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Bring together and advance emerging research topics in the history of science diplomacy in twentieth-century China

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This special issue has been produced based on the International Symposium on the History of Science Diplomacy in Twentieth-Century China, which was held at Peking University in March 2022.

Here, I would like to share with you some thoughts on the relationships between science and diplomacy. We are more than three years into the global COVID-19 pandemic, which has had profound impacts on people's lives around the world. Since the breakout of the pandemic, we have seen the importance of international collaboration in science and technology in both containing the spread of the pandemic and safeguarding sustainable global economic development. We are well aware that, unless every corner of the world gets the pandemic under control, it will be difficult to prevent ongoing transnational mass transmission. However, we have also seen how a lack of good-faith cooperation between governments and diplomats can seriously hamper scientific efforts. The value of modern public health and science has been ignored as political mistrust and mutual recriminations have arisen in many parts of the world. Emergency medical supplies do not always go to the places where they are needed most, but rather to where they have the greatest political potential.

Take COVID-19 vaccines as an example. Although they have been produced in a few large, developed countries during the pandemic, their global distribution has been highly uneven and politicized. Whether the 'Global South' can attain herd immunity via vaccination has been largely dependent on the will of a handful of Western countries, leaving the Global South at a significant disadvantage.

Some questions arise: How did such politicization and lack of cooperation in the global fight against the COVID-19 pandemic come about? How can it be changed? Is it possible to use the analytical framework of science and technology diplomacy to study it in depth and find ways to change it?

In 2010, the British Royal Society and the American Association for the Advancement of Science jointly released a report titled *New frontiers in science diplomacy*. The report stated that 'science diplomacy' encompasses at least three different components: *science in diplomacy*, which relies on science and technology to achieve diplomatic goals; *diplomacy for science*, which promotes international cooperation in science and technology through diplomatic means; and *science for diplomacy*, which promotes relations between countries through international cooperation in science and technology.

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The disagreements and contests in the global fight against the COVID-19 pandemic have made it clear that science and diplomacy are never two distinct fields with clear boundaries. In the field of global health, it is precisely the interaction between science and diplomacy that is needed to coordinate international cooperation and channel resources internationally. Public-health officials assume the dual role of scientists and diplomats when negotiating transnational scientific projects.

The havoc wreaked by COVID-19 has prompted some to look back on the patterns and lessons of similar pandemics in the past. Although historians are often wary of drawing parallels between present-day and historical events, fearing that such lessons may, as historian Robert Peckham suggests, constrain our ability to grasp the complex place- and time-specific variables that drive contemporary disease emergence, I believe that studying history will help us understand the ways in which humans, governments and societies have responded when faced with crises. For instance, during the horrifying Manchurian pneumonic plague from 1910 to 1911 in North-east China, there was ostensible international cooperation to control the epidemic. Still, under the surface lay fierce competition among the Qing Government, Japanese imperialist forces and Russian power. The science of public health was inevitably politicized by each side in an effort to demonstrate its mastery of modernity, and, by extension, to demonstrate the superiority of its civilization.

Modern epidemiology experts in China, represented by Wu Liande (Wu Lien-Teh), fully mobilized international medical forces to effectively contain the dangerous pneumonic plague. They also convened the influential International Plague Conference, which provided an opportunity to build a highly internationalized Chinese public-health system while promoting the process of globalized pandemic prevention. Looking at these events, we see a strong correlation between the past and our present reality, which can inspire us to delve more deeply into the history of science diplomacy.

Peking University, one of China's first research universities, has been a leader in the study of international relations and the history of diplomacy for decades. With a comprehensive School of International Relations dedicated to the study of contemporary foreign relations between various countries, and recognizing the importance of diplomatic history, Peking University has established a strong academic tradition in the study of the past and the present. Yet, most Chinese scholars of diplomacy and history have concentrated on the non-scientific aspects of these fields. The Department of the History of Science, Technology and Medicine at Peking University and the Division of History of Science and Technology Commission on Science, Technology and Diplomacy have organized the International Symposium on the History of Science Diplomacy in Twentieth-Century China in the hope of bringing together and advancing emerging research topics in the history of science diplomacy in twentieth-century China.

Articles in this special issue have been selected from papers submitted to the conference. The topics cover a wide range of themes relating to the interaction between science, technology, medicine and diplomacy from the late Qing Dynasty to the era of the People's Republic of China. The history of science, technology and medicine in China in the twentieth century is very important both for modern China and for Chinese people. To accurately understand the modernization of China over those 100 years, it is necessary to analyse in greater depth the enormous impacts of modern scientific and technological developments on Chinese society, as well as the profound changes in the development of Chinese society as it interacted with the outside world. I believe that this special issue will greatly enrich our knowledge of the history of twentieth-century Chinese science diplomacy.

Today, science and diplomacy are game-changers in emerging global crises. This must prompt us to revisit existing scholarship and re-examine our scientific and diplomatic paths. Such an examination will greatly expand our understanding of the impacts of past, present and future technological advances on human society and civilization. It is my sincere hope that this special issue on science diplomacy will serve as a milestone and impetus for the study of science diplomacy in China and beyond, inspiring scholars from different disciplines to join our research network. I believe that such research will, in the end, benefit all humanity and contribute to global peace and harmony.

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An information channel under technological blockade: The science and technology information system in China (1956–1966)

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Abstract
In the 1950s, aided by the Soviet Union, the Chinese government established a multilevel science and technology (S&T) information system covering many regions and professional departments across the country. The system's primary objective was to improve scientific research conditions and promote information exchange. With the deterioration of the Western technological blockade in the 1960s, the system's primary focus shifted to the acquisition of foreign S&T information. This article provides an in-depth analysis of the set-up, growth and activities of China's S&T information system between 1956 and 1966, with particular emphasis on the Institute of Scientific and Technical Information, its core establishment. The article examines how China facilitated S&T exchanges, despite the challenging international environment, and the role of the S&T information system as a crucial information pathway during China's early years under the People's Republic.

Keywords
Institute of Scientific and Technical Information of China, S&T information work, S&T exchange

1. Introduction

Modern science and technology (S&T) information emerged during World War II. Due to the information isolation caused by the extreme situation, France, the Soviet Union, the United States (US) and other countries organized different institutions to address the need for information collection in wartime. The rapid development of S&T after the war resulted in the birth of scientific information institutions, and S&T information science began to develop as an independent discipline. It is generally believed that China's S&T information work has a long premodern tradition. However, due to the inherent deficiency of scientific foundations in China, the war did not catalyse the maturity of the Chinese S&T information system as it did in France, although they both experienced the misfortune of being occupied. Even after the founding of the People's Republic of

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China, only a small amount of S&T literature work was carried out, such as compiling an index of science journals and establishing a reference group to carry out consulting services (Ministry of Science and Technology, 2019). Although some societies and organizations published indexes and abstracts in some disciplines, the overall situation remained unorganized and unsustainable.

The weak foundation is only one aspect of China's slow development in the S&T information system. Another significant factor was that China faced a technological blockade caused by the US for a long time during the early years of the People's Republic of China. This policy turned into a more comprehensive embargo in 1950, which included freezing foreign exchange and intervening in book orders, making it even more difficult for China to obtain high-grade S&T information (Feng, 2019). However, from 1956, China's ardent pursuit of S&T development made information and documents an urgent need, and the exploration of S&T information work was launched.

This article mainly focuses on the early history of China's S&T information industry. It examines how China drew lessons from international experience to design its S&T information system, as well as how it overcame obstacles to establish itself in the industry. The paper also pays attention to the effects of this work and its significance to S&T development.

2. Global trends and the influence of the Soviet Union: The background to the establishment of the S&T information system in China

The 1950s was a period when a large number of S&T information agencies were established worldwide. The Chinese government followed this trend not only because of suggestions from the Soviet Union but because it also closely coincided with China's internal demand for the development of S&T. Due to the practice of the revolutionary cause, S&T information as a special form of intelligence work could arouse resonance from the top of the Chinese government and win its endorsement. In this case, China's S&T information work was inherently characterized by international competition and ideology, and its importance was self-evident. However, China was in economic distress and faced a severe international blockade at that time, so it was extremely difficult to develop an S&T information system and carry out this work. These kinds of contradiction and tension were key factors in China's early S&T information work.

With the completion of the first five-year plan in 1957, the foundation of modern industry was established in China. Collecting international S&T information to serve the development of China's S&T became a pressing need (Ministry of Science and Technology, 2009). In a report meeting of the Chinese Academy of Sciences (CAS) in January 1956, Zhou Enlai questioned Zhang Jiafu (vice president of the CAS) and Wu Heng (general secretary of the CAS), after listening to their reports: 'How could you fight the war for so many years without even establishing an intelligence agency?' (CAS Library, 1985: 9). This shows that Zhou Enlai's understanding of S&T information work was mainly based on his personal work experience. Moreover, the comparison of S&T work to war reflects the sense of urgency and importance that China placed on its S&T development during that period. Some scientists put forward suggestions to the government on this issue, which may have become a force driving the government to make the decision to establish an S&T information system. For example, Qian Xuesen pointed out the importance of S&T data in his report titled 'Opinions on the establishment of China's national defence aviation industry', which was submitted to the State Council in February 1956. Some commentators even believe that Qian's opinions played a decisive role in the government's decision-making (Xi, 2011).

The development of S&T information in China was also a response to the worldwide trend, especially to those suggestions from Soviet consultants in the context of the Sino-Soviet 'Honeymoon Period'. In the 1950s, S&T information became a more important means of competition between the two camps during the Cold War. Especially within the socialist camp, several countries established S&T information systems based on the Soviet concentrated model. In 1952, the Soviet Union established an intensive national information centre within the framework of the Soviet Academy of Science—the Scientific Information Research

Institute (ГСНТИ)—which was reorganized as the All-Union Institute of Scientific and Technological Information (VINITI, ВИНИТИ) in 1955 (Kirson, 1973). The institute ended the former decentralized situation and became the leading organization with the largest scale, the most advanced equipment and the most publications in the world at that time, and was thus admired by its Chinese comrades (Yang, 1981). Influenced by the world's first S&T information conference held by the United Kingdom (UK) in 1948, the US, Japan and other capitalist countries also established various agencies for S&T information in the 1950s. Although these countries usually adopted the form of multiple decentralized sectors, there were also some relatively intensive integrated institutions, such as the Division of Information Science and Technology and the National Technical Information Service in the US, and the Japan Information Centre for Science and Technology built in 1957 (Taguchi, 1967). Although China was not directly involved, all of these changes were observed by the Chinese government. Under the influence of ideology, it was a reasonable choice for China to follow the direction of the socialist camp. In November 1955, EP Lazarenko (БР Лазаренко), who served as a consultant to the CAS president, suggested that the CAS should also establish its own S&T information agency, based on the experience of the VINITI, to carry out the compiling of express reports and abstracts.

Suggestions from all sides promoted the need for corresponding policy support. At first, the government's understanding of this issue was in the context of improving scientific research conditions. At the conference on the issue of intellectuals in January 1956, Zhou Enlai's report was considered a mobilization order for 'marching towards science'. He noted that, to develop S&T, all necessary conditions must be prepared for scientific research. Of primary significance was to enable scientists to obtain necessary books, technical materials and other working material. Therefore, China needed to improve the import situation of foreign books and periodicals, expand the translation of important foreign books, and rationally distribute the existing books and periodicals to relevant departments (Zhou, 1956). This can be viewed as Zhou Enlai's initial design for S&T information work.

At the national policy level, in May 1956, S&T information work was listed in the National Long-term Plan for the Development of S&T (1956–1967) (also called the 12-year Long-term Plan). The plan was to establish institutions, train experts in information work, comprehensively and rapidly collect, study and report on S&T development and new achievements both at home and abroad—especially in advanced countries—so that the Chinese S&T community could understand the latest achievements (Ministry of Science and Technology, 2018). Moreover, in October of the same year, S&T information work was listed as one of four urgent scientific tasks, and governmental policy emphasized that its implementation should be accelerated in the first few years of the Long-term Plan. All these actions on the policy level revealed that the Chinese government attached great importance to this issue, demonstrating the necessity of developing S&T information at that time.

3. Learning from the Soviet Union: The initial stage of China's S&T information work and its imitation of the Soviet model

Wu Heng, who was in charge of S&T information work in several different positions from 1956 to 1966, regarded the 1956–1961 period as the exploration stage of this career (Yang, 1996). At that time, the S&T systems of the Soviet Union—as a country at the forefront of this field in both theory and practice—became a model for China. When the CAS established its first S&T information institute in 1956, Dmitry Panov (Панов Дмитрии Юрьевич), one of the 16 members of the Soviet Advisory Group, who was the director of the VINITI and deputy director of the Institute of Precision Machinery and Computing Technology, put forward oral and written suggestions on the planning of China's S&T information system to Yuan Hanqing, who later served as the director of that institute (Yuan, 1985). From that time, learning from the Soviet Union was an important principle of China's S&T information work, and that principle was written into the Provisional Organizational System Table of the S&T information institute of the CAS in 1956. In 1958, Guo Moruo, president of the CAS, noted the importance of scientific information as an important aspect of learning from the Soviet Union in his summary report (ISTIC, 2016).

China's S&T information system copied the radiating network model of the Soviet Union. The main experience of the Soviet Union was to establish a comprehensive national institution, because 'scattered information is often one-sided and unreliable, while a small intelligence agency often could not do comprehensive work' (Wu, 1992). In the first statutory document on information work, the Plan on Carrying Out S&T Information Work, issued in 1958, China redesigned the system to accommodate decentralized institutes that had already been established. The S&T information institute of the CAS, which was established in October 1956, was recognized as the national centre and renamed the Institute of Scientific and Technical Information of China (ISTIC). ISTIC was under the dual leadership of the State Science and Technology Commission and the CAS, similarly to the situation of VINITI, which was also subordinate to the State Science and Technology Commission and the Academy of Sciences of the Soviet Union (Li, 1980). At the same time, the State Science and Technology Commission set up the Scientific Information Bureau as an administrative unit responsible for the construction and management of intelligence agencies at all levels throughout the country; it was also an imitation of the Soviet Scientific Intelligence Agency. At the local level, China also learned from the Soviet Union to establish a multidimensional information system, including institutes in 17 professional departments, such as the ministries of Weapons, Electronics, Nuclear Industry, Aviation, and Chemical Industry. Seven major cities, including Beijing and Tianjin, established regional information centres. Primary-level offices were also established in 18 provinces and autonomous regions by the year 1960[1] (Li, 1981). To facilitate the 'third-line construction',[2] ISTIC set up a branch in Chongqing, which played an important role in the later development of S&T information.

The research of the Soviet Union's information science also influenced China to a great extent. China sincerely believed that the socialist information system represented by the Soviet model had incomparable advantages (Wu, 1992). Because the science of scientific information had been established only recently, China's theoretical basis was mainly absorbed from the Soviet Union. For example, in terms of the definition and the connotation of the term 'S&T information', different countries had varied opinions on whether information work is equivalent to documents and materials. The S&T information centre in East Germany was called the Institut für Dokumentation, showing that the Germans regarded literature as the most important part, while, in the Soviet Union, it was called the Institute of Science and Technology Information. When ISTIC was built, China also had a dispute between those two definitions, and it finally followed the Soviet method and believed that literature work was crucial but not the whole thing (Yuan, 1983). The focus of this highly comprehensive work was to transmit S&T information through translating, processing and reporting literature (ISTIC, 1963). The Soviet Union also had a deep impact on China through work experience and theories published in journals in this field (Yan, 1992). In the first year of its publication, the journal *Scientific Information Work* introduced the situation, especially the experience of the Soviet Union. According to statistics, 89 documents were published in the first year, of which 61 introduced foreign intelligence work, and the literature introducing the Soviet Union accounted for a large proportion (Chinese Library Society, 1992).

When S&T information was first mentioned in the 12-year plan in 1956, its mission was interpreted as extracting papers from S&T journals all over the world and publishing them in the form of express reports and abstracts. However, this policy was not fully implemented, and the range was limited to the introduction of Soviet achievements. At the first National Intelligence Work Conference held in 1958, the collection and collation of important domestic inventions and scientific research achievements was placed before the collection of foreign ones. The timely and systematic introduction of the S&T achievements of the Soviet Union and other socialist countries was emphasized, while those of capitalist countries were only selectively reported. This policy was determined by the specific historical background of the Great Leap Forward. Under the policy of 'catch up with the UK and the US', it is not surprising that the focus of S&T information work was on the reporting of domestic S&T achievements. However, it does show that China's S&T information work at this stage did not focus on introducing the S&T situation of various countries.

In less than five years, China established a radial intelligence system from the central government to the local provinces, which was enough to show China's determination. The imitation of the Soviet model undoubtedly played a positive role. The S&T information work in this period had a distinct ideological slant, but, with the increasing tension between China and the Soviet Union in the 1960s, China chose to end its follow-up to the Soviet experience.

4. A new system of organization: China's independent exploration of S&T information work after the rupturing of Sino-Soviet relations

Although China never shies away from admitting it once followed the 'Soviet road' in the establishment of its S&T information system, it was defined only as a 'short way' (Zhou, 1984). After the 1960s, facing the great pressure of the split in Sino-Soviet relations, China put forward the countermeasure of 'working hard and being self-reliant', and S&T information work was given great practical significance because it could reveal the world's latest information. That led to the rescheduling of the organizational system and operational model. At the second S&T Information Work Conference held by the State Science and Technology Commission in January 1961, Wu Heng pointed out that, under the conditions of the technological blockade, a faster and wider collection of foreign scientific information was the key to changing the situation. To establish an efficient translation system, Wu required the ISTIC to become a core institute in translating and introducing foreign scientific achievements, especially those involving cutting-edge theories and comprehensive strategic intelligence. During the 1961 conference, a new two-year working draft dealing with the translation of foreign documents, and a series of policy documents on the methodology of carrying out the collection, were formulated. This included a plan on how to register documents collected from various channels and a plan on how to divide the work of translation among different institutes—a radical shift in the focus of China's S&T information system.

