to take representations as the Archimedean standpoint of cognitive science, instead regarding cognition as an embodied action. It emphasizes that cognition is the joint enaction of the mind and the world on the basis of all kinds of activities that human beings engage in. It is the history of structural coupling and a reflection of real human life experience in the process of 'generation' (Bergen and Feldman, 2008: 315–318). Other scholars believe that human cognition has no structures and no rules; since at any given time there is an information exchange in a continuously changing state between the brain and the environment, cognition is the interaction between the cognitive subject and the environment. They interpret cognition as a dynamic system that includes anything that changes over time. In their view, symbolism and connectionism overlook the role of time in the cognitive picture.

In fact, the state of the brain is constantly changing, as the state space in a non-computational dynamic system (how the subject of cognition deals with information from the environment) is constantly developing. It follows that, as long as we know the changing process of mental state at different times, we can solve the mystery of the mind (Eliasmith, 2003). Thus, by focusing on how agency distinguishes mere 'thrashing about' from meaningful movement, Merritt (2015) strengthens the position of radical enactivism from the unique perspective of the dance of sense-making. Similarly, using the concept of cognitive niche, Werner (2020) unpacks ideas that are crucial for the enactivist movement, particularly in its original formulation by Francisco Varela, Evan Thompson and Eleanor Rosch. The work of those researchers has undoubtedly provided a naturalistic explanation for the continuity of cognitive behaviours in the time dimension. If a refusal to accept psychological representation as authoritative dispels the so-called foundation of the external world, then the negation of cognitive structures and rules points towards a more thorough anti-foundationalism.

The psychological value of phenomenology lies in its emphasis on the unity of people and the world. The object that exists in consciousness is different from that of nature, and spirit is independent, self-contained existence. The experience and the significance presented through experience can become the object of psychological research. It should be noted that phenomenology does not exclude empirical methods, and phenomenological and empirical methods are in fact interdependent (Yoshimi, 2016: 287–304). Certain substantive questions have to be faced. For instance, how can we ensure that a convincing framework for psychological development is constructed through phenomenology? How can real-life experience be included in a psychology that continues to use scientific research methods? Until those problems are addressed, the status of phenomenological psychology as a non-mainstream psychology remains uncertain.

5. Body image, self-identity and body metaphor

The return to the body creates a new quest for self-identity. Under the conditions of high modernity, the relationship between the body and the self is far more intimate than it was in premodern times. In the 1920s, psychology and sociology communities opened up research into body image – the depiction of one's own body in one's own mind, or how an individual thinks of his/her body. Body image is not only a cognition structure but also includes the attitudes of others and interaction with others as sources of somatotype perception changes, feelings of being too light or too heavy, and influences on interpersonal interaction (Waintrater, 2015: 49–53). The concept has been used to explore individuals' awareness and experience of their own bodies.

Over the past 10 years, in particular, both academics and the general public have begun to pay attention to the issue of body image, prompting Bryan Turner to characterize contemporary society as the 'somatic society'. Psychologists, too, have explored the psychological factors that affect individuals' satisfaction or dissatisfaction with their own bodies. Grogan (2007: 40, 135, 190) defined body image as perceptions, thoughts and feelings about one's body and its elements, including a speculative estimate of the size of the body, an assessment of its attractiveness and a sense of one's own somatotype. Body dissatisfaction involves negative thoughts and feelings of the individual about his/her body. This self-perception of the body is not limited to the individual's subjective sense of experience; since it is influenced by experiences of social interaction, it is also a product of social construction.

Central to body image is the self-identity of the body. The embedding of the body in daily interactions is a fundamental way of maintaining a coherent sense of self-identity. In order to maintain a 'normal' appearance and at the same time be convinced of their continuity beyond time and space, individuals must maintain stable behaviours over changing interactive scenes and must effectively integrate their behaviours into a personalized narrative.

The work of Goffman (2008: 41–47) has shown the tightness and complexity of the control that individuals are expected to maintain over their bodies in all social interactions. Regular control of the body is a fundamental means of preserving the personal experience of self-identity; meanwhile, the self is ceaselessly 'presented' in front of others according to its incarnation. Routine control of the body constitutes the active nature and the acceptance (trust) of others as an intrinsic part of the existence and essence of competence. The consistent expressions required for role performance in everyday life mark a crucial difference between our humanized selves and our socialized selves. As human beings, we may be animals driven by capricious emotions and unpredictable energy, but in our social role we must maintain relatively stable states, not allowing our high-level social activities to change as our perceptions and body consciousness follow our body states. Self-monitoring and the reactions of others remind people continually of the gap between the ideal body and the body in the mirror, and people use that self-monitoring to detect and try to correct that distance.