In the period of imitating the Soviet Union, China accumulated a lot of information through compiling international abstracts and express reports, and the translation work became the core mission of the ISTIC. As soon as the ISTIC was founded in 1956, it translated and published two Soviet abstract magazines (*Mechanical Engineering Volume* and *Metallurgical Volume*) and 11 professional express newspapers. In 1957, the ISTIC published a journal named *Metallurgical Abstracts*, which was a direct translation of the original edition from the Soviet Union. Therefore, when ISTIC was initially established, the majority of its staff were Russian translators mobilized from the north-east part of China, whereas the S&T personnel accounted for only 9% (ISTIC, 1996).

Translating foreign literature was a convenient path, but the information often lagged, making it impossible to assess the latest S&T progress, and content could not be acquired to meet the actual requirements. In October 1961, the Foreign Science and Technology Literature Compilation Committee of China (FSTLCC), an organization especially responsible for translating and compiling foreign scientific documents and journals, was established. As the core organ for introducing foreign S&T literature, it was not only responsible for the translation work—especially for those documents and patents that were difficult to obtain—but also for formulating the guidelines, tasks, annual plans, long-term plans, relevant rules and regulations for the overall operation. The mission of the FSTLCC was to change the form of the translation work, from completely translating the documents of the Soviet Union to independently compiling original documents from countries around the world. After 1962, to make full use of the collection of more than 10,000 kinds of S&T documents, reporting on this collection became the primary task. The FSTLCC formulated a 10-year plan, striving to approach the world level in the amounts of collection within 10 years and to ensure the coverage of a relatively complete range of disciplines.

How China spared no effort in introducing and translating scientific literature can be seen in the case of Shanghai. Although an open city in modern China, Shanghai's accumulation of foreign S&T documents was poor at the early stage. In February 1960, to facilitate the formulation of relevant policy, the Shanghai Municipal Committee requested the Institute of Science and Technology Information of Shanghai (ISTIS) to provide relevant information on foreign S&T development. However, the ISTIS was not clear about documents stored in the Shanghai area, not to mention understanding the trends in world science development. Thus, it had no choice but to translate some content from the Telegraph Agency of the Soviet Union (ISTIS, 2008).

This situation reminded ISTIS workers of the gap between actual needs and supply, and they then began a series of explorations. In 1961, the ISTIS investigated the information needs of the metallurgical industry. It was found that 80% of the 118 items proposed by experts and technicians were foreign S&T documents, and they could only provide a small part of them (ISTIS, 2008). Therefore, the institute focused its work on the collection and compilation of foreign patents and government research reports, especially in the fields of industrial technology, applied science and new technology. These materials were scarce at that time but were the most useful for promoting industrial production. In 1962, the ISTIS established a foreign literature office responsible for collecting, sorting and translating foreign patents. To implement this task, the staff of the institute expanded from nine in 1958 to 323 in 1966 (ISTIS, 2008). However, the international blockade and limited foreign exchange at that time made obtaining foreign literature a difficult task. Especially after the souring of relations with the Soviet Union in the 1960s, China had to invest more than ever in this cause.

In addition to Mao Zedong's instructions, the 10-year plan issued in 1963 pointed out that China should improve the management methods for imported books and periodicals, open up a wide range of channels, and accumulate and store all the important documents and materials publicly distributed abroad. In Shanghai's case, the ISTIS collected patent documents scattered in various departments in Shanghai and acquired a batch of documents from the CAS and ISTIC. With the support of the State Science and Technology Commission, the ISTIS went on an international exchange to order a batch of American patent documents of the 1950s (ISTIS, 2008). The ISTIC also explored indirect methods to acquire S&T materials, such as transiting through Eastern Europe or other Asian countries. Some documents were collected directly by those returnees, and this secrecy made this work more distinctive as 'intelligence'.

5. International exchanges driven by S&T information work

International exchange is an internal attribute of S&T information work. Especially for China, which was under internal ideological control and external technological blockade, the S&T information system became an important window to carry out S&T exchanges with other countries. China participated in a series of academic and technical exchanges in the field of scientific intelligence. To learn from the experience of the Soviet Union, the ISTIC maintained continuous interaction with its Soviet counterparts in the first few years of its establishment. For example, in 1958, China sent several business cadres to the VINITI to learn about machine-translation technology. In the following year, CM Lisipkin (СМ·лисипкин), deputy director of the VINITI, visited the ISTIC. In his report titled *Overview of the Soviet Union's scientific and technological information work*, he pointed out that China should pay attention to publishing scientific abstracts to actively participate in international exchanges (Chinese Library Society, 1992). His related works were also widely translated as references for China's scientific intelligence community.

Besides direct contact with the Soviet Union, China also participated in exchanges within the broader socialist camp. For example, in 1960, China organized an academic delegation in the field of S&T information to visit the Soviet Union, East Germany and the Czech Republic. In the following year, China participated in a meeting about S&T information held within the socialist camp in Prague on how to establish a unified information network and make full use of the Soviet literature. In 1962, representatives of Cuba and Vietnam came to China to attend a conference on international standards of S&T information work and paid a special visit to the ISTIC (ISTIC, 2016).

Another form of communication is the exchange of data and equipment. Through the activities of the ISTIC, China established S&T literature-exchange relations with many other countries. In 1959, for example, the ISTIC ordered 6824 copies of S&T journals, of which 6016 were not in Chinese or Russian. In 1965, China imported several large copiers from the Federal Republic of Germany and broke through the blockade to purchase a Boolean punch-card computer from France (ISTIC, 2016). By 1966, China had established data-procurement relations with the UK, France, Switzerland, Sweden, Japan, Denmark and other countries, as well as indirectly importing some equipment.

This exchange was not a one-way input—China also transmitted its scientific achievements to the outside world. In 1958, according to the provisions of the Sino-Soviet S&T cooperation project, the ISTIC selected more than 200 domestic S&T journals, translated those abstracts into Russian (or English) and sent them to the VINITI for compiling the *Abstract Journal*—the most famous S&T information publication in the Soviet Union. By 1963, China's self-compiled journal, *Scientific Abstracts of China*, had established exchange relations with 1628 institutes in 50 countries, and 2242 books and periodicals had been exchanged with 52 countries.

As a special institution focusing on the introduction of foreign literature, the ISTIS attached great importance to exchanges with relevant foreign organizations and institutions. Due to the constraints of the international environment at that time, international exchanges were difficult. However, the leaders overcame the difficulties to create favourable conditions for 'bringing in' and 'going out'. In the early 1960s, the ISTIS hosted an exhibition of Japanese industrial products, which attracted people from all walks of life. After the exhibition, a technical discussion was arranged to exchange with Japanese delegates on the technical issues of industrial products. The exhibition resulted in an enthusiastic response in Shanghai (ISTIS, 2008).

China's exchanges with the rest of the world were now not limited to the socialist camp and included other international organizations. In 1961, Nie Chunrong, director of the intelligence bureau of the State Science and Technology Commission, led a delegation to participate in the 27th Conference of the International Federation for Documentation held in the UK. The delegation's intention was to investigate the international background of the federation and its cooperative relationship with Taiwan. Although this process was interrupted by the political situation, the experience at the meeting had an enlightening effect on China's S&T information work. For China at that time, carrying out such S&T exchange activities was a particular focus, but that work was still limited in many aspects—as Wu Heng concluded, 'in general, foreign cooperation at this stage was limited, and intelligence work was basically closed' (Wu, 1958).

6. Serving the development of science: The role of the S&T information system

By 1965, the documentation centre of ISTIC had collected 11,000 foreign S&T periodicals, 54,472 volumes of materials, 5 million patents from 24 countries, 350,000 product samples from more than 20 countries, 170,000 national standards from 42 countries, and more than 200 foreign S&T films (ISTIC, 1996). ISTIC was also the only institution in China that had a complete collection of the 'four sets of reports' (documents of the Armed Services Technical Information Agency, Publication Board, National Aeronautics and Space Administration and American Engineering Council) from the US.

Another example of the work of S&T information agencies was that of the ISTIS, which specialized in collecting foreign literature. It had more than 3 million patent documents, nearly 5000 domestic and foreign S&T periodicals, 300,000 foreign S&T reports and other documents, and about 100,000 domestic and foreign S&T materials. As a local scientific information agency, such a reserve was enough to make it a data centre in Shanghai (ISTIS, 2008).

To display the collected materials and provide services to the public, China invested 2 million *yuan* in 1965 to build an eight-story building as the base for

ISTIC. Four of the floors were used to store documents, including 30 reading rooms and 700 reading seats, as well as some expert reading rooms.

At the beginning of the S&T information work, the reason why it received attention was to carry out soft science research to cooperate with the formulation of relevant policies, just as Guo Moruo put it in his speech at the national advanced producer representative conference in 1956. This function was retained even after the scientific intelligence institutes had operated for many years. In 1969, an internal publication named the *Reference for Technology Catch-up* was issued by ISTIC to serve and help ISTIC leaders to learn current trends in foreign S&T in a timely and comprehensive manner (Liang, 1992).

The practical value of S&T information that could provide intellectual resources for China's S&T development was highly emphasized. Wu Heng positioned S&T information work as a political task rather than as technical work (Wu, 1958). It was required that S&T information work be carried out in conjunction with the key projects in the 12-year plan and the 10-year plan. For example, agriculture had always been an important priority in this work and, after 1962, it was regarded as a key project, along with industry. S&T information had played some roles in development, especially in the provinces. For example, the Chongqing Branch of ISTIC supported the third-line construction projects and provided subject determination information services and tracking services for the construction of the Gezhouba Dam, the 1.7-metre rolling mill of the Wuhan Iron and Steel Company, and other national projects. In 1966, a south-west information station was established to provide services for the exploitation of vanadium and titanium deposits in Panzhihua.

In terms of cutting-edge science, the ISTIC introduced several scientific signs of progress to China, such as the green revolution and the recognition of the problem of plastic pollution. It also directly served basic scientific research by providing information to top scientists, such as Hua Luogeng, Li Siguang, Zhu Kezhen, Qian Weichang, Wang Ganchang, Tong Dizhou and Chen Jingrun. Hua Luogeng believed that the information provided by ISTIC made it easier to see the broader prospects of his theory, which led him to carry out the research and promotion of systems theory. ISTIC served not only top scientists but also a large number of other scientific researchers. For example, the ISTIS investigated the needs in production and compiled an introduction of patent documents and distributed them to the majority of S&T personnel (ISTIS, 2008). In the south-west region, intelligence workers used baskets to bring reference books to technicians in remote factories (ISTIC, 2016). This attitude of overcoming difficulties was called the 'basket spirit' and became a much-told tale in the field of S&T information.

7. Conclusions

During the 1950s, the general trend in the development of S&T information around the world was to actively establish intelligence agencies at all levels. In the 1960s, countries began to explore diversified classification and multiple service modes. China followed this general trend and was more advanced in some fields during its early exploration. The construction of the S&T information system was promoted through the convening of three national S&T information conferences. Thus, China found a path that was suitable for its national conditions and put forward the idea of establishing a national information network. In the publication and printing of S&T information journals, a relatively complete system of 'three categories and nine subcategories' was established. Therefore, China's S&T information work from 1956 to 1966 was fruitful, reaching a peak in institutional construction, data storage, international exchanges and other aspects. More importantly, it seems to have created a feasible development path. However, due to changes in China's domestic political situation, contact with foreign countries was interrupted in December 1966, the exchange of information publications completely stopped, the foreign S&T film libraries were sealed up, and organizational expansion and services broke down. As a result, China's S&T information work fell into a state of near paralysis, essentially led to the end of the early exploration stage of development.

The decade from 1956 to 1966 marked the first stage of China's S&T information work. Its achievements in introducing international S&T achievements are beyond doubt, although it is difficult to quantify its actual value for China's S&T development. The important value lies in the fact that it had broken through ideological restrictions, opened up a channel for China's foreign exchanges and laid a solid foundation for the normalization of S&T exchanges. This was proved by the fact that the S&T information system was not completely abolished even in the 1966–1970 period, when the situation was serious after the outbreak of the Cultural Revolution. The ISTIS maintained technical discussions with Japan, the US and other countries. When a large number of enterprises were forced to interrupt their exchanges with the outside world, the S&T information system played a crucial role in obtaining foreign S&T information. For example, in 1972, the Shanghai Institute of Petroleum Chemistry planned to import an atomic absorption spectrometer. The ISTIS assisted the institute in consulting about several product samples from Japan and the UK, analysing the performance of equipment from manufacturers in various countries, and finally selecting the most suitable model from the Pye UNICAM company in the UK. This facilitated the output of the institute's scientific research. After the political situation improved, S&T information work was among the first fields to recover, thus opening a new chapter in China's international S&T exchanges.

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1. The list includes Hebei, Inner Mongolia Autonomous Region, Liaoning, Heilongjiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi Autonomous Region, Sichuan, Guizhou, Shaanxi and Gansu.
2. The 'three-line construction' refers to the development strategy that was implemented by the Chinese government in the 1960s to build three key infrastructure projects that were intended to serve as a national strategic defense system: a network of railways, highways and infrastructure, known as the 'first line'; a network of hydropower plants, called the 'second line'; and a network of underground tunnels, called the 'third line'. The three-line construction was considered to be a major milestone in China's modernization history and played a critical role in the country's economic and military advancement.

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The 1972 Stockholm Conference and China's diplomatic response

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Abstract

Increasing public pollution and US President Nixon's environmental diplomacy strategy led to the 1972 United Nations Conference on the Human Environment (also known as the Stockholm Conference), to which China was invited as one of the United Nations member states. Before the conference, the Chinese government clearly understood the purpose of its participation in international environmental issues and the way to demonstrate its political position. During the conference, the Chinese delegation promoted the establishment of a group to revise the declaration on the human environment by uniting with Third World countries. China quickly established an effective environmental management system and contributed to the improvement of international environmental issues by acquiring scientific and technical information through participation in international conferences.

Keywords

United Nations Conference on the Human Environment, Stockholm Conference, China, environmental issues, international cooperation

1. Introduction

Since the Industrial Revolution, environmental problems caused by excessive carbon emissions have become one of the important challenges faced by humans. After entering the twenty-first century, developed countries or regional alliances led by the United States (US) have put forward the goal of 'carbon neutrality'. On 22 September 2020, at the 75th United Nations (UN) General Assembly, China officially proposed the goal of achieving carbon peaking by 2030 and carbon neutrality by 2060 (i.e., the 'double carbon' goal). This is an important commitment that China has made in addressing environmental issues such as worldwide climate change. In addition, in the process of achieving economic growth and the double carbon goal at the same time, China aims to become a knowledge provider for environmental protection in developing countries, and the transformation of energy structure will also reduce China's political barriers in international competition. Therefore, environmental protection is not only a concrete practice of scientific activities but is also a diplomatic means under complex international relationships.

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Of course, this also raises questions: When did environmental issues begin to receive common attention from countries around the world? When did China start devoting attention to environmental issues?

From 5 to 12 June 1972, the UN Conference on the Human Environment (the Stockholm Conference) was held in Stockholm, Sweden. It was the first international conference on environmental issues in human history. A total of 113 countries, including China, attended the conference. At the same time, this was also the first UN conference that China had been invited to participate in since it regained its legal seat in the UN in 1971. Previous studies of the Stockholm Conference have focused on its contribution to the promotion of international environmental governance and the relationship between different countries and the conference. The relationship between China and the conference has been discussed from the perspectives of environmental governance, political considerations (Wang, 2012) and the improvement of relations between the US and the Soviet Union, but the international context and real intentions of China's participation in the conference have not been sufficiently discussed. This paper analyses the contradiction and complexity of China's participation in international affairs in this special historical period on the basis of re-examining the relationship between China and the Stockholm Conference by combining relevant archives.

2. Origin of the Stockholm Conference

In 1962, *Silent Spring*, written by Rachel Carson, was officially published in the US, sounding alarm bells and quickly generating great public concern about environmental issues. The book described the widespread use of chemicals and fertilizers by humans to increase agricultural yields, triggering a serious ecological crisis that eventually backfired on humanity itself. Along with the deliberate push by the forces of environmentalism, environmental pollution became one of the major issues that the US government had to face at the time. In fact, countries in other industrialized regions of the world also faced serious environmental problems. In December 1930, a combination of gases and dust killed 60 people in a week in the industrial area of the Meuse Valley in Belgium. In December 1952, a smog event in London killed more than 4000 people in four days. In 1953–1956, people living in Minamata, a city in Japan, had multiple cases of Minamata disease, mainly due to the consumption of fish contaminated by industrial wastewater, and more than 60 people died. In addition, in the late 1960s, more than two-thirds of the arable land in the Soviet Union suffered from various degrees of ecological damage (Moynihan, 1969). Accordingly, both capitalist and socialist regions are plagued by public pollution, making it a global issue.

In July 1968, Sweden, which was deeply affected by pollution, proposed 'convening an international conference on problems of the human environment' at the UN Economic and Security Council (UN, 1968). On 3 December 1968, at its 23rd session, the UN General Assembly adopted this proposal, which was supported by most of the participating countries. After adopting the proposal, the 23rd UN General Assembly decided to convene the UN Conference on the Human Environment in 1972. The resolution emphasized the participation of developing countries, hoping that they would gain knowledge and experience on human environmental issues through international cooperation. As expected, the preparation for the conference was not easy, and the concrete manifestations of this complexity came from hundreds of countries in the world that had different ideologies and different perceptions of environmental issues. In December of the following year, the 24th UN General Assembly agreed to set up a preparatory committee of highly qualified people appointed by governments and a conference secretariat, and to appoint a conference secretary-general to ensure that the conference would be held as soon as possible (UN, 1969).

In addition to the Swedish government and the UN Secretariat, the US government was also concerned with the preparation of the human environment conference. This was related to the philosophy of President Nixon's administration. After Nixon became President of the US, he established the Council on Environmental Quality, which increased attention to environmental affairs. On the one hand, this was to fulfil Nixon's campaign promise to the public to solve domestic environmental pollution; on the other hand, it was shaped as a new form of diplomacy. With the purpose of facilitating the summit between the US and the Soviet Union, the Nixon administration included the environment among the issues of

US–Soviet cooperation. For US–China relations, the Nixon administration similarly used environmental issues as a method of enhancing contacts. In other words, the low political and volatile nature of environmental issues made a new instrument of the Nixon administration's foreign policy. Overall, if this conference could be organized as planned, it would undoubtedly provide a new platform for dialogue for the US.

Maurice Strong was appointed secretary-general of the conference as a result of a tripartite effort among Sweden, the UN and the US. An outstanding diplomat with a deep background in business, politics and environmental significance, he was Canada's representative to the UN beforehand. As Strong (2010: 148) recalled, '[The] Swedish ambassador to the UN, Sverker Astrom, who had spearheaded the idea, contacted me through a mutual friend. We met at his residence in New York, hit it off and he recommended to Philippe de Seyne, UN undersecretary-general for economic and social affairs, that they approach me to head the conference secretariat. A young Canadian friend, Wayne Kines, who was a media consultant to the UN at the time, arranged a meeting with de Seyne'. Subsequently, Christian Herter, who served on the US's conference delegation, invited Strong to his home, and, after much persuasion, Strong accepted the appointment. Eventually, Maurice Strong became secretary-general of the conference and undersecretary-general of the UN responsible for environmental affairs. Notably, Strong's colleagues did not support his decision, which they considered a mission doomed to failure.

Many analyses and viewpoints have been published on Strong's efforts towards the human environment conference, especially on promoting the participation of developing countries, such as the Founex Report (Manulak, 2016); accordingly, I will not review the details here but will only add that China was invited to the conference. Notably, the US was quite concerned about China's attendance at the conference (Xu and Xia, 2010). In December 1971, Strong approached the head of the Chinese delegation to the UN, Qiao Guanhua, with the intention of inviting China to the conference. He also expected China to make a presentation at the conference, for example, introducing China's experience with garbage sorting and waste utilization. It is noteworthy that Russell E Train, Nixon's environmental adviser, suggested increasing contacts with China through environmental cooperation, mainly in the areas of earthquake prediction, recycling of industrial waste, dryland use and water management, and wildlife conservation. In other words, one must ponder whether Strong's recommendations on the contents of the report to China were authorized by the US.

Subsequently, Qiao relayed that message to the authorities. On 15 December, the Chinese Ministry of Foreign Affairs and the Military Affairs Commission of the Ministry of Health jointly requested the State Council's approval to participate in the Stockholm Conference on environmental pollution, and the request was approved by Premier Zhou Enlai.

Improving international relations through environmental issues was a significant diplomatic strategy of the Nixon administration, and China was one of the key targets in practice. In fact, both the UN and the US expected China to participate in the conference. How China should respond to this situation was an important diplomatic challenge for the Chinese government, which had just recently regained its legal seat in the UN.

3. China's goal setting and role positioning before the conference

On 14 February 1972, the Secretary-General of the UN sent a formal note to the Chinese Foreign Minister inviting China to submit as soon as possible a list of its delegates to the conference, including a head of the delegation, no more than five accredited representatives, and such alternates and advisers as might be required. In terms of the selection of the delegation, the UN General Assembly recommended that it be composed of policy-making figures, including political leaders and senior administrative officials, supplemented by a relatively small number of technical advisers with broad exposure to key environmental issues, economic experts, material designers and other social scientists, and possibly opinion makers (Qu and Peng, 2010a). In terms of proposed participants' status, there were more political than scientific roles. China provided a list of participants as required.

In fact, the list of the Chinese delegation went through several deliberations before it was approved by Premier Zhou. To some extent, the department that was in charge and the person who was the head reflected the Chinese government's intention to participate in the conference. Initially, the Ministry of Health was elected to be the head. Zhou Enlai thought that this was not comprehensive enough and proposed that the industrial sector should also participate. Subsequently, the competent authorities submitted a list of delegation members, mainly from the Ministry of Fuel and Chemical Industries (Gu, 1998). On 15 December 1971, Zhou Enlai gave instructions on the composition of the delegation: 'The environmental issue is not only a health issue, but also involves all aspects of the national economy' (Qu and Peng, 2010b: 204). The finalized Chinese delegation consisted of one head, one deputy head, four delegates, five alternate delegates, six counsellors, two secretaries, four entourages and seven interpreters, representing a total of 31 people from the State Planning Commission, the Ministry of Foreign Affairs, the Ministry of Fuel and Chemical Industries, the Ministry of Health, the Ministry of Metallurgy, the Ministry of Second Machinery, the Ministry of Light Industry, the Ministry of Agriculture and Forestry, the Bureau of Oceanography, the Xinhua News Agency, and industrial and mining enterprises in Beijing and Shanghai. Among the members, the Chinese delegation was led by Tang Ke, vice minister of the Fuel and Chemical Industries Ministry, and Gu Ming, vice director of the State Planning Commission, and the four delegates were Bi Jilong, Chen Haifeng, Hou Xianglin and Li Jiarui. In terms of the identity of the main members of the delegation, most of them were from the industrial sector and had certain decision-making power.

Subsequently, the members of the delegation studied intensively for several months, thoroughly discussed the draft of the UN Declaration on the Human Environment and the conference documents, and formed the 'Request of the Ministry of Foreign Affairs and the Ministry of Fuel and Chemical Industries on the Program of Attending the Conference on the Human Environment' and the statement of the delegation. The request included two parts: information about the conference and the delegation's guidelines, and a request for instructions on specific issues. Regarding the purpose of the conference, the delegation considered that 'it is ostensibly a professional conference, with the aspect of exchanging experiences on environmental issues and seeking international cooperation, but in essence it has to reflect the current international political struggle, mainly the struggle between control and counter-control' (Qu and Peng, 2010c). Moreover, the delegation expected that there would be a number of developing countries with some illusions about receiving technical and financial assistance from developed countries. The main reference here was to the Nixon administration's proposal to raise a billion-dollar environmental fund. In other words, the delegation thought that developed countries were trying to use the conference to improve their environmental woes and thus achieve leadership in international environmental affairs. Although the Chinese delegation's judgement was consistent with the Nixon administration's strategic intent of environmental diplomacy, it reflected to some extent the delegation's attitude to some hegemonic countries. Certainly, in the context of the Cold War, this judgement was reasonable.

Importantly, China had a clear understanding of its role in the conference. Before the conference, the Chinese delegation formulated specific guidelines and practices: (1) to stand firmly on the side of the Third World and the people of the world; (2) to work with Asian, African and Latin American countries to win over small and medium-sized developed countries and to expose and fight against the US and the Soviet Union, based on the policy of exploiting contradictions and expanding the international united front; (3) to point out the root causes of environmental problems and encourage the peoples of all countries to protect and improve the environment; (4) to work more and take proper care of some wrong views and unrealistic illusions of Asian, African and Latin American countries that aimed to seek assistance from developed countries; and (5) to introduce and publicize China's environmental problems in a factual and realistic manner and firmly reject any slander against China. These guidelines and practices also reflect the Chinese delegation's response to the draft declaration on the human environment, which may be called diplomatic means. Importantly, note that the delegation planned to introduce some of China's effective experiences on and measures of environmental issues, not to deny the existence of environmental pollution in China, but to build the country's image. Qu Geping, one of the main members of the delegation, recalled that, in 1970–1972, several incidents of environmental pollution occurred in China, leading to great attention by the State Council and plans for a special conference. This was temporarily shelved due to preparations for the Stockholm Conference (Qu, 1997). In addition, Premier Zhou Enlai instructed the delegation that 'through this conference, we should learn about the state of the world environment and the significant impact of environmental problems on economic and social development in various countries, and use this as a mirror to understand China's environmental problems' (Qu and Peng, 2010d: 206).

In fact, China has always been cautious about engaging with other countries. Before the conference, the delegation made advance plans on what attitude to adopt in facing different participating countries. For the Third World countries, it was thought that China should take the initiative to contact them; for the US delegation, it was thought that China should maintain a certain etiquette and not take the initiative to receive them; for the Japanese delegation, it was thought that China should remain aloof and avoid issues such as Sino-Japanese relations; for other capitalist countries, it was thought that China should treat them with courtesy and make appropriate contacts; for Sweden, it was thought that China should take the initiative to contact the conference secretariat and express its friendship; and for South Korea and South Africa, it was thought that China should not deal with them. This was consistent with the established practice of the Chinese delegation's participation in the conference.

Overall, the Chinese delegation set a clear policy before participating in the conference. On the one hand, China hoped to gain more experience in pollution control and prevention through the conference; on the other hand, China also expected to demonstrate its political position and give signals of international cooperation.

4. China's diplomatic efforts to promote the revision of the Declaration on the Human Environment

In its invitation note to China, the UN stressed that several drafts, including a declaration on the human environment and a plan of action, needed to be considered at the conference. Prior to its arrival in Stockholm, the Chinese delegation had made clear its commitment to promoting the revision of the declaration. There have been a number of specific studies on China's efforts to promote the revision of the content of the declaration, and the present paper only adds to those efforts.

The Chinese delegation thought that the declaration would be the focus of the struggle at the conference, mainly because the document did not adequately reflect the demands of developing countries and avoided the main responsibility of developed countries for environmental pollution. Many developing countries were also dissatisfied with these aspects of the document. On 30 May, Chinese delegates Bi Jilong and Chen Haifeng took the initiative to visit Nelfin, the assistant secretary-general of the conference, to discuss and negotiate the draft declaration. Nelfin revealed that 'if many governments agree to the changes, the drafting group will continue its work' (Qu and Peng, 2010e: 170). This attitude made the Chinese delegates realize that it was possible to revise the declaration, and the delegations of Argentina, Uruguay and Venezuela proposed the establishment of a group to revise the declaration at the preparatory meeting on 31 May. This coincided with the Chinese position.

On 1 June, Bi Jilong and Chen Haifeng reached out to representatives of developing countries such as Pakistan, Syria, Egypt and Algeria to explain the importance of the declaration for developing countries and to try to gain their support. This development also attracted the attention of the Canadian, Swedish and British delegations. In the afternoon of the same day, the representatives of the three countries took the initiative to talk to Bi Jilong with the intention of accepting the declaration, which they stressed was the result of a compromise among many countries and would be difficult to change.

The Chinese delegation's idea of amending the declaration did not gain the support of the conference, and, on 3 June, the head of the Chinese delegation, Tang Ke, the deputy head, Gu Ming, and others arrived in Stockholm and immediately met with the secretary-general of the conference, Maurice Strong. Strong showed a clear view of rejection. Additionally, Strong's assistant, Winter, suggested that the Chinese side abstain from voting on the declaration, and, on 4 June, Tang Ke and others visited the President of the General Assembly, Bengt Save-Soderbergh, to present their views on amending the declaration. Until the day before the conference, the Chinese delegation was still making efforts to amend the declaration. Judging from the results, this attempt was not successful. On 5 June, the conference was formally convened, and Strong said during the plenary session that the declaration should not be revisited.

On the conference day, the Chinese delegation invited the heads of the delegations of Algeria, Syria, Pakistan, Argentina, Venezuela, Egypt and Zambia to lunch; Egypt and Zambia were absent. After thorough discussion, the six delegations agreed on the revision of the declaration and the establishment of a working group on the revision. At the same time, the delegations undertook to divide and consult with other delegations by region. On 6 June, the host delegation, Sweden, extended an invitation to a dozen delegations to hold small informal consultations on whether to revise the draft declaration. The Chinese delegation did not consider this to be broadly representative. Therefore, on 7 June, the Chinese delegation formally submitted an urgent written motion to the General Assembly to establish a special committee on the declaration and requested that the President of the General Assembly read it in the plenary session. In the afternoon of the same day, the Swedish delegation expanded the delegation's invitation, and two heated opinions were formed at the meeting, which allowed for a focused and formal presentation of the opposing views in the draft declaration. Ultimately, the Swedish delegation decided to report the issue to the governing body of the conference.

The Chinese delegation's efforts to revise the draft declaration had positive effects, and, on 8 June, the delegations of Syria and Chile made overtures to China. Additionally, the Asian delegations held consultations on the revision of the draft declaration, which resulted in agreement. In the end, the General Assembly also agreed to the urgent motion proposed by China and decided to involve all participating countries in the revision of the declaration. As the Swedish newspaper *Dagens Nyheter* commented, 'this action by China shows that China is willing to exert its influence at international conferences' (Qu and Peng, 2010f: 152).

Besides contributing to the revision of the draft declaration, the Chinese delegation also exerted an influence on other international disputes related to environmental pollution. In the case of the US invasion of Indochina, for example, on 10 June, the Chinese delegation issued a strong condemnation to the US in the plenary session on the grounds that it had used chemical agents in the war to destroy the human environment. In addition, the Chinese delegation tried to join other delegations in proposing a motion to condemn the US to the General Assembly. This was too difficult to accomplish, and the motion was therefore withdrawn. In fact, before the Chinese side took the floor, several delegations had already condemned the US in the plenary session. The Swedish Prime Minister and Tanzania, Syria and Zambia, and Romania and Libya took measures in their statements on 5, 8 and 9 June, respectively. In fact, the US delegation had expressed its goodwill to the Chinese side by offering a handshake greeting and inviting a meeting, which was related to Nixon's visit to China. Faced with the Chinese side's condemnation, the US delegation was quite upset and immediately offered a reply, then postponed it, and finally responded only briefly. This reflected the US government's position on the de-escalation of Sino-American relations. On the morning of 13 June, Zhou Enlai issued an urgent instruction requiring the delegation to 'stop when appropriate' (Qu and Peng, 2010g).

5. Conclusion

The Stockholm Conference was an international conference that focused on environmental issues in the context of the Cold War, and its convening had much to do with the environmental protection movement and the environmental foreign policy pursued by the Nixon administration. It can be said that the conference provided an opportunity for the US to take the lead in international environmental affairs and to further ease international relations. As a sovereign nation that also suffered from public pollution, China expected to learn about environmental problems and management experiences from other countries. Therefore, China not only sent a 31-member delegation with industrial and political backgrounds, but it also played a key role in the conference. By proactively seeking cooperation and demonstrating a political stance, the Chinese delegation pushed the conference to make limited changes in the declaration to give developing countries a voice in international affairs.

Undeniably, the conference also permitted the successful acquisition of international scientific and technological intelligence. Upon its return to China, the Chinese delegation conveyed to Premier Zhou Enlai useful information that it had acquired at the conference, including about international environmental efforts. Under Zhou Enlai's direction, the State Council Environmental Protection Leading Group was created, with Gu Ming, deputy head of the delegation, as one of the main leaders. It is clear that the Stockholm Conference shaped China's environmental management system.

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In the name of Asian solidarity: Sino–Japanese competition for technology diplomacy in Burma, 1955–1965

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Abstract

A decade after the 1955 Bandung Conference, China and Japan engaged in a competition for technological exports to Burma.[1] During this process, technocrats in Beijing and Tokyo mobilized non-governmental collaborators—local Chinese industrialists and Japanese businesses seeking overseas expansion—as proxies to maximize their technological output to Burma. The Burmese, on the other hand, used the competition between Beijing and Tokyo as a bargaining tool, and pressed the two regional powers to provide at Rangoon's request. The technical aid Burma received was also affected by its shifting visions for development. Factionalist struggles between 1958 and 1962 changed not only Burma's political landscape but also its leadership's mind-set regarding the economy: the nation moved away from aid-driven industrial modernization towards a self-reliant, agricultural economy based on limited foreign technologies. Consequently, the meaning of the term 'technological aid', though used throughout the decade, became flexible and indistinct, carrying vastly different connotations at different stages of the Burmese state-building process. In this way, Burma's experience as an aid-receiving country in Cold War Asia may speak to the flexible power dynamics between the aiding and the aided countries, and shed light on the diversified means through which states employed science and technology as diplomatic tools in Cold War competition.

Keywords

Technology transfer, industrialization, Sino–Japanese competition, Burma

1. Introduction

Revisiting the economic legacy of the 1955 Bandung Conference, it is almost impossible to miss the disparity between the promising economic agenda it put forward and the lack of progress in its aftermath. As confrontation in Indochina escalated during the mid-1960s, and countries (Indonesia, Malaysia and Burma, in particular) engaged in civil uprisings and territorial disputes, the region received increasing military aid and witnessed a decline in intra-regional economic cooperation during the two decades after

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1955. The substitution of technological support with military aid attested to the diminishing sense of the idealism stipulated at Bandung.

However, it would be hasty to dismiss the economic initiatives at Bandung as utterly unrealistic. By examining newly declassified diplomatic documents from the 1950s to 1960s, it is possible to argue for a re-evaluation of the technological cooperation practised in the post-Bandung decade. China, Japan and Southeast Asian countries managed to forge important connections in bilateral cooperation during this period. As this paper demonstrates, these bilateral technological programmes were shaped by diplomatic dynamism involving multiple countries.

Existing scholarship has paid attention to this aspect of the Cold War, and explored how the geopolitical confrontation facilitated the founding of such aid programmes. This research is exemplified by monographs from Jeremy Friedman and Gregg Brazinsky. In his book *Shadow Cold War*, Friedman (2015) examines the competition for leadership between China and the Soviet Union, the two socialist giants, through economic and technical assistance to developing countries. Brazinsky (2017), in contrast, offers an analysis of the Sino–American competition for prestige, which was also conducted under economic terms.