With the emergence of a high degree of modernity, an important element of self-identity is a more durable form of self-reflection that also extends to the body. Reflective monitoring of the body is in fact reflection on the 'system of life', and constant concern for the 'body' means choosing and adopting an ideal system of life in line with bodily changes.

Giddens (1998: 65) has examined the phenomenon of self-identity through the internal reference system of the self and the body, making use of Jean-Claude Kaufmann's concept of 'normal appearance' – a (closely monitored) physical behaviour in which individuals actively reproduce protective shells in a 'normal' situation. A normal appearance allows individuals to continue their current activities without having to pay much attention to the stability of the environment. Most of the time, however, people are still anxious, because physical appearances are not consistent with selves or self-identity. This is the separation of physical action and self-identity, which directly affects self-identity and generates 'existential anxiety'. The reason why the body plays such an important role in selves and self-identity is that it is a form of expression for obtaining what might be termed a sense of ontological security, and people monitor their bodies closely in order to obtain it. Physical exile can be felt in the tensions of everyday life when everyone's ontological safety is disrupted, but this is usually a temporary reaction rather than a permanent separation. Once the separation becomes permanent, self-distorting or mental division results. The difference between a person with schizophrenia and one without is that maintaining a normal appearance is a terrible burden for the former. In such situations, the self-identity narrative leads individuals to view physical activities with alienation, hatred or cynicism.

Recognition of the self also depends on the self being free from the body's experience, and diseases are often seen as a form of self-trial or self-betrayal. In terms of body image, if health is a state in which each organ is at peace, then disease is a rebellion by some organs. Disease is a language spoken by the body and a will expressed by the body.

Sontag (2001: 8–12) examined how disease (especially malignant tumours and infectious diseases such as tuberculosis, leprosy, syphilis and AIDS) is metaphorized step by step, transformed from 'just' a disease of the body into a moral judgement or a political attitude. Tuberculosis, cancers and AIDS have been given very different meanings, stamped with the brands of the eras of aristocratic society, industrial society and contemporary society, respectively.

Tuberculosis used to be a relatively common fatal disease, but its association with elegance, thinness and intense emotion made it a romantic disease in the 19th century. The metaphor of the disease increased the spiritual status and value of those who suffered from it.

In contrast, cancer is regarded as easily contracted by people who are frustrated, angry or depressed in ways that lead to lack of prudence or an unhealthy lifestyle. For example, oesophageal cancers are associated with alcoholism, and lung cancers are associated with smoking. Myths about certain behaviours (overconsumption, lack of exercise) that are seen as problematic can have the effect of 'punishing' those with cancer and may prevent them from seeking appropriate treatment.

AIDS has been stigmatized to an even greater degree than cancer. It has been considered as a disease of indecency or misconduct resulting from weakness or unsafe behaviour, and as applying specifically to groups regarded as 'dangerous' or 'untouchable'. Sontag (2001: 92–99) identified two prevalent metaphors for the micro-process and mode of transmission of AIDS: invasion and pollution. In addition, she found that AIDS is described as an invasive disease. Viruses can live in it, and even occupy the territory. It is imagined as an alien 'otherness' that first occurred in underdeveloped areas and then spread to the United States and Europe, replacing the plague as a retribution to society for its supposed licentiousness.

Above all, the interpretation of the body in the 20th century has placed less emphasis on its natural composition and has sought to integrate value judgements of different visual thresholds. The philosophy of the body involves the deepest essential questions of human society and culture, and it can provide original and detailed analysis of human nature and its roles and performances in social operations, revealing the operating mechanisms and internal contradictions of contemporary Western society.