However, the scholarship remains scarce on Burma, a country that played an essential role in forming the Non-Aligned Movement. Existing research primarily examines Burma's industrial development through the lens of foreign technical assistance, and evaluates the significance of these aid projects in the economic landscapes of both aiding and aided countries. Aaron Moore's (2014) study on the hydropower project at Balu Chaung provides an excellent example of this line of inquiry. Examining how Japan used its reparations deal to facilitate its grasp on Burma's course of development, Moore (2014: 322) argues that the project itself was an agglomeration of governmental initiatives to create 'a new network of power', and bring together America's geopolitical design for Southeast Asia, Japan's ambition for economic leadership in the region and the Burmese regime's efforts to establish effective control over its borderlands. Zou and Fan's (2019) study of Burma's national economic development plan (*Pyidawtha*) also contributed to the understanding of Burma's struggle for modernization in the post-war period. The Burmese government's unique interpretation and pursuit of a welfare state shaped its decision to replace British aid with assistance from China, signalling the interrelation between the country's domestic political and economic development and the international context.

Nevertheless, focusing on the initiatives of aiding countries, these studies risk overlooking the multilateral nature of foreign technological assistance to Burma. Utilising the country's neutral position during the Cold War, the Burmese government was able to parley with its foreign investors and shape the proceedings, terms and eventual outcomes of its aid. For instance, the U Nu and Ne Win governments both took advantage of the conflict between Cold War blocs, and turned aid from one camp—for instance, that from China and the Soviet Union—into bargaining chips for negotiations with the rival camp. As a result, negotiators from China and Japan often found themselves forced to offer better terms to their Burmese counterparts, citing the fear that Rangoon would be swayed by the preferential offers from the opposing camp. Leaving out this story may risk blurring the agency that aided countries had, and may underplay the multilateral nature of science diplomacy during the Cold War.

Existing studies also pay insufficient attention to non-governmental initiatives involved in forming technological aid, leaving a significant part of the exchanges unaddressed. The economic assistance programmes examined by Friedman and Brazinsky were secured primarily in intergovernmental agreements, through either formal negotiations or memorandums exchanged via diplomatic channels. However, the Cold War also witnessed the extensive mobilization of non-governmental proxies, including businesses and individual entrepreneurs. This point is well exemplified in China's and Japan's aid to Burma. In the 1950s and 1960s, Beijing actively solicited help from local Chinese entrepreneurs in Burma to promote its industrial equipment. At the same time, Tokyo was able to employ the country's industrial giants—Panasonic, Hitachi and Nichimen, in particular—as foot soldiers to provide technological support. Therefore, these companies and entrepreneurs had to carefully integrate diplomatic aims into their commercial activities, creating much tension and political risk in the process.

Using recently declassified documents in China and Japan, this paper examines the competition between Beijing and Tokyo in their technical assistance to Burma, and how Burma strategically employed the competition to tighten its grasp on the national economy. During this process, economic bureaucrats in the two countries mobilized non-governmental collaborators as channels to maximize their technological output in Burma, while the Burmese leadership used the competition to balance China's and Japan's economic influence in the country. This paper also highlights the fluidity of technological aid, in which Burma's perspectives for national development constantly shaped the meanings, terms and forms of the technological aid that it desired. I argue that the factionalist struggles transformed Burma's economic ambition over time: from industrial modernization and an open economy driven by foreign investment to a self-reliant, agricultural economy based on limited foreign technologies. As a result, China's and Japan's respective aid to Burma carried vastly different connotations at the different stages of the Burmese state-building process. In this way, Burma's experience as an aid-receiving country in Cold War Asia may speak to the flexible power dynamics between the aiding and the aided countries, and shed light on the diversified means through which states employed science and technology as diplomatic tools in Cold War competition.

2. Non-governmental proxies in Sino–Japanese competition for technology output to Burma, 1955–1958

Having been one of the main operational theatres in World War II, Burma faced difficulties pursuing economic recovery in a war-shattered landscape. In addition to the heavy fighting in Rangoon, Meiktila and Mandalay between the Japanese Army and the Allied forces, a civil war between the ruling Anti-Fascist People's Freedom League (AFPFL) and Burmese communists in 1948 also stymied the country's economic development (Smith, 1991). From 1948 to 1953, U Nu's government suffered from a sharp decline in rice exports and a stagnated domestic economy that forced the government to seek economic aid from the international community (Zou and Fan, 2019). However, U Nu's dedication to neutralist diplomacy made Rangoon a reluctant participant in the Western bloc's initiatives, including the Colombo Plan—the technological cooperation group led by its former colonial suzerain (Egreteau et al., 2013). Scepticism about Washington's support for Kuomintang forces' presence in north Burma also prompted U Nu to reject the aid that Vice-Prime Minister Ne Win secured from the United States in 1953 (Jiang, 2022). Consequently, Burma's initial approach to the West did not procure the economic aid it so desperately needed.

Under such circumstances, Burma turned its focus eastward, to China (its new socialist neighbour and former ally in the independence struggle) and Japan. The 1955 Bandung Conference provided a gateway for such an attempt. During the conference, the Burmese made it clear that, while the country did not want 'conditioned aid' from the United States, it would welcome any funds and technologies from outside the region (Zou and Fan, 2019: 570). This call echoed Japanese delegate Takasaki Tatsunosuke's speech, in which he pledged that Japan was 'anxious to contribute her share' to address the 'scientific and technological lag of Asia and Africa' (Takasaki, 1955: 75). The Chinese delegation, too, had made contact with the Burmese delegation. As Zhou Enlai (1955) reported to the Central Committee of the Communist Party of China (CPC), the Burmese side demonstrated much interest in acquiring Chinese machinery—mainly textile machinery—to develop its industries. As a result, both Beijing and Tokyo stepped up their aid efforts to Burma after 1955, supplying industrial equipment to Rangoon under the pledges made at the Bandung Conference.

However, the Burmese leadership's ambition for rapid industrialization was not unopposed within its ranks. Even before the political upheavals in 1958, there existed a long-term division within the AFPFL regarding Burma's route to industrialization. The ministers Ba Swe and Kyaw Nyein, and the so-called 'educated group' they led, prioritized industrial development and had a more welcoming attitude towards foreign investment. In contrast, the Thakin faction, led by Thakin Tin and Thakin Kyaw Don, favoured agricultural development over industrialization, fearing that the current pursuit of rapid industrialization through foreign aid was unfit for Burma's situation (Pho, 1963). Nevertheless, since Ba Swe and Kyaw Nyein maintained firm government control from 1955 to 1958, both ministers ensured that the opposing voices remained irrelevant and moved their industrialization ambitions forward with aid from Japan and China.

To exert influence on Burma's ambition for industrialization, economic technocrats in Beijing and Tokyo mobilized a wide range of non-governmental initiatives at their disposal. For China, the 350,000 Chinese ethnics in the country (or 2% of the total population) were natural collaborators, should Beijing play its cards right (Overseas Chinese Research Association, 1955). In addition, unlike their counterparts in Malaya, Thailand and Indonesia, who maintained significant influence in the commercial activities of their countries of residence, Chinese communities in Burma were primarily concentrated in various handicraft and light industries, including soap, timber, breweries and rice-grinding factories (Overseas Chinese Research Association, 1955). The Burmese Chinese communities' preoccupation with manufacturing rather than commercial activities corresponded with the strategy Beijing envisioned for the overseas Chinese. From Beijing's perspective, the overseas Chinese needed to become as 'relevant' as possible in the national economies of their countries of residence, both for their safety and for China's national interest in these places. Such an idea was proposed by Liao Chengzhi, who argued that overseas Chinese in Southeast Asia would benefit from actively participating in the industrialization of regional countries. Liao's argument received support from Zhou Enlai. In his report to the 8th CPC National Congress in 1956, Liao made his arguments clear:

> Admittedly, as the colonial economy in these [Southeast Asian] countries collapses, and the national capital develops, there will be a conflict between the overseas Chinese capital and the national capital … However, this conflict is reconcilable when we encourage Chinese capital to work together with the national capital and develop enterprises that contribute to people's livelihood there … Overseas Chinese in Southeast Asia should work with our policy. If overseas Chinese capital can invest in local industries gradually, steadily, and in an organized way, it will reduce the negative influence of Chinese commercial capital in their respective national economies and become a positive factor in making local economies prosper … We are ready to encourage overseas Chinese to unite and work in this direction. (Liao, 1956/1990: 307–308)

With Zhou's support, Liao further developed his theory and proposed that the Chinese government should support overseas Chinese in their 'transition to manufacturing' by incorporating their products into China's national economy: 'If necessary, we should include their factories in the domestic economic plan. Moreover, to compete with imperialists, we should connect [their manufacturing business] to our production and consumption chain, and solve difficulties through one supporting the other' (Liao, 1957/1990: 320). These ideas were then publicized in the *People's Daily* and *Ta Kung Pao*, and circulated by Chinese traders in Hong Kong and Singapore.

Some Chinese entrepreneurs in Burma welcomed Liao's proposal and travelled to China to arrange imports of Chinese industrial equipment for their factories. One example was Zeng Chengfa, a Chinese entrepreneur and board member of the Myanmar Chinese Chamber of Commerce (MCCOC), who was invited to attend China's National Day celebration and to visit Shanghai and Beijing to tour Chinese factories in September 1956. As the Chinese document (China Import and Export Company Shanghai Branch, 1956) shows, the tour for Zeng and his companions emphasized light industry factories that produced consumer goods because the Chinese expected Zeng to help promote Chinese factory equipment upon returning to Rangoon. In return, Zeng helped to organize an MCCOC entrepreneurs' visit to the Autumn Trade Fair in Guangzhou in 1958, and actively promoted Chinese products to Burmese technocrats with whom he became acquainted.

Beijing's strategy with local Chinese industrialists was partially effective. In addition to the increasing imports of Chinese machinery—most notably for timber-cutting and cotton-spinning—Chinese entrepreneurs in Burma also sought technological input from China for their factories. An example of such cooperation over technological support was seen in May 1958, when the Chinese National Transport Machinery Import Corporation (CNTMIC) signed a contract with the Yin Yin & Sons Company. Owned by Daw Yin from Fujian Province, the company was one of two major Chinese soap-manufacturing companies in Burma, with assets worth more than US$210,000 (Hara, 1959). According to the contract, the CNTMIC would send four technicians to build a soap factory in Rangoon with the glycerine machinery supplied by Chinese manufacturers (CCO, 1958a). Beijing even demonstrated a significant level of tolerance when these local entrepreneurs violated the contracts. When Chinese technicians arrived at Daw Yin's factory, they found themselves short of supplies agreed to by the Burmese. When two of the four technicians complained to the Chinese Consulate that the pension paid by the local Chinese company was less than the agreed amount, they were instructed to address the issue internally and not bring the complaint to their employer (CCO, 1958b). The flexibility—and, to some extent, tolerance—that China demonstrated with local Chinese collaborators boosted Beijing's presence as a technology provider in Burma.

Compared to the Chinese, Japanese leadership emphasized soliciting help from domestic industrialists to expand Japan's influence. In 1954, Takasaki Tatsunosuke and Kishi Nobusuke—the former became the president of the Economic Planning Agency in 1955 and the minister of the Ministry of International Trade and Industries (MITI) in 1958, while the latter became the Prime Minister in 1957—held a conversation regarding the future of the Asian economy. Both agreed that corporate Japan should adopt an aid-centred policy in Southeast Asia. Instead of pragmatic, commercial calculations based on the principle of 'give and take', both corporations and the government should engage in a strategy of 'give and give' in their interactions with their Southeast Asian counterparts, focusing on providing technology to locals and incorporating them into the Japanese manufacturing process (Kishi and Takasaki, 1954). The two politicians believed that coexistence and co-prosperity (*kyōsonkyōei*) would be in the long-term interest of Japanese businesses in Southeast Asia.

Nevertheless, not all Japanese entrepreneurs shared the politicians' sanguinity for regional development. Instead, corporate Japan held a more reserved—and pragmatic—attitude in committing investment to Southeast Asia. For Japanese merchants, it was in their best interest that the region meet Japan's needs for raw materials and markets, and, should it require technological support, the need would be for the extraction of natural resources. This was especially true for Burma, whose attraction to corporate Japan remained focused on its natural resources, including iron, timber and oil. Thus, it was not surprising that the Japanese mining industry championed advocating for Japanese investment in the country.

In January 1955, Kurushima Hidesaburō, the president of the Dowa Mining Company and a board member of the Japan Business Federation (JBF, Nippon Keizai-dantai Rengōkai), visited Burma and met U Nu, who returned from his visit to China the previous December. In their conversation, Kurushima told U Nu that it was Japan that built the Manchuria that he had seen during his visit, and, if given the chance, Japan could help build in Burma 'just as it did 30, 40 years ago in Manchuria' (Kurushima, 1955: 43). Upon returning to Japan, Kurushima wrote to promote his idea, claiming that exporting Japanese technology to Burma would 'wake up the sleeping resources there' (Kurushima, 1955: 45). Since 1955, Kurushima had used his influence in the JBF to persuade his colleagues of the necessity of providing technology to Burma for the development of its natural resources.

In 1958, Kurushima went even further and supported the exchange of specific industrial equipment with Burma to facilitate Japan's interests. When he was invited to talk with Takasaki, both figures criticized the 'myopic' practices of simply exporting manufactured goods to underdeveloped countries. Kurushima believed that Japan must 'take the initiative' to export the technology and equipment of the 'obsolete industries' to these countries (Takasaki et al., 1958: 13–14). Such arguments were welcomed by Takasaki, who was eager to accelerate Japan's overseas ventures during his appointment as the head of the MITI later that year.

Kurushima's and Takasaki's anxiety about the lack of progress in Japan's technological output in the region was understandable: despite the advocates in both business and the government, Japanese industrialists remained reluctant to invest in manufacturing capacities in the region. According to MITI statistics, from 1954 to 1957, corporate Japan had sent 1298 technicians abroad, 'an absolute majority of which were in Southeast Asia'. Among the technicians, 85% were in the mining industry, signifying that 'technological assistance flourishes mostly in fields directly related to [the region's] export of raw materials' (MITI, 1958: 16–17). This contrasts with China, which had already made much progress in extending technological support to Burma's industrialization.

As early as June 1956, China had signed a contract with the Burmese to help the latter to design and build a textile factory with more than 20,000 operating spinners (*People's Daily*, 1956). When the construction was completed in 1958, Beijing provided another US$4.2 million loan to Rangoon, enabling the latter to build a textile factory with more than 40,000 spinners (JICA, 1966: 31; *People's Daily*, 1958). Admittedly, such construction projects proved to be very costly to China: China had to not only develop a set of equipment rendered for Burmese weather and cotton conditions, but also cover the costs for sending materials, technicians and even medical teams to support the construction (Liu, 1960/2011). Nevertheless, the construction of textile factories was cheered as a remarkable achievement in the propaganda, and was used to set a contrast to the conditioned aid and economic pragmatism provided by Japan and the United States in the region.

China's success put pressure on the Japanese government, which attempted to address businesses' reluctance to invest by incorporating Japanese businesses in its war-reparations arrangements with Southeast Asia. Burma, the first Southeast Asian country to settle reparations with Japan, was no exception to this strategy adopted by Tokyo (Kajima Institute of International Peace, 1963/1984). The capital goods provided by Japanese manufacturers, including factory and industrial equipment, constituted most of the 72 billion yen that Japan agreed to provide to Burma. From 1955 to 1958, Japan delivered 21.4 billion yen in capital goods to Burma, constituting 75.1% of all reparations it paid (Research Committee on the Problems of Reparation, 1959). From the Balu Chaung hydropower project to canneries and factories for car repairs, dye manufacturing and fridge production, the factory programmes were conducted via close coordination between Japanese industrial conglomerates and general trading companies (*sōgō shōsha*) (Research Committee on the Problems of Reparation, 1959). For instance, the construction of the Balu Chaung Hydropower Station was contracted to Nippon Koei and the Kajima Corporation, while the Nichimen Group constructed the power grid for Rangoon (Moore, 2014; BAJCTC, 1972). These companies then received compensation from the Japanese government for their endeavours in Burma.

To compete with Beijing's industrial aid, Japan used its advantages in industrial technologies, highlighting transportation machinery and heavy industrial equipment in its aid to Burma. In their internal papers (DAMOFAJ, 1958), Japanese technocrats divided the aid to Burma into three categories, including the whole factory and industrial project (category A), the heavy industry equipment and vehicles (category B), and the other manufactured goods (category C). Of the 20.3 billion yen allocated for 1958, the first two categories accounted for 12.3 billion yen, or more than 60% of the total aid. As its competitor in Beijing could not match the equipment that Japan could provide, such an arrangement contributed to Japanese manufacturers' profits by enhancing the country's technological dependence on them. According to the Congressional Committee of Investigation on Science and Technology (CCIST, Kagaku gijutsu chōsa iinkai), Japanese businesses exported more than 26 billion yen's worth of industrial equipment and parts to Burma in addition to the repatriation programmes between 1956 and 1959 (CCIST, 1963). This was also reflected in the changing landscape of Japanese–Burmese trade: from 1956 to 1962, the percentage of consumer goods (textiles and food) that Burma imported from Japan dropped from 58.8% to 28.4%, while the percentage of capital goods and chemicals increased from 29% to 58.6% of total imports (JETRO, 1964). As a result, Japanese industrialists in equipment, machinery and transportation boosted their role as the primary equipment providers and technology suppliers in Burma.

However, Japanese enterprises' preoccupation with commercial interests through aid projects disappointed the Burmese, who expressed their scepticism towards Japanese businesses' intentions during Kishi's state visit in May 1957. As U Nu told the Japanese Prime Minister, while 'there was nothing wrong with the Japanese government', he regretted that 'a group of Japanese businesses only minded their immediate interest and hampered the Japanese–Burmese cooperation' (DAMOFAJ, 1957). Kyaw Nyein also accused the Japanese enterprises of having an 'excessive obsession with their profit' and manipulating the prices for Japanese equipment via a 'cartel-like' practice. In response, Kishi assured the Burmese that he would convey these concerns to relevant Japanese businesses and promised to boost the level of textile equipment as a sign of goodwill (AABMOFA, 1957).