In terms of methodology, the philosophy of the body abandons the idea of a binary opposition between the body and mind. However, research into the body still finds it difficult to rid itself of certain basic patterns of thought about the relationship of the individual to society, about nature and culture, or essentialism and constructivism. The ontology of the body usually follows the path of fundamentalism or anti-foundationalism; the former understands the living experience from the perspective of physical phenomenology and attempts to analyse the complex interactions between the bodily system, the cultural framework and the social process; the latter conceptualizes the body as a discourse about the nature of social relations or as a metaphor for a symbolic system or a social structure. Particularly with regard to its problems (and the accompanying truth questions), the body is negotiated and confirmed – a product of the legitimate discourses of which it is constructed. If we take the embodied milieu as both precondition and result of our theoretical and practical activities, then that challenges the traditional sense of the word 'social' and, in turn, the basic purposes of a social philosophy of science (Stoliarova, 2016).

In terms of epistemology, the main debate is between social constructivists, who believe that the body is constructed socially by discourse practice, and anti-constructivists, who regard the body as independent of the discourse forms that represent it (Turner, 2008: 12–16). It is necessary to break the binary opposition between the epistemology and the ontology of body studies, between the noumenon of the body and its representations and discourses. A truly phenomenological approach not only cares about how the body is shaped in society but also reveals how society itself is constructed in the affairs of the body, thus taking full account of the complexity of the body as a special historical connection.

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References

Allen M and Friston KJ (2018) From cognitivism to autopoiesis: Towards a computational framework for the embodied mind. *Synthese* 195(6): 2459–2482.

Bergen B and Feldman J (2008) Embodied concept learning. In: Calvo P and Gomila A (eds) *Handbook of Cognitive Science: An Embodied Approach*. Amsterdam: Elsevier, pp. 313–331.

Bartlett FC (1932) *Remembering: A Study in Experimental and Social Psychology*. Cambridge: Cambridge University Press.

Baudrillard J (1998) *The Consumer Society: Myths and Structures*. London: SAGE Publications.

Best S and Kellner D (2011) *Postmodern Theory: Critical Interrogations* (trans. Zhang ZB). Beijing: Central Compilation & Translation Press (in Chinese).

Bourdieu P (2012) *Le sens pratique* (trans. Jiang Zihua). Nanjing: YiLin Press (in Chinese).

Deleuze G (2011) Body without organs (trans. Chen YG). In: Wang MA and Chen YG (eds) *Post-Body: Culture, Power and Life Politics*. Changchun: Jilin People's Publishing House, p. 112 (in Chinese).

Dove G (2018) Language as a disruptive technology: Abstract concepts, embodiment and the flexible mind. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 373(1752): 1–9.

Dove G and Elpidorou A (2016) Embodied conceivability: How to keep the phenomenal concept strategy grounded. *Mind & Language* 31(5): 580–611.

Eliasmith C (2003) Moving beyond metaphors: Understanding the mind for what it is. *Journal of Philosophy* 100(10): 493–520.

Eysenck MW and Keane MT (2010) *Cognitive Psychology*. Hove: Psychology Press.

Foucault M (2004a) Nietzsche, genealogy, history (trans. Wang J). In: Du XZ (ed.) *Foucault Collection*. Shanghai: Shanghai Far East Publishers, pp. 152–153 (in Chinese).

Foucault M (2004b) Right of death and power over life (trans. Shang H). In: Du XZ (ed.) *Foucault Collection*. Shanghai: Shanghai Far East Publishers, p. 383 (in Chinese).

Galotti KM (2008) *Cognitive Psychology In and Out of the Laboratory*. Belmont, CA: Thomson Wadsworth.

Garnham A (2009) Cognitivism. In: Symons J and Calvo P (eds) *The Routledge Companion to Philosophy of Psychology*. Abingdon: Routledge, pp. 99–110.

Giddens A (1998) *Modernity and Self-Identity* (trans. Zhao XD and Fang W). Beijing: SDX Joint Publishing Company (in Chinese).

Goffman E (2008) *The Presentation of Self in Everyday Life* (trans. Feng G). Beijing: Peking University Press, pp. 41–47.

Grogan S (2007) *Body Image: Understanding Body Dissatisfaction in Men, Women and Children*. Abingdon: Routledge.

Husserl EGA (2001) *Die Krisis der europäischen Wissenschaften und die transzendentale*

Phänomenologie: Eine Einleitung in die phänomenologische Philosophie (trans. Wang BW). Beijing: The Commercial Press (in Chinese).