In part, Kishi's somewhat deferential attitude to Burma was incorporated into his plan to deter China's influence in Southeast Asia. Since 1957, Japanese decision-makers had stressed the threat of Chinese expansion in Southeast Asia, citing Beijing's use of overseas Chinese to advance its 'trade war' in the region (*The Japan Times*, 1958). Sino–Japanese relations further deteriorated following their diplomatic dispute over Japan's unyielding stance over the burning of China's national flag in the Nagasaki flag incident. Consequently, from 1958 to 1960, the two sides intensified competition for both commercial interests and diplomatic prestige in Southeast Asia. Under such circumstances, technological aid to Burma became a crucial theatre in Sino–Japanese competition and did not lose momentum until the late 1960s.

3. Beijing–Tokyo competition and Rangoon's turn to agricultural modernization, 1958–1962

Sino–Japanese competition for influence in Burma's industrialization faced a reorientation in 1958 due to Burma's internal political disturbances. In April, Ba Swe and Kyaw Nyein split with U Nu, dividing the AFPFL into the AFPFL (Clean) under the Prime Minister and the AFPFL (Stable) under the two ministers. However, U Nu was able to defeat the vote of no confidence that Ba Swe and Kyaw Nyein initiated with the help of the Thakin faction and the leftists in the National United Front (Yin Hlaing, 2008). The division within the party led to an interim military government under Ne Win, who received U Nu's support while maintaining close ties to the leadership of AFPFL (Stable). As a result, a caretaker government under Ne Win was established in October 1958, with the Thakin faction controlling the cabinet and the parliament.

The immediate effect of the decline of Ba Swe and Kyaw Nyein in 1958 was the reorientation of the country's economic strategy, moving away from rapid industrialization towards an emphasis on agricultural development. Despite Ne Win's interpersonal connections to the leaders of the AFPFL (Stable), the military government had to distance itself from the losing side and appeared more sympathetic to the Thakin faction's agriculturally centred agenda. This trajectory was clear when General Aung Gyi, Ne Win's top economic acolyte, visited Japan in 1959. As he told the Japanese Foreign Minister Aiichiro Fujiyama, the new government would now move away from the 'overemphasis on the industrial development of the previous government, which crippled the national economy and disrupted the stability of our people's livelihood' (Fujiyama, 1959). Aung Gyi promised that the military leadership considered Japan the most suitable ally for the government's effort to 'keep a balance between agriculture and industry, and prevent the country from becoming a breeding bed for communism' (Fujiyama, 1959). Following Aung Gyi's statement, Ne Win's interim government adopted a series of approaches that effectively ended the aid-motivated industrialization that had characterized Burma's economy in the post-Bandung period.

Nevertheless, Aung Gyi's promise to Fujiyama faced much scepticism among foreign investors. Rangoon's reorientation efforts also included a strict nationalization and import-substitute strategy, which aimed to reduce the country's dependence on foreign merchandise and technology. In 1952, Aung Gyi established the Defence Service Institute (DSI), a military-controlled economic body to protect service members' welfare. After Ne Win rose to power in 1958, the DSI accelerated its confiscation of assets owned by British, Indian and local Chinese firms and individuals (Yaguchi, 1961a). Consequently, both foreign investors and Burmese entrepreneurs complained about the DSI's abuse of militaristic power for economic benefit, driving the military government to consider an alternative body that had—or at least appeared to have—less association with the military.

That concern prompted Ne Win and Aung Gyi to establish the Burma Economic Development Corporation (BEDC) in 1961 to carry out nationalization without raising too many criticisms of the military. As Aung Gyi claimed, the BEDC had taken over 17 corporations from the DSI and would welcome non-governmental capital and entrepreneurs (Yaguchi, 1961a). Nevertheless, the BEDC maintained essential ties to the Burmese military. As Japanese Ambassador Higuchi reported, the BEDC demonstrated little enthusiasm for soliciting non-governmental capital for its projects (Yaguchi, 1961a). Nevertheless, the creation of the BEDC and the DSI, and their essential roles in the government's economic landscape, boosted Aung Gyi's importance in his diplomatic manoeuvres with China and Japan, and provided him with a better negotiating position in securing the two countries' technological aid to Burma.

The nationalization effort failed to bring immediate relief to Burma's dependence on foreign technology. Both the BEDC and the DSI were hindered by the country's lack of capable technicians and managerial experts. As Japanese technicians sent to Burma observed, even with policies aimed at training native technicians, the Burmese government faced extreme difficulties in cultivating a technician community of its own:

> Admittedly, the Burmese government sought to address its lack of technicians by promoting technology education and sending technician students abroad for training. Consequently, many young engineers emerged quickly … Nevertheless, able technicians who could manage design and implementation remained highly scarce. This was because the valuable [Burmese] talents would immediately become administrators, and stop accumulating experience from actual practices. (Sakaida, 1960: 14)

As the lack of technicians remained unresolved, Burma had to secure further aid and technical support from China and Japan. To address its immediate problems, Burmese economic bureaucrats made frequent visits to Japan and China between 1958 and 1961, seeking additional reparations and help in Burmese development. However, Burmese officials faced many difficulties in securing continuous support from Japanese enterprises. Both Burmese technocrats and Japanese experts involved in the negotiation found the progress stymied. While Rangoon held a more sceptical view of foreign control in the Burmese economy, corporate Japan demonstrated little enthusiasm to invest in Burma's development, citing the fear of sudden nationalization.

When U Rashid, Burma's minister of industry, visited Japan in 1960, he approached Japanese corporate leaders and negotiated terms for Japanese technological assistance. As the negotiation memorandum shows, the demands from the two sides were far apart. The Burmese hoped that Japanese investors would establish factories as joint ventures so that the Burmese could learn from their professional knowledge, and both sides could share the burden and profit. In addition, the Burmese held to their nationalization schedule, rejecting Japanese demands to extend the grace period from 10 years to 20. However, the Japanese corporations dismissed Rashid's proposal, demanding a lower percentage of capital contribution, and asked the Burmese to pay a technical fee up front for Japanese technology and equipment (Kosaka, 1960). The unyielding stance that the Japanese adopted upset Rashid, who then complained that the 'failure to deliver any of the promised aid' over the past few years had caused political problems in Burma, especially when Nichimen's plan to build a textile factory failed to make any progress, even after years of negotiation (Kosaka, 1960). Upon returning to Burma, Rashid also conveyed his frustration with Ambassador Hara, worrying that the failure to secure a Japanese compromise might further endanger the bilateral relations between the two countries.

The lack of progress in Japanese–Burmese technological cooperation is significant for the Sino–Burmese case, primarily since Chinese engineers had already delivered two textile factories in Burma from 1956 to 1960. Moreover, Zhou Enlai met with Aung Gyi in January 1961 to finalize the negotiation for the border between the two countries, and agreed to provide additional economic assistance to Burma through the Sino–Burmese Agreement on Economic and Technology Cooperation. As the agreement prescribed, Beijing would provide Rangoon an interest-free loan of £30 million to purchase technology and equipment from China and 'send technicians and professionals to Burma at China's expense' (*Peoples' Daily*, 1961). As Aung Gyi told the Japanese, the factories that China promised to Burma were mainly processing factories for the country's agricultural products, including paper mills and textile, sugar and bamboo pipe factories (Deng et al., 1989). Despite China's economic difficulties in the aftermath of the Great Leap Forward, these programmes were mainly delivered on time in the mid-1960s, boosting Burma's manufacturing capacities.

China's progress in Burma unsettled Japanese decision-makers, who were concerned about Beijing's expanding influence in the country. As the Japanese Ministry of Foreign Affairs (MOFA) estimated, compared to the £30 million promised by the Chinese, the sum of Japanese aid and investment in Burma in 1960 was only US$153,000. As a result, China's aid would 'take over a significant share of [equipment in] Burma's four-year plan, thus affecting our country's future economic assistance to the country' (China Division, AABMOFA, 1961). Tokyo also feared that China's technological aid would turn Burma's power dynamics to Beijing's advantage. As Ambassador Yaguchi (1961b) estimated, Chinese aid to boost Burma's processing abilities for agriculture products would help the Thakin faction, which held a pro-China position, to expand its support base in rural areas and give it an advantage in the next election.

Ironically, China's progress prompted a sense of urgency in the Japanese government and, in turn, helped Rangoon's negotiating position with Tokyo. When Aung Gyi visited Tokyo in 1961 to secure Japanese assistance, he was able to take advantage of Japan's concern, and used it to facilitate the aid that the Japanese would provide. 'In order to balance Chinese communists' expanding [influence]', Aung Gyi told Prime Minister Ikeda, it was essential for 'Japan and Burma to build closer ties between themselves' (DAMOFAJ, 1961a). In addition, Aung Gyi exaggerated the scale of Chinese aid to Burma, claiming that Beijing had offered a hundred million dollars worth of credit to Burma. In response, Ikeda told Aung Gyi that Japan would love to provide Burma with the 'technical know-how' it needed (DAMOFAJ, 1961a). In his subsequent negotiations with Japan's economic technocrats and business leaders, Aung Gyi was able to secure a cooperative attitude from the Japanese. He pressed Sato Eisaku, the minister of MITI, to instruct Nichimen to accelerate the construction of textile factories it had promised but also secured additional technological aid—in the form of Japanese exports and the promise to cover their expenses—from the Japanese (DAMOFAJ, 1961b). As a result, the year 1961 marked the high tide of Beijing's and Tokyo's aid competition in Burma, in which Rangoon strategically used one side against the other to gain preferential terms that it had failed to procure in earlier negotiations.

4. Beijing and Tokyo's technology diplomacy under the shadow of the 'Burmese Way to Socialism', 1962–1965

In 1962, Burma's see-saw strategy with Beijing's and Tokyo's aid again faced turbulence due to the country's political upheavals. In March 1962, Ne Win mobilized his supporters in the military and launched a successful coup to apprehend U Nu. The military coup effectively put an end to the civilian government in Burma and replaced it with the military-controlled Revolutionary Council. Even though some civilian ministers remained in the government, the military headquarters, along with the DSI and BEDC it controlled, now held power in every aspect of political and economic life in the Union of Burma.

Technocrats in Beijing and Tokyo were concerned about the coup, fearing that the new development would disrupt their relations with Rangoon. In 1962, the Japanese MOFA sent Okuda Shigemoto as a special emissary to Burma to speak with representatives of the new regime, and to ensure that the military government maintained a friendly attitude towards Japan. In his conversation with Aung Gyi, the latter assured Okuda that existing programmes signed by the U Nu government, although 'unrealistic in many ways', would only be adjusted rather than abandoned, since the new government wished to remain on good terms with foreign governments (Southwest Asia Division, AABMOFA, 1962). Aung Gyi pledged that, although the country would no longer favour setting up joint ventures with Japan, the new government still wished to solicit help from Tokyo, especially in technology transfer (Southwest Asia Division, AABMOFA, 1962). However, Aung Gyi's assurances soon expired.

In 1963, Aung Gyi, the chief negotiator for aid with China and Japan, was forced to resign as the Minister of Trade and Industry and BEDC president (Seekins, 2006). His resignation also suggested that Ne Win had lost interest in the staged import-substitution strategy enabled by competitive professional knowledge from foreign aid. The mild nationalization policy gave way to an accelerated course of 'Burmanization' that Tin Pe, Ne Win's new economic adviser, advocated. On 15 February, one week after Aung Gyi's resignation, Ne Win rolled out his 'new economic policy' and publicly proclaimed that the country would pursue the nationalization of all economic sectors, including the 'production, distribution, import, and export of all commodities' (Trager, 1963: 325). From 1963 to 1964, the Burmese government accelerated the nationalization effort, and fully annexed foreign banks, factories and commission trading agencies. This also included a complete nationalization of semi-civil, semi-governmental entities under the nominal directorship of the BEDC and DSI (JETRO, 1964). Consequently, the foreign managerial experts and technical advisers on whom these economic bodies relied were replaced by military officers appointed as managers and board members.

Rapid Burmanization challenged both China's and Japan's economic agendas in Burma. For the former, the new momentum of nationalization dealt a heavy blow to local Chinese entrepreneurs, who had held a pro-Beijing stance since the mid-1950s. Before the rapid Burmanization in 1962, Chinese entrepreneurs in Burma partially circumvented governmental regulations by registering their companies as Burmese companies—using Burmese nationals as the nominal company representatives—to retain control of these businesses. The nominally Burmese companies were then recognized by Beijing, which offered support by using them as entry points for Chinese equipment into Burma. In 1960, the Chinese Embassy in Rangoon suggested that Beijing consider delegating its exports to Burma to two local companies—the Oriental Trading Company and the Myint Aung Company—which were registered as Burmese companies, as their Chinese owners were naturalized Burmese citizens. Beijing approved the plan and made the former the agent for general Chinese manufactured goods and the latter the sole agent for printing machinery from China (CCO, 1960). These approaches ensured that Beijing's non-governmental proxies would remain relevant in Chinese technological exports to Burma.

However, Ne Win's rapid nationalization agenda eliminated the loopholes that Chinese entrepreneurs had exploited. The complete nationalization of all foreign trade agencies and most industrial plants drove Chinese industrialists out of business. As a Japanese agent in Rangoon reported, the nationalization effectively 'moved Chinese and Indian merchants' control of the economy to the hands of the Burmese government' (Tanaka, 1966: 127). Even though Beijing deemed these efforts unfriendly actions 'suppressing' local Chinese, it did not risk antagonizing Burma, citing potential political consequences of undermining the 'Five Principles of Peaceful Coexistence' prescribed at Bandung. Additionally, Beijing yielded to Burma's nationalization of the Bank of China in Rangoon, featuring it as 'a gift' to the Burmese (Fan, 2010). Consequently, Beijing's reluctance to protect overseas Chinese commercial interests from the nationalization policy led to some dissatisfaction among local Chinese, whose support for Beijing faded. According to the Japanese estimation, Beijing's reluctance to protect overseas Chinese properties from governmental seizure turned previously pro-Beijing Chinese in Burma towards a more neutral stance between Beijing and Taipei (China Division, AABMOFA, 1967). Losing local Chinese entrepreneurs' channels, Beijing switched its goal to ensuring the overseas Chinese communities' long-term survival in Burma instead of soliciting their help in technological exports (Chinese Foreign Ministry, 1964a).

Ironically, the economic fiasco following Ne Win's coup and the increasing management difficulties caused by the lack of expertise strengthened Burma's need for foreign technological input. Replacing managerial professionals with military officers, the rapid nationalization under the DSI and BEDC led to immediate and dire consequences. As the Chinese Embassy in Burma observed, the lack of professional guidance disrupted industrial and agricultural production, leading to a decline in Burma's national economy. Ne Win himself was disappointed at the economic fallout caused by Tin Pe's plan. According to Chinese intelligence, the commander-in-chief asked his ministers to hold steadfast to the nationalization policy but tried to mitigate the dire economic consequences (Chinese Foreign Ministry, 1964c). 'I do not know what the outcome will be', Ne Win told his subordinates on 5 May 1965; 'What's done is done, and must be seen through to the end. We cannot abandon it halfway' (Chinese Foreign Ministry, 1964c). From Ne Win's perspective, while Burma might survive without foreign investment and joint ventures, it still needed agricultural expertise and industrial know-how to build the self-sustaining economy envisioned in his 'Burmese Way to Socialism'.

Technocrats in Beijing and Tokyo detected Ne Win's subtle attitude towards foreign input, and developed corresponding modes of action highlighting technical assistance to address the country's isolationist turn. In 1964, the Japanese MOFA developed new policies for economic assistance abroad, making the 'effective utilization of technical cooperation as a powerful means to achieve diplomatic objectives' the essential aspect of Japan's aid policies (MOFAJ, 1964). In explaining the new strategies, the technocrats at MOFA were unequivocal that the plan was developed to address Japan's ongoing competition with Beijing, and highlighted the significance of sending technicians to Burma:

> The Asia region, where our country is located, is the joint point between the communist bloc—China, for a start—and various underdeveloped countries. In light of this [situation], the economic development that would sustain the political stability of our Asian neighbours is an indispensable premise to the prosperity and security of our nation … The technological elevation, as well as the development of human resources, is of particular significance … Maybe small in scale, the technical assistance projects contributed to the national development of regional countries, and helped them form closer ties with us. (MOFAJ, 1964: 4–5)

Japanese enterprises in Burma quickly adopted this strategy. As the Japan Economic Research Institute (JERI, Nippon keizai chōsa kyōgi-kai)—the investigative body under the JBF—reported, Japanese enterprises changed their mode of operation in Burma towards a more technologically centred approach. Instead of setting up joint ventures and seeking direct investment, Japanese industries adopted the method of 'termed technological assistance', allowing them to provide equipment and technology that would enable the 'Burmese to take over management and operation over a limited period' in exchange for a sum of commission fees (JERI, 1967: 319). As a Japan External Trade Organisation (JETRO) report shows, Japanese manufacturers—including Panasonic, Hino Motors, Nippon Electronic Company, and Toyo Kogyo (Mazda)—developed new interests in Burma through 'termed technological assistance' (JETRO, 1964: 33). As a MITI report shows, from 1965 to 1966, the number of interns and professionals provided by corporations in these sectors exceeded that in the government-sponsored programmes, making it the central channel for Japanese technological exchange with Burma (MITI, 1966, 1967).

The technological assistance, in turn, enhanced Burma's technological dependence on Japan in critical industrial sectors. This was especially true for Japanese manufacturers in transportation and electronics—the fields in which Burma had already developed a reliance on Japanese technological input. As Tanaka Tsutomu, a technician of Nichimen sent to Rangoon, wrote in 1966, Burma's transportation system was solely dependent on Japanese technologies. According to his report, the Burmese national railway was 'predominantly supplied by Japanese trains, rails and carriages', and 'it is advantageous for Japan since the Burmese side kept placing orders on compartments [for replacement]' (Tanaka, 1966: 127). In this way, the Japanese technological turn enabled it to further Burma's technological dependence on Japan, and it kept Japanese industries relevant even after Burma's national economy became increasingly isolationist.