Jackendoff R (2002) The mind doesn't work that way: The scope and limits of computational psychology. *Language* 78(1): 164–170.

Lakoff G and Johnson M (2015) *Metaphors We Live By* (trans. He WZ) Hangzhou: Zhejiang University Press (in Chinese).

Medina J (2013) An enactivist approach to the imagination: Embodied enactments and 'fictional emotions'. *American Philosophical Quarterly* 50(3): 317–335.

Merleau-Ponty M (2007) *Eye and Mind* (trans. Yang DC). Beijing: The Commercial Press (in Chinese).

Merleau-Ponty M (2010) *The Structure of Behaviour* (trans. Yang DC and Zhang YJ). Beijing: The Commercial Press.

Merritt M (2015) Thinking-is-moving: Dance, agency, and a radically enactive mind. *Phenomenology and the Cognitive Sciences* 14(1): 95–110.

Miller M and Clark A (2018) Happily entangled: Prediction, emotion, and the embodied mind. *Synthese* 195(6): 2559–2575.

Neisser U (1999) Ecological psychology. In: Wilson RA and Keil FC (eds) *The MIT Encyclopedia of the Cognitive Sciences*. Cambridge, MA: MIT Press, pp. 255–256.

Pickel K (2008) Memory and eyewitness testimony. In: Davis SF and Buskist W (eds) *21st Century Psychology: A Reference Handbook*. London: SAGE Publications.

Rupert RD (2016) Embodied knowledge, conceptual change, and the *a priori*; or, justification, revision, and the ways life could go. *American Philosophical Quarterly* 53(2): 169–192.

Sharkey AJC and Sharkey N (2009) Connectionism. In: Symons J and Calvo P (eds) *The Routledge Companion to Philosophy of Psychology*. Abingdon: Routledge, pp. 180–191.

Slatman J (2014) *Our Strange Body: Philosophical Reflections on Identity and Medical Interventions*. Amsterdam: Amsterdam University Press.

Smith DW (2016) Cognitive phenomenology. In: Dahlstrom DO, Elpidorou A and Hopp W (eds) *Philosophy of Mind and Phenomenology*. Abingdon: Routledge, pp. 15–33.

Sontag S (2001) *Illness as Metaphor and AIDS and Its Metaphors*. New York: Picador.

Stoliarova O (2016) Milieu, embodiment, and cultural studies of science: Comment on Rom Harré's 'The Social ingredients in all ways of acquiring reliable knowledge'. *Epistemology & Philosophy of Science* 47(1): 78–83.

Thagard P (2012) *Mind: Introduction to Cognitive Science* (trans. Zhu J and Chen MY). Shanghai: Shanghai Lexicographical Publishing House (in Chinese).

Toon A (2015) Where is the understanding? *Synthese* 192(12): 3859–3875.

Turner BS (2008) *The Body and Society: Explorations in Social Theory*. London: SAGE Publications.

Varela FJ, Thompson E and Rosch E (2017) *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, MA: MIT Press.

Waintrater R (2015) Body image and identity in victims of extreme violence. In: Sukhanova E and Thomashoff H-O (eds) *Body Image and Identity in Contemporary Societies*. Abingdon: Routledge, pp. 49–53.

Walter RM (2011) Natural body. In: Wang MA and Chen YG (eds) *Post-Body: Culture, Power and Life Politics*. Changchun: Jilin People's Publishing House, p. 138 (in Chinese).

Werner K (2020) Enactment and construction of the cognitive niche: Toward an ontology of the mind-world connection. *Synthese* 197(3): 1313–1341.

Yoshimi J (2016) Prospects for a naturalized phenomenology. In: Dahlstrom DO, Elpidorou A and Hopp W (eds) *Philosophy of Mind and Phenomenology: Conceptual and Empirical Approaches*. Abingdon: Routledge, pp. 287–304.

Zahavi D (2009) Philosophy, psychology, phenomenology. In: Heinämaa S and Reuter M (eds) *Psychology and Philosophy: Inquiries into the Soul from Late Scholasticism to Contemporary Thought*. New York: Springer, pp. 247–262.

Zavota G (2016) Expanding the extended mind: Merleau-Ponty's late ontology as radical enactive cognition. *Essays in Philosophy* 17(2): 94–155.

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