Echoing Tokyo's considerations, Beijing also stepped up its aid to Burma due to the country's exacerbating economic difficulties. As the Chinese Foreign Ministry (1964a) noted, Burmese nationalization may have strengthened the country's economic dependence on China: '[the nationalization] has caused every crucial connection in the Burmese economy to suffer disruption … Burma relies heavily on us and Russia; they are a crucial communications channel for us, so we need to continue maintaining an amicable relationship with the Burmese'. In June, Beijing decided to move forward to support Ne Win's government. The Chinese Foreign Ministry instructed Geng Biao, the Chinese Ambassador in Burma, to use Ne Win's diplomatic isolation and economic difficulties as diplomatic leverage to facilitate bilateral relations: 'He [Ne Win] needs to find help, and lately he has appeared friendly to us … We should take this opportunity to send coal during snow, working with vigorous ardour' (Chinese Foreign Ministry, 1964b).

Beijing also adjusted its aid programmes to compete with Japan, highlighting technical support to supplement Burma's loss during the chaotic nationalization. In its plan for foreign technical assistance for 1965, the Chinese Ministry of Light Industry (MLI) gave Burma priority in exchanging technicians and trainees: of the 149 trainees MLI intended to receive for the year, one-third came from Burma. The MLI also decided to send to Burma one-fifth of the 500 technicians whom China intended to send abroad (MLI, 1964). The expenses of technicians and exchange students were covered mainly by the Chinese government.

In addition, Beijing made efforts on the propaganda front to prove the superiority of Chinese aid over that sent by the Japanese. As Chinese technocrats emphasized in their explanation, Chinese aid was altruistic and was most compatible with the aided countries' goal of achieving self-reliance. This point was also revealed in a report of the State Planning Committee (now the National Development and Reform Commission) in October 1965. As China could not match the quantities of aid that Japan could provide, it had to compete based on quality instead of quantity in technological aid: 'We do not need to compete with imperialists and revisionists for quantities [of aid programmes]. Instead, we compete with them regarding policies, performances, achievements, and how we help aided countries develop a self-reliant economy' (State Planning Committee, 1965/2011: 554). To differentiate it from Japan's aid, China's technological aid was carried out under the 'Eight Principles of China's Economic and Technological Aid' announced in December 1964, which emphasized that China would 'facilitate the aided country's level of self-reliance, and would not increase the aided country's dependence on China' (State Council, 1964/2011: 554–555).

However, China's aid to Burma reached an abrupt end in 1967. As the radicalization of domestic politics during the Cultural Revolution gained momentum among overseas Chinese, Chinese residents' conflicts with indigenous populations in Burma intensified. Eventually, a series of ethnic conflicts led to the storming of the Chinese Embassy in Rangoon on 27 June and to the death of a Chinese technological expert working on the aid programme (Ji and Su, 2000). China's technological aid to Burma also experienced a decline following the death of the Chinese expert Liu Yi when Burmese protesters stormed the Chinese Embassy, and did not recover until Rangoon's decision to break connections with the Western bloc in 1988.

5. Conclusion: Breaking the fluidity of technological aid in Cold War Asia

In hindsight, China's and Japan's economic and technological assistance to Burma in the post-Bandung decade was an unfruitful case compared to the two countries' aid to other nations. China's aid to its Cold War allies—North Korea, Mongolia and North Vietnam—was much more prominent in terms of the trainees exchanged and factories built than that to Burma, while Japan's technological output had more influence in reshaping the industrial landscape in Western-leaning countries including Malaysia, Thailand and South Vietnam. Compared with other neutral countries, Burma proved to be a problematic case for decision-makers in Tokyo and Beijing, as Tokyo's and Beijing's technological packages had supplemented the industrial ambitions pursued in Sihanouk's Cambodia and Sukarno's Indonesia.

What, then, are we to make of China and Japan's competition in their aid to Burma? As this paper shows, the aid Burma received in the decade after the Bandung Conference speaks to the fluidity—in more ways than one—in the technological assistance envisioned in the final communique of the conference. Burma's initiatives in receiving aid—primarily how its decision-makers strategically used the aid to advance its economic agenda—offer a glance at the undercurrents involved in offering technological aid during the Cold War. This paper reveals that the leadership of Burma—both the civilian government under U Nu and the military junta under Ne Win—made clever use of aid as a bargaining chip. The welcoming attitude that Burmese negotiators demonstrated towards foreign aid was in stark contrast to the hard-line positions taken during parleys, forcing the two aiding countries to yield to the Burmese agenda. In this way, the interactions between economic technocrats in Rangoon, Beijing and Tokyo helped to reveal the somewhat flexible power dynamics between the aiding and the aided countries during the economic Cold War.

Moreover, the aid that Burma received from the two countries between 1955 and 1965 speaks to the fluidity of the idea of technological aid: while the term 'technological aid' (*ji shu yuan zhu* in Chinese; *gijutsu kyōryoku* in Japanese) was used in communiques and contracts throughout the period, it had entirely different connotations due to Burma's changing mindset on national development. Under Ba Swe's industrial ambitions, technological aid was synthesized to include foreign investment, industrial equipment, factory design and technological know-how. For U Rashid and Aung Gyi, technological aid had to represent Burma's interests and emphasize the training of Burmese personnel in joint ventures under the directorship of foreign managerial experts. Under Ne Win and Tin Pe, Burma's ambition for self-reliance reduced technological aid to its simplest form, involving only limited exchanges of trainees, technicians and equipment across borders. In this way, technological assistance evolved to become increasingly inclusive and was conditioned by the national interests and strategic considerations of the parties involved.

In addition, the flexibility of technological aid is seen in the variety of aiding bodies involved in the transfers to Burma. From 1955 to 1965, technocrats in Beijing and Tokyo employed non-governmental proxies to serve as channels for spreading technology. The solicitation of local entrepreneurs on China's end and the use of Japanese corporations as 'foot soldiers' in providing aid suggested that the technological diplomacy was not limited to intergovernmental activities but also included civilians mobilized to extend governments' diplomatic projects. Therefore, Burma's experience as an aid-receiving country in Cold War Asia may shed light on the diversified means through which states employed science and technology as diplomatic tools during Cold War competition.

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Note

1. Burma/Myanmar disambiguation: until 1989, the Union of Burma remained the country's official name. However, a few countries—including Japan—continued to use 'Burma' (*Biruma* in Japanese) to refer to the country, even after it adopted its current name, Myanmar, in 1989. For historical accuracy and disambiguation purposes, this paper uses 'Burma' throughout. For similar reasons, I use 'Rangoon' instead of 'Yangon' to refer to the country's capital and central government.

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Science diplomacy in China: Past, present and future

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Abstract
Science diplomacy has played an important role in Chinese history, including in the history of science and technology (S&T) development. While we may consider science diplomacy as simply a part of China's Reform and Opening-up policy, the fact is that even in the Kuomintang period (1925–1949) or the Maoist period (1949–1976) it was a key element of Chinese foreign relations. The targets and nature of science diplomacy were shaped by the prevailing politics and economic issues of the times. For example, the Cold War limited the breadth and depth of S&T cooperation between China and the West. Nonetheless, the People's Republic of China pursued cooperation with the Soviet Union and newly independent countries in a very steadfast manner and continues to engage with Russia and developing countries today. This article analyses the nature of science diplomacy as an element of both China's S&T development and its foreign relations. The interactions and practices at the intersection of science and foreign policy in China are manifold. In addition to providing a comprehensive overview, this article also highlights evolving trends, especially in terms of the deepening of China's linkages across the international S&T system. Finally, the article examines the recent impact of the apparent rise of techno-nationalism and how this has affected the nature of China's international S&T activities regarding Beijing's use of science diplomacy.

Keywords
Science diplomacy, China, science and technology policy, science and technology development

1. The pre-1949 period: Neglect and ignorance

The earliest science diplomacy[1] case in China dates to the Warring States Period (475–221 BCE), during which more than 20 rival states battled viciously for territorial advantage and dominance before Emperor Qin Shi Huang eventually united China. According to the 'Gong Shu' chapter of the book *Mozi*,[2] the ancient Chinese philosopher and inventor Mozi (Micius) demonstrated on a wargaming table how defence technologies that he had developed could thwart siege engines designed by the master craftsman Gongshu Ban (Lu Ban), thus persuading the king of Chu not to launch a military campaign against the vassal state of Song.

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Once an innovative civilization, China produced great inventions such as papermaking, printing, gunpowder and the compass. Technologies were diffused through the Silk Road to other parts of Asia and Europe (Zhang, 2019a). However, China's indigenous advancement of technology gradually became stagnant before and after Jesuit missionaries introduced Greek mathematics, the latest European knowledge of astronomy and mapping, and devices such as the chime clock and clavichord to China during the 16th and 17th centuries. Western knowledge and technologies were used as stepping stones to promote missionary work in China.

When King George III sent the Macartney Mission to China in 1792, Emperor Qianlong refused to give up the long-standing policy of self-isolation and rejected any idea of learning from foreigners. Carefully selected state gifts such as astronomical instruments, which represented the newest evidence of British scientific and technological progress, were intentionally disparaged and locked in the storehouse of the Forbidden City thereafter (Guo, 2019; Han, 2005). Nevertheless, Lord Macartney did not return empty-handed. His mission conducted a variety of local surveys of techniques, geography, fortress building, medicine and textiles; his colleagues also collected more than 400 plant specimens from China, including tea seeds (Chang, 2009).

In 1872, as part of the Self-strengthening Movement, the Qing government sent its first batch of students abroad to study advanced technologies (Zhang, 2011) after China was defeated overwhelmingly in the two Opium Wars and was forced to sign a series of unequal treaties with the Western powers. Factories based on imported machines and technologies were built in China, and science and technology (S&T) books were translated into Chinese. However, China's defeat in the First Sino-Japanese War of 1894–1895 marked the failure of the Self-strengthening Movement and called into question its principle of 'Chinese Substance and Western Utility'.

In 1909, the first group of Chinese students funded by the Boxer Indemnity Scholarship Program arrived in the US. Two years later, the Tsinghua School was established in Beijing as the programme's official preparatory school. The school became Tsinghua University in 1929 and went on to become one of China's most prestigious research universities. Most of the first generation of Chinese scientists were sponsored by the Boxer Indemnity Scholarship Program and studied abroad. The Rockefeller Foundation channelled funds to research-based clinical medicine in China, which led to the establishment of the Peking Union Medical College in 1917. China's modern church-run universities sponsored by Western European and North American churches also made contributions to science and medical education in China. Generations of returned students and scholars have introduced modern S&T to China with the goal of building a more prosperous and stronger country. The conclusion that 'lagging behind leaves one vulnerable to being bullied and humiliated' would constantly recur to Chinese leaders of different political backgrounds and to patriotic scientists.

Although they were few in number—and also by and large neglected and insufficiently funded—Chinese scientists launched national societies and academic journals, strove to explore research areas new to China, and kept in communication with the international scientific community. During World War II, Joseph Needham was dispatched to become Scientific Counsellor to China and oversaw a British effort to help China maintain its scientific activity despite the hardship caused by the Japanese occupation across many parts of the country.[3] His experience inspired a monumental work, the voluminous *Science and Civilization in China*, which reminded Chinese intellectuals that China had a rich and glorious history of S&T development in ancient times. However, in a backward nation stricken with poverty, political turmoil, foreign aggression and civil war before 1949, successive Chinese governments neither took science seriously nor practised science diplomacy in any meaningful manner to facilitate domestic research or international cooperation.

2. 1949–1978: From 'leaning to one side' to China–Western world rapprochement

With the founding of the People's Republic of China in 1949, the ruling Communist Party of China was determined to develop S&T and cultivate domestic talent on a large scale to change the country's extremely lagging status. Around 1200 Chinese students and scholars returned from the US before the outbreak of the Korean War or after the Eisenhower administration lifted its travel ban in 1955 (Wang and Liu, 2012). One typical case of science diplomacy illustrated what could happen between two hostile nations: although the US refused to recognize the newly established Chinese government, the China–US Ambassadorial Talks at Geneva in 1955 (Chang, 1996)[4] led to the release of the Chinese scientist Qian Xuesen, who had been detained in the US since 1950.

The 1950s witnessed more than 18,000 Soviet experts arrive in China, and 38,000 Chinese students, researchers and technicians studied or trained in the Soviet Union (Shen, 2015). With the aid of the Soviet Union, the '156 Major Projects'—most in the coalmining, power, steel and iron, non-ferrous metals, petroleum, chemical, mechanical, medical and military industries—not only laid the foundation for industrialization in China but also served as the greatest example of comprehensive technology transfer in history. When the Chinese government drafted its first national S&T development plan (the Long-term Plan for Science and Technology Development 1956–1967) and sought comments from the Soviet Union, Premier Zhou Enlai declared that prominent researchers and students should be sent to the Soviet Union as soon as possible for training or graduate education. They would return and serve as seeds for the development of many new disciplines in China (Zhang and Zhang, 2019).

Following the 'leaning to one side' foreign policy, China's science diplomacy activities can be viewed in terms of three categories: 1) intergovernmental cooperation with the Soviet Union and other socialist countries based on formal agreements; 2) exchanges with Asian and African non-socialist countries through government agencies; and 3) people-to-people exchanges with Western countries and Japan. China signed its first governmental S&T cooperation agreement with Czechoslovakia in 1952 and another later with the Soviet Union in 1954. A Technology Cooperation Bureau was set up under the State Planning Commission (SPC) in 1953 to carry out all bilateral agreements. In 1956, the SPC formulated the 1956–1967 International Cooperation Plan, and, one year later, China and the Soviet Union signed another agreement on research cooperation emphasizing 16 fields with 122 joint projects, all of which were designed to facilitate the implementation of the S&T development long-term plan.

Since 1956, the Chinese Academy of Sciences (CAS) has encouraged the exchange of academic publications with scientists, academic societies and research institutions in both socialist and Western countries (Zhang, 2019b). China's collection and exchange of S&T information (journals, publications, patents, standards etc.) with foreign partners developed gradually and was retained as an important channel for knowing the world, even in the Cultural Revolution period. Based on the 'Five Principles of Peaceful Coexistence' proposed in 1953 and the 'Eight Principles for Economic Aid and Technical Assistance to Other Countries' announced during Premier Zhou Enlai's visit to 14 Asian and African countries during 1963–1964 (Jin, 2017), China started to provide technological aid to newly independent nations in Asia and Africa, as well as socialist nations such as the Democratic People's Republic of Korea, the Democratic Republic of Vietnam (North Vietnam) and Cuba. In early 1963, the first Chinese medical assistance team arrived in Algeria. As the first foreign medical team in Algeria after its independence, it also launched the history of Chinese medical teams providing assistance to other nations (CIDCA, 2018). Technical aid was considered as part of Sino-Soviet or Sino-US competition to gain influence in the Third World.

In 1958, the State Science and Technology Commission (SSTC) was established and took responsibility for managing international S&T exchanges and cooperation. From this time, science diplomats were assigned to Chinese embassies in the Soviet Union and Eastern European socialist countries. The SSTC introduced several adjustments to China's science diplomacy policy after the Sino-Soviet split in 1960. Bilateral collaboration with the Soviet Union was drastically reduced. Meanwhile, people-to-people exchanges with Western European, Australian and Japanese scientists increased and surpassed those with the Soviet Union and Eastern European socialist countries during the 1963–1965 period. Foreign experts invited from Japan and Western Europe also outnumbered those from the Soviet Union and other socialist countries by the mid-1960s (Zhang, 2019b). The SSTC began to send science diplomats to the UK, Sweden and Switzerland in 1961. In the early 1960s, China signed import contracts with Japanese and Western European suppliers for 84 sets of equipment and technology in the petrochemical, metallurgical, mining, electronic and precision mechanical industries (Niu, 2016).

Science diplomacy played an important role in breaking the arbitrary US blockade on China. In 1956, Beijing hosted the 16th executive council meeting and 10th anniversary celebrations of the World Federation of Scientific Workers, which was the first international conference organized by an international science organization in China after 1949. The 1964 Peking Symposium[5] marked the first large-scale international science conference that China had organized. A total of 367 scientists from 44 countries and regions in Asia, Africa, Latin America and Oceania attended the symposium. In 1966, the Straton model put forward by Chinese physicists was presented at the Summer Physics Colloquium of the Peking Symposium (Liu, 2018).[6] Although Chinese scientists withdrew from many international academic organizations and conferences to protest against the violation of the one-China principle (Zhang and Wang, 2009), they actively participated in the Pugwash Conferences with colleagues from both the Eastern and Western blocs in the late 1950s to seek a world free of nuclear weapons and other weapons of mass destruction (Zhou, 2005). All these activities showcased China's unremitting efforts to break the 'Bamboo Curtain' imposed by the US. Unfortunately, soon thereafter, international exchanges came to a halt due to the onset of the Cultural Revolution (1966–1976).

The Chinese scientific community was in chaos and isolation during the early years of the Cultural Revolution. The SSTC was dissolved in 1970, and all activities under the China Association for Science and Technology (CAST) were suspended; the CAS served as the only window (sometimes in the name of CAST) to the outside world for the Chinese scientific community. After the United Nations (UN) recognized the government of the People's Republic of China and restored all its rights in 1971, China established formal diplomatic relations with most Western countries. China resumed its membership of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and attended the UN Conference on the Human Environment in 1972—the first international conference that China had participated in since the restoration of its lawful seat in the UN. Sino-US people-to-people exchanges were restored after President Nixon's historic visit to China in 1972. With the support of both governments and as one of the results of the China–US rapprochement, the Committee on Scholarly Communication with the People's Republic of China, together with the CAS, actively organized exchanges of visits before China and the US established formal diplomatic relations in 1979 (Smith, 1998). Both Chinese-Americans and returned scientists from the US enthusiastically facilitated numerous two-way visits (Zhang, 2020a).

During the same period, Western European countries, Japan and Australia opened a series of industrial exhibitions in China to promote more sales of technology, products and equipment (Chen, 2017). In 1973, a new wave of equipment and technology imports from Western countries began; the items included 26 full-scale plants or complete sets of equipment, totalling US$4.3 billion, in key sectors such as petrochemicals, power and steel (Chen, 2008). Still confronting the US embargo—which was even stricter than that on the Soviet Union—and the dramatic interruption of assistance from the Soviet Union, both returned and domestically trained scientists in China worked together against enormous odds to make a series of significant achievements before 1978, such as the 10,000-ton hydraulic press (1961), the total synthesis of bovine insulin (1965) (Mcelheny, 1966), the Nanjing Yangtze River Bridge (1968), the Dongfanghong-1 satellite (1970), artemisinin (1971)[7] and hybrid rice breeding (1973)[8] (WFPF, 2008).

3. 1978–2000: Integration into the international scientific community and global innovation network

With the downfall of the 'Gang of Four', Deng Xiaoping and other reform-oriented Chinese leaders made frequent visits to Western Europe, Japan and the US in the late 1970s (Cao, 2018; Sina News, 2008). Their sense of concern for the prevailing Chinese situation was heightened when they realized the widening gap between China and the Western world. The Chinese government re-established the SSTC in 1977, and it quickly resumed its responsibilities for managing international S&T exchanges and cooperation. Nine months before the formal adoption of the Reform and Opening-up policy, Deng declared at the opening ceremony of the first National Science Conference, held in March 1978, that China would actively carry out international academic activities and strengthen friendly exchanges with the scientific communities of other nations. He also expressed sincere gratitude to all foreign friends who helped China in developing S&T (Sohu News, 2008). The 'Springtime of Science' after the Cultural Revolution boosted not only intergovernmental ties but also people-to-people exchanges with foreign partners.

In January 1978, China signed an S&T agreement with France as its first intergovernmental S&T agreement with a Western nation. Deng Xiaoping and President Jimmy Carter signed an umbrella-like bilateral S&T cooperation agreement during Deng's official visit to the US in January 1979 (Zhang, 2014). Having recognized the potential of S&T ties as a precursor to bilateral trade, the US government moved to loosen export controls on China. Agreements with Italy, West Germany, the UK, Sweden and Japan were successively forged during the 1978–1980 period. From these initial broad agreements, numerous protocols and memorandums of understanding (MoUs) were signed targeting specific fields of cooperation between Chinese ministries and their foreign counterparts according to their principal range of responsibilities. A third wave of equipment and technology imports occurred in 1978 and included 22 complete sets of equipment from Western countries (Liu, 2008). The Chinese government also accepted technological aid from many Western countries, including grants from the Japan International Cooperation Agency (JICA), the UK Overseas Development Administration (ODA), the International Development Research Centre (IDRC) of Canada and the UN system. China made donations to the UN Fund for Science and Technology and also received funds to build new research institutes. A quarter of the UN Development Programme grants to China was spent on S&T projects with a focus on areas such as new energy, computers, information technology and new materials. China joined the World Intellectual Property Organization in 1980, when the concept of intellectual property was almost unknown in China (WIPO, 2010). The Patent Law promulgated four years later cleared the way for both trade and S&T cooperation between China and Western countries. In 1991, the World Bank approved the Key Studies Development Project, which provided loans to China to support research and graduate-student training in state key laboratories.[9] Quite clearly, from the perspectives of both China and the West, S&T cooperation was seen as an effective mechanism to bring China into the mainstream of international relations and help support China's 'four modernizations' programme (for the modernization of industry, agriculture, national defence and science and technology).

China resumed its S&T ties with the Soviet Union in 1984, but China's science diplomacy maintained its principal focus on cooperation with the Western world in the 1980s. After joining more international academic organizations, such as the International Council of Scientific Unions (now the International Science Council), increasing numbers of Chinese scientists were elected to senior positions. Since 1987, the CAS has been supporting scientists from developing countries to receive training, attend academic seminars and conduct joint research and investigations in China through a south–south cooperation fund established with the Third World Academy of Sciences (TWAS, later renamed as The World Academy of Sciences for the advancement of science in developing countries).

Outside of government, 'bottom-up' personal connections, along with formal or informal institutional collaboration, have been flourishing among scientists, universities and research institutes in China and around the world. In addition to exchanges of visits, it has been common for Chinese scientists to conduct joint R&D programmes with foreign partners and to host or attend workshops and exhibitions worldwide. The Chinese government has continued to send batches of publicly funded students and visiting scholars to Western countries since 1979, and it later encouraged a larger number of self-funded students to study abroad. However, during the initial three decades of sending Chinese students and scholars abroad, China suffered from a serious ‘brain drain’ problem because most of the best and the brightest students were inclined to stay abroad and acquire foreign citizenship (Wu, 2007). In 1983, in parallel to the efforts at ‘going out’, Deng Xiaoping decided to invite and enable more overseas Chinese and non-Chinese talent to come to China to underpin both economic growth and S&T development. Meanwhile, increasing numbers of joint ventures and non-Chinese-owned companies were opened in China’s eastern coastal areas; some of them brought new technologies and managerial skills to China and yielded some important results in terms of technology transfer.

Since 1985, the Chinese government has launched several rounds of reforms across its S&T system (IDRC and SSTC, 1997; OECD, 2008). The National S&T Conference held in 1985 set the S&T policy tone that ‘economic development must rely on science and technology, which in turn should be oriented to economic development’. National S&T initiatives were deployed in three areas: economic development, high-tech research and high-tech industry development, and fundamental research. In 1986, the SSTC recalibrated its science diplomacy policy, which up to that point had been primarily focused on serving only national S&T initiatives. A new effort in science diplomacy was launched to support national S&T programmes and overall economic development. The new policy also enabled the introduction of foreign experts and technologies, as well as the export of domestic expertise and technology-based products as part of a broadening of the country’s science diplomacy agenda. Research institutes and universities, all of which were state-owned at the time, bore both positive and negative consequences during the transition from the former command economy to a new market-oriented economy. The key concepts and best practices of intellectual property rights (IPR) protection, commercialization of R&D results, and open competition and merit-based peer-review procedures were introduced to China from Western countries and international organizations. As a result, a brand-new intellectual-property regime was established, the National Natural Science Foundation of China (NSFC) was formed, new nuclear safety regulations were put in place, an improved R&D statistical system was introduced, a venture-capital market was initiated, and science parks and incubators were gradually established in China in the 1980s and 1990s.

Science diplomacy also played a key role in repairing Sino-US relations after 1989. In 1991, after four rounds of negotiation in three years, China and the US signed the IPR Annex of the bilateral S&T Cooperation Agreement (Duan, 2003)—a landmark document that highlighted China’s determination to protect IPR in international S&T collaborations. SSTC Minister Song Jian led a senior officials delegation to visit the US and co-host the Joint Commission Meeting on S&T Cooperation in 1994. The strategic role of science diplomacy was strongly in evidence during this period as both China and the West sought to bring about a new era of closer relations and to expand cooperation, since S&T collaboration was playing a very significant role in building trust and bringing mutual benefits.

In 1995, the then Chinese President Jiang Zemin put forward the ‘Strategy of Invigorating China through Science and Education’ at the National S&T Conference in Beijing. Under the guidance of China’s diplomatic strategy, the mission of international exchanges and cooperation became focused on promoting S&T progress in different economic and social domains, and science diplomacy was to be used first and foremost to serve the needs of economic development. International cooperation made a significant contribution to domestic research projects such as the Beijing Electron–Positron Collider (with the US), the demonstration project of the renewable-energy system in Dachen Island (with the then European Economic Community), the Sino-Japan Friendship Center for Environmental Protection, and the HT-7 Superconducting Tokamak (with Russia), among others.

The Friendship Award set up by the Chinese government in 1991 is regarded as the highest award for non-Chinese experts who have made outstanding contributions to China's economic and social progress. Since 1995, the China International S&T Cooperation Award has been conferred on non-Chinese individuals or organizations that have made important contributions to China's S&T development (NOSTA, 2017). China's growing role in multilateral mechanisms also led to more initiatives calling for S&T cooperation, such as the first APEC Regional Science and Technology Cooperation Ministerial Meeting (APEC, 1995), the ASEM Science and Technology Ministers' Meeting (MOFA, 1999a, 1999b), the first Meeting of Heads of Science and Technology Ministries and Departments of the Shanghai Cooperation Organisation (SCO) Member States (2010), the Group on Earth Observations Ministerial Summit (GEO, 2010), the Third World Organization for Women in Science Fourth General Assembly and International Conference (CAS, 2010), the Carbon Sequestration Leadership Forum 4th Ministerial Meeting (2011),[10] TWAS general conferences and general meetings (1987, 2003, 2012 and 2022),[11] the G20 Science, Technology and Innovation Ministers Meeting (2016)[12] and the 5th BRICS Science, Technology and Innovation Ministerial Meeting (2017).[13] China was among the first countries to formulate a national population and development strategy, titled 'China's Agenda 21: White Paper on China's Population, Environment and Development in the Twenty-first Century', soon after the UN Conference on Environment and Development in 1992, and it adopted a series of policies and measures to fully capitalize on S&T for sustainable development.

4. The new century: Opportunities and challenges for China as an initiator and contributor

In 2000, gross domestic expenditure on R&D accounted for only 0.89% of China's gross domestic product (NBS and MOST, 2020). Clearly, this placed the country at the low end of the rankings among the world's leading technological countries. In fact, at that time, if one were to describe the Chinese S&T situation, three shortcomings stood out: insufficient funding, lack of high-end talent with a ceaseless brain drain, and dated infrastructure with inadequate equipment and facilities. Since that time, however, the Chinese government—at both the national and local levels, as well as across many industrial sectors—has drastically increased its R&D investments. Two decades later, China has now become the second-largest R&D performer in terms of overall spending on a per country basis, and it accounts for over 22% of total world R&D expenditure (NSB, 2022). It is also increasingly prominent in industries that rely intensively on S&T knowledge.

The booming domestic market has bred many privately owned high-tech companies, such as Lenovo, Huawei and DJI, which have also become competitive in the global marketplace. After China's accession to the World Trade Organization in 2001, increasing numbers of multinational corporations expanded their presence in the Chinese market and opened local R&D centres to tap into China's growing talent pool. In 2003, the first ever National Talent Conference was held, and the then Chinese President, Hu Jintao, elaborated that China should evolve from a populous nation to one with a competitive talent pool. With ever-increasing domestic research and market opportunities, overseas Chinese students and scholars have gradually started to return home to pursue their research careers or build start-up businesses. The numbers of non-Chinese scholars sponsored by talent programmes and non-Chinese STEM students in China, however, are still very limited today.

The SSTC was renamed the Ministry of Science and Technology (MOST) in the government restructuring of 1998. The MOST took the leading role in drafting the National Medium- and Long-term S&T Development Plan 2006–2020, which called for China to become an innovation-driven society by the year 2020. Because of worries about China's heavy reliance on foreign technologies, the plan put indigenous innovation at its core while still highlighting the significance of international exchanges and collaboration (State Council, 2006). The MOST has also formulated five-year guiding plans for international S&T cooperation since 2000 (State Council, 2000; Xinhua News Agency, 2006; MOST, 2011, 2017). By 2020, China had signed 114 intergovernmental S&T agreements and established cooperative ties with 161 countries and regions (State Council, 2020a), although the limited staff and financial resources of the MOST often leave some agreements sitting idle while others get extensive attention (Wagner and Simon, 2022; Wagner, 2022).

Today, increasing numbers of stakeholders in China are taking part in international S&T activities. In 2018, the MOST merged with the State Administration of Foreign Experts Affairs (SAFEA) and strengthened its function of attracting non-Chinese talent. In addition to the five S&T-related agencies (MOST/SAFEA, CAS, CAE, NSFC and CAST), other ministries[14] of the central government, local governments, universities, public research institutions, and state-owned and private enterprises also play their roles. Since the missions of individual government ministries vary, there are different agencies involved in each case of bilateral or multilateral cooperation. In general, people-to-people S&T exchanges and collaborations have outpaced activities under most of the bilateral agreements with developed countries. The internationalization of the Chinese S&T system has begun to take hold via both official and non-official efforts since 2000. However, Chinese scientific enterprise is still less international than that of Western scientific powers.

While many prominent researchers in China have studied and worked abroad, China's S&T is still overwhelmingly dominated by ethnic Chinese people, and there is a very limited presence of non-Chinese scholars and students, who often have difficulty pursuing their professional careers in China (Serger et al., 2021). A new portfolio of diversified policy tools for science diplomacy has also been implemented. These new approaches have the principal goals of deepening and expanding China's ties with the global scientific community and ensuring that China has a major role in shaping international S&T relations. Since the remarkable progress in China has attracted worldwide attention, more S&T diplomats have been sent to both developed and developing nations to promote bilateral S&T ties and to publicize Chinese science, technology and innovation (STI) policies and practices.

Entering the new millennium, China has become both a taker and a giver in terms of conducting eye-catching joint projects with Western and Russian partners, such as the Daya Bay Reactor Neutrino Experiment (Xin, 2021), the Wuhan P4 Laboratory (CAS Wuhan Branch, 2017), the Tibet ASγ (ASgamma) experiment (CAS, 2021a, 2021b; Tibet ASγ Collaboration, 2021), and the China Experimental Fast Reactor. Despite its rapid growth in terms of publications over the last 20 years, China has a low rate of international collaboration, and this has hardly grown since 1999 (Flagg et al., 2021). In 2018, US authors of science and engineering articles collaborated most frequently with partners from China (25.71%), and vice versa (43.65%) (NSB, 2019). The trend of weakening collaboration between China and the US since 2017 has already been identified (Zhu et al., 2021; Jia et al., 2022; Crow, 2022a; Baker, 2022), and the number of researchers with dual US–China affiliations is falling (Noorden, 2022). Studies have also shown that the US has benefited significantly from such partnerships (Lee and Haupt, 2020), and strategies requiring US allies to 'decouple' from China in key fields of R&D will potentially hurt 'Five Eyes' partners far more than either the US or the European Union (Flagg et al., 2021).

Before the COVID-19 pandemic, 'innovation dialogue' mechanisms with the US, the European Union, Germany, France and Japan had been established, as increasing numbers of Western countries had started to pay more attention to Chinese innovation policies, especially those related to high-tech industries, IPR protection, technical standards and so on. China's rapid rise from an innovation laggard to becoming a potential leader has driven this new attention, which has had both positive and negative consequences, as discussed below.

Regarding cooperation in space engineering, more bilateral trust and complicated arrangements are needed between China and partners in other countries. China has signed more than 100 space agreements and MoUs with other countries and international organizations since 1985,[15] which was the year when China announced that the Long March rocket family would offer commercial satellite launch services for users abroad. The first commercial Chinese launch of a US-built satellite occurred in 1990. However, the 1999 Cox Report ended Chinese launches of any satellite built by the US or with US components (Kulacki, 2011). Since 2011, the Wolf Amendment added to the annual Appropriation Bill has further banned scientific cooperation with China by the US National Aeronautics and Space Administration. In 2008, China and other Asian countries established an intergovernmental organization: the Asia–Pacific Space Cooperation Organization (APSCO). Headquartered in Beijing, APSCO provides a cooperative mechanism for developing countries in the region to be able to make peaceful use of space as a driver for development. Joint projects with the European Space Agency (ESA) and Russia, France, Italy, Brazil and other developing countries are booming in the fields of space science, deep-space exploration, manned space missions, Earth observation, satellite navigation, applications of space technologies, space debris, and commercial satellite manufacturing and launches. The China–Brazil Earth Resources Satellite programme, which was launched in 1988, is often cited as a rare but very successful case of south–south cooperation in the high-tech domain.

South–south collaboration is now a priority in China's science diplomacy portfolio. China has launched S&T partnership programmes with Africa, the Association of Southeast Asian Nations, South Asia, Arabic states, Latin America and SCO member countries since 2009. China's persistent strategy of using S&T to empower socio-economic development and alleviate poverty helps to motivate other developing countries. In 2013, the CAS launched an International Science and Education Outreach Programme on training and joint research with developing countries (Xinhua News Agency, 2014). Centres of excellence in the fields of astronomy, space weather, medicine, biodiversity, ecology and environment, earth science, and marine science have been built in South America, Central Asia, South and Southeast Asia, and Africa.

In 2016, the MOST issued the Belt and Road Science, Technology and Innovation Cooperation Plan (MOST, 2016). Follow-up actions have consisted of people-to-people exchanges, including talented young scientist programmes and international training programmes, joint laboratories, science parks and technology-transfer centres (China Plus, 2017). Many developing countries hope to learn a great deal from the Chinese experience, while the Chinese government hopes to solidify China's economic ties with more nations and enhance China's position as a global agenda setter. To date, it seems that the Belt and Road Initiative (BRI) has had no evident effects on China's scientific research output. China's top universities may have ever more students from the BRI countries, but they recruit their faculty from and focus their premier research partnerships on leading Western universities (Armitage and Woolston, 2021).

China is no longer a bystander and is now a major contributor to international research programmes and megascience projects such as the International Thermonuclear Experimental Reactor and the Square Kilometre Array. In 2018, the Chinese government issued a plan to encourage its domestic scientific community to initiate international megascience research programmes or projects (State Council, 2018). The UN/China Cooperation on the Utilization of the China Space Station initiative provides scientists from around the world an opportunity to conduct their own experiments on board the China Space Station.[16] In June 2019, the UN Office for Outer Space Affairs and the China Manned Space Agency announced that six experiments had been granted a place aboard the China Space Station, and three more received conditional acceptance. The accepted proposals cover areas including astronomy, space medicine, space life science, biotechnology, microgravity fluid physics, microgravity combustion and space technologies. The 23 winning institutions are based in a wide range of 17 developed and developing countries (Jones, 2019). Lunar samples and data collected by the *Chang'e* mission will also be shared with international partners (Zhang, 2020b). The Five-hundred-meter Aperture Spherical Radio Telescope (FAST) built by the CAS in south-west China's Guizhou Province, which is by far the largest single dish radio telescope in the world, has been open to astronomers worldwide for observation applications since April 2021 (China Daily, 2021).

As a member of the group of developing countries, China has actively participated in the discussion of common challenges and STI governance under the frameworks of the UN Commission on Science and Technology for Development, UNESCO, the UN Facilitation Mechanism (which was established by the 2030 Agenda to support the implementation of the Sustainable Development Goals), the Technology Mechanism under the Paris Agreement on climate change, and the first International Summit on Human Gene Editing,[17] among others. China's involvement in these activities highlights its transition from being a marginal player in international S&T affairs to being a key player in helping to define priorities for global action in the coming years.

When the COVID-19 pandemic started, in Wuhan, China, the Chinese Center for Disease Control and Prevention quickly isolated the first novel coronavirus strain, and, together with the Chinese Academy of Medical Sciences and the Wuhan Institute of Virology, submitted the genome sequence of the novel coronavirus to the World Health Organization (WHO), and the sequence was published by the Global Initiative on Sharing All Influenza Data to be shared globally (State Council, 2020b). Later, Chinese doctors and researchers organized numerous video conferences on the diagnosis and treatment of COVID-19 and shared clinical research findings with peers from all over the world. China has also been a leader in combating the coronavirus pandemic, making its medical equipment and successfully approved vaccines available to many countries in need. China's rapid suppression of the virus on the domestic level has also served as a positive example for many countries. The Chinese government has indicated its firm commitment to cooperating with the WHO and other countries to help prevent future viruses from becoming global pandemics.

The newly revised *Law on Progress of Science and Technology* dedicates a chapter to international S&T cooperation.[18] In 2017, a document named *Guideline for Foreign Scientists to Participate in National R&D Programs* was issued by the MOST. Non-Chinese scientists will be invited to participate in the strategic study, task design and evaluation of national R&D programmes. They can also submit proposals as principal investigators or join the peer-review team. More national laboratories and megascience research infrastructure projects have been opened to the world (Normile, 2021). The Chinese government also plans to establish global research funds and open to the world during the 14th Five-year Plan period (2021–2025).

The above-cited progress notwithstanding, in recent years, various challenges to China's science diplomacy policy and practices have emerged. They include political interventions by other governments in S&T cooperation, 'China-bashing' by Western countries, questions about research integrity and ethical codes in the Chinese S&T system, and underrepresentation by China in international organizations. When the former Trump administration in the US waged its so-called 'trade war' against China in 2018, most observers noticed that the 'war proclamation'– the *Section 301 Report*[19] released by the United States Trade Representative —mentioned 'trade deficit' only once—at the beginning of the report when it quoted President Trump's instructions to start the investigation. The chapter titles of the report, which refer to areas including the technology-transfer regime, licensing restrictions, investment to acquire foreign technology, standardization laws and talent acquisition, clearly illustrate that it has been a war targeted largely at S&T competition. A later document issued by the White House (2018) even blamed China for open-source collection of S&T information.

The ongoing efforts of the US to 'decouple' from China have not only disrupted the global trade and supply chains of many high-tech industries but also hindered academic exchanges as well as research and education collaboration (Tang et al., 2021). Partial decoupling—especially in high-tech domains and critical supply chains, industrial policy, and technology-related national security issues—is now at the forefront of bilateral tensions. Sino-US S&T cooperation has been affected by an emerging geopolitical rivalry and exposed to intensive public scrutiny; many programmes and projects between China and the US—as well as between China and Europe, Japan and Australia—have fallen victim to unwarranted political attacks because of the unease raised by China's rapid rise as a country of growing influence in international S&T competition. The notorious China Initiative (DOJ, 2021) executed by the US Department of Justice (DOJ) and the Federal Bureau of Investigation has already had a chilling effect on scientific collaboration and created fear and distraction among the US scientific community. Although the DOJ (2022) announced the end of the China Initiative in February 2022, continued prosecutions serve as a warning to other Asian and Asian-American researchers and technologists who have increasingly come to view US universities as hostile places to work (German and Liang, 2022). It has also blocked the issuance of visas to many Chinese scholars hoping to engage in collaboration with their US counterparts. When scientists in the US became more cautious about communicating with their Chinese counterparts, the latter were also hesitant to collaborate with former colleagues at US national laboratories—not because of concern from the Chinese side, but because of how this might affect US colleagues' jobs. This will be a tragedy for a generation of scientists who, right from the start, were pressured to be suspicious of their biggest collaborators (Crow, 2022b). US–China tensions are likely to last and thus have long-term consequences.

In September 2020, Chinese President Xi Jinping stressed at a symposium attended by domestic and foreign scientists in Beijing that international cooperation in S&T is a general trend of the times. The more blockades and suppression China may encounter, the more it should avoid isolating itself from the rest of the world (Xinhua News Agency, 2020). President Xi reiterated at the 2021 Zhongguancun Forum that China will strengthen international S&T exchanges with a more open attitude and will actively participate in global innovation networks to jointly promote basic research and push forward the application of S&T achievements. China will also shape the concept of 'developing S&T for good purposes', improve global S&T governance, and enhance the well-being of mankind (*People's Daily*, 2021; Xinhua News Agency, 2021a). Accepting the bumpy road ahead, the newly approved *14th Five-year Plan and Long-range Objectives through 2035*, issued in March 2021, set the policy tone that China will implement an international S&T cooperation strategy featuring openness, inclusiveness and shared benefits, and it will actively integrate into the global innovation network (Xinhua News Agency, 2021b; NDRC, 2022). To fulfil the goal of building a community with a shared future for humankind, China's science diplomacy will continue to promote international exchanges and cooperation to expand the frontiers of human knowledge, to tackle all types of common challenges, and to improve the global governance of STI.

Science provides a non-ideological environment for participation in the free exchange of ideas between people, regardless of their cultural, national or religious backgrounds. It is perceived as the institution that stands out in an exemplary manner or—to put it more bluntly—as a beacon of hope and a key source of human development, well-being and global understanding (Rungius, 2018). Science is also naturally and inherently inclined to international exchange and cooperation. The trend of internationalization of S&T shall not be reversed, and the global scientific community shall not be fragmented. For China, based on statements from the government leadership over the past several decades, S&T cooperation is not a one-way street and has never been a zero-sum game. A strategy to contain or isolate China might yield some short-term results, but it will not succeed in the longer term, as globalization remains a given in the world of the twenty-first century. The creation of new knowledge is no longer something that occurs in a single country but is now embedded in a series of new international networks. The Chinese government remains committed to encouraging domestic scientists and engineers to participate actively in such networks and, on many occasions, has indicated a willingness to contribute to the solution of many global challenges through expanded collaboration and cooperation. With its growing S&T capabilities, talented pool of scientists and engineers and increasingly advanced S&T infrastructure, China will continue to be a proactive player in international S&T affairs in the foreseeable future.

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Notes

1. In this article, 'science diplomacy' refers to science and technology diplomacy, which also covers relevant issues in areas such as agriculture, health, the environment and space technology. In China, science and technology diplomacy is considered to be more official, while international science and technology exchanges and cooperation include both intergovernmental and people-to-people endeavours.
2. See full text of the 'Gong Shu' chapter at https://ctext.org/mozi/gong-shu.
3. See more information about Needham at https://www.encyclopedia.com/people/medicine/biochemistry-biographies/joseph-needham.
4. See also information about the talks at https://2001-2009.state.gov/r/pa/ho/time/lw/88750.htm.
5. See details about the symposium in no. 35 of *Peking Review* at https://www.marxists.org/subject//china/peking-review/1964/PR1964-35.pdf; and no. 36 at https://www.marxists.org/subject//china/peking-review/1964/PR1964-36.pdf.
6. More information about the Straton model is available at https://www.mpiwg-berlin.mpg.de/research/projects/straton-model-and-yang-mills-theory.
7. See more information about the discovery of artemisinin at https://www.nobelprize.org/prizes/medicine/2015/tu/biographical/.
8. See also more information about Yuan Longping at https://msa-foundation.org/blog/msa-member/professor-yuan-longping/.
9. See details about the Key Studies Development Project at https://projects.worldbank.org/en/projects-operations/project-detail/P003478.
10. See more information about the meeting at https://www.cslforum.org/cslf/Events/Beijing2011.
11. More information about the meetings is available at https://twas.org/sites/default/files/nl16_1.pdf; https://twas.org/article/chinas-president-opens-twas-conference; and https://www.nature.com/articles/455598a.
12. See the statement of the meeting at http://www.g20chn.org/English/Documents/Current/201611/P020161125474288889305.pdf.
13. See more information about the meeting at http://brics-sti.org/?p=news/Meetings.
14. The list may include the National Development and Reform Commission, Ministry of Education, Ministry of Industry and Information Technology (or China National Space Administration, or China Atomic Energy Authority), Ministry of Natural Resources (or State Oceanic Administration), Ministry of Ecology and Environment (or National Nuclear Safety Administration), Ministry of Housing and Urban–Rural Development, Ministry of Transport, Ministry of Water Resources, Ministry of Agriculture and Rural Affairs, National Health Commission, Ministry of Emergency Management, State Administration for Market Regulation, China Meteorological Administration, National Energy Administration, National Forestry and Grassland Administration (or National Park Administration), National Railway Administration, and China Earthquake Administration.
15. Different editions of China's aerospace white papers are available at http://www.cnsa.gov.cn/n6758824/n6758845/index.html.
16. More information about the initiative is available at http://www.unoosa.org/oosa/en/ourwork/psa/hsti/chinaspacestation/ao_main.html.
17. The summit was hosted by the US National Academy of Sciences, the US National Academy of Medicine,

the Royal Society and the Chinese Academy of Sciences in 2016.

18. Full text of the law is available at http://www.npc.gov.cn/npc/c30834/202112/1f4abe22e8ba49198acdf239889f822c.shtml.
19. More information about the report is available at https://ustr.gov/about-us/policy-offices/press-office/press-releases/2018/march/section-301-report-chinas-acts.

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A discussion on practices and characteristics of science and technology diplomacy in twentieth-century China

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Abstract
Scientists and diplomats have significant differences in professional skills, activity time and work content, but they should work together. With the deepening impact of science and technology (S&T) on socio-economic development and international relations, S&T has become a crucial component of national strategies, particularly for diplomacy. There is a need for scientific evidence and advice, meaning that mastering more knowledge and skills in S&T would be helpful in negotiations. This paper analyses the ideas of S&T diplomacy, including a review of its 40-year history in China, its definition (with detailed connotations) and its characteristics. The paper focuses on the significant role of people-to-people communication in S&T, which may inform future work. Five suggestions are given to strengthen the strategic planning of S&T diplomacy: (1) A more clarified, strategic goal of future-oriented S&T diplomacy is required; (2) It is important to build a theoretical system for China to describe S&T diplomacy; (3) The creation of a global S&T cooperation map that adapts to the new type of international relations would be valuable; (4) Fairness and justice shall be maintained, while a reform of the global S&T governance system is promoted; (5) It is a must to adhere to bottom-line thinking and strengthen risk prediction and emergency responses.

Keywords
Science and technology, people-to-people exchange, science diplomacy, history

1. Background

Scientists and diplomats have significant differences in their professional skills and work time and content, but they must work together. On the one hand, with the deepening impact of science and technology (S&T) on socio-economic development and international relations, S&T has become a crucial component of national strategies, particularly for diplomacy. There is more need for scientific

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evidence and advice, meaning that more S&T knowledge and skills would be helpful for international negotiations. On the other hand, in the fast-changing world of S&T, scientists and engineers should participate in diplomatic and global activities. There are many diplomatic issues involving S&T. It requires more flexible 'smart power' and strong support from national diplomatic institutions and the skilful mediation of diplomats when it comes to such issues as S&T development, the facilitation of exchanges between S&T personnel, the construction of large scientific research facilities, international organizational cooperation, and the formulation of common rules and standards in S&T.

Therefore, S&T and diplomacy overlap, which is an inevitable result from a holistic and systematic view, and that overlap is increasingly important in modern international relations. The combination of S&T and diplomacy (that is, S&T diplomacy) has new connotations. As diplomacy includes the political activities of sovereign countries, S&T diplomacy could be explained as activities dealing with S&T issues between countries. However, a more precise definition is needed for a deeper understanding of the concept. Based on a review of the history of China's S&T diplomacy, we propose a new definition of S&T diplomacy and summarize its characteristics in the context of closer international exchanges.

2. Three stages of China's S&T diplomacy in the twentieth century

The history of S&T diplomacy, including S&T exchanges and cooperation, can be reflected in the process of reform and opening-up of China, and can be generally divided into three stages: breaking through the blockade (1949–1977), resuming normal exchanges and cooperation (1978–1988), and difficult development in complex situations (1989–2000) (Luo, 2018). The S&T diplomacy activities at each stage bear distinctive characteristics of the times and historical imprints. However, the national S&T strategy and foreign policy goals were always implemented as the principle in those activities.

2.1 Breaking through the blockade (1949–1977)

The founding of the People's Republic of China (PRC) in 1949 ushered in a new era in China's international relations, ending the humiliating diplomatic history of the country. The new government needed to win the recognition and respect of the international community, and S&T cooperation became an important channel for China to show its progressive and developing image. Against the background of the confrontation between the United States (US) and the Soviet Union and the changing international situation, China pursued an independent foreign policy of peace. Opposing imperialism and hegemonism, maintaining national security and maintaining world peace were the basic goals of China's diplomacy during this period. In pursuit of these basic diplomatic goals, the focus of China's foreign exchanges was adjusted to changes in the international situation. The field of S&T diplomacy, as an important force in China's diplomatic work, was the theatre for various work in line with the adjustment of the country's diplomatic strategic focus.

Adhering to independence while learning from other countries. In the early days of the PRC, according to the international situation at that time and China's historical situation, China proposed three basic foreign policy principles: 'start anew', 'clean up the house before entertaining guests' and 'be one-sided'. In this context, in line with the principle of not being arrogant in international exchanges and learning the strengths of other nations, China established S&T cooperation and exchange with other countries as the basic policy of S&T diplomacy, including learning the advanced technology of the Soviet Union, Eastern Europe and other countries. In the autumn of 1956, the Joint Nuclear Research Institute led by the Soviet Union was established. Its main research directions included high-energy physics experiments, nuclear structure, nuclear reactions, neutron physics and theoretical physics. The Chinese government sent Wang Ganchang, Zhou Guangzhao and more than 100 other S&T workers to the institute. Work and study enhanced the friendship between the Chinese S&T personnel and researchers from other socialist countries.

Opposing the hegemony of the US and the Soviet Union and uniting with partners in Asia, Africa and Latin America. In the 1960s, international dynamics were turbulent. China was under the double pressure of the hostility of the US and the breakdown of relations with the Soviet Union. While opposing the hegemony of the US and the Soviet Union, China's diplomacy insists on the principle of 'for the benefits of the Chinese people and the people of the world'. Starting from the fundamental interests of the PRC, China targeted strengthening extensive ties with the people of the Third World, doing more work and making friends. The S&T diplomatic front worked around this basic foreign policy. China established and developed S&T cooperation relations with 24 Asian and African countries and signed four intergovernmental bilateral S&T agreements. The Beijing Science Symposium in 1964 was the first large-scale international academic conference held in China; 367 scientists from 44 countries and regions in Asia, Africa, Latin America and Oceania attended. At the 1966 Summer Physics Symposium, 144 scientists from 33 countries and one regional academic organization attended. Chairman Mao Zedong met with the representatives of scientists from various countries who attended the meeting. Besides international exchanges, China also provided technical assistance to countries in Asia, Africa and Latin America and won the friendship of the Third World countries.

Allying with the US against the Soviet Union and implementing the 'one line' and 'large area' diplomatic strategy. In the 1970s, China–Soviet relations deteriorated, and the US adjusted its strategy and showed its will to improve China–US relations, which gradually embarked on the road of normalization. China's diplomatic work began to unite all available forces, including the US and Japan. China established diplomatic relations with many countries in the world, participated in international affairs and opposed hegemonism. In this context, the Chinese scientific community actively promoted exchanges with Western countries. Following the restoration of its legal rights in the United Nations in 1971, China's S&T cooperation under the UNESCO framework began to develop. It established contacts with Western countries in the form of non-governmental S&T exchanges. From 1972 to 1973, scientific delegations from China and the US exchanged visits. From 1977, scientists such as Li Zhengdao, Yang Zhenning and Ding Zhaozhong were invited to visit many times, and they worked hard to cultivate S&T talent for China. The Chinese Medical Association was invited to send a delegation to visit the US in October 1972, which was the first scientific delegation. Chinese scientists also participated in international S&T affairs and united and supported the progressive forces of the international scientific community. In May 1949, the president of the World Federation of Scientific Workers (WFSW), Frédéric Joliot-Curie, was persecuted by the French authorities, and the Chinese Association of Scientists expressed its protest. In October 1950, the US government illegally arrested Chinese scientists Qian Xuesen and Zhao Zhongyao. The Chinese government strongly protested. In April 1951, the All-China Federation of Science and Technology sent a delegation to attend the second plenary meeting of the WFSW. The meeting elected Li Siguang as the vice-chairman of the WFSW.

2.2 Restoring normal exchanges and cooperation (1978–1988)

Since the reform and opening-up policy, China's diplomatic work has created a new situation. Major adjustments were made in its foreign policy, and the policy of independent and peaceful diplomacy was further improved. China proposed an era of peace and development and regarded maintaining world peace, promoting economic development and creating a favourable international environment for socialist modernization as a basic policy.

In 1978, China began to implement the reform and opening-up policy and resume normal exchanges with Western countries. In particular, the National Science Conference in March 1978 ushered in a 'spring of science' together with non-governmental S&T exchanges and communication among S&T communities. Zhou Peiyuan delivered a speech at the conference on behalf of the China Association for Science and Technology (CAST) and its affiliated societies. He proposed that CAST and various specialized societies should be more active in carrying out international academic exchange activities. In this stage, China signed bilateral agreements on S&T cooperation with France, West Germany, the United Kingdom (UK), Italy, the US and other Western countries, and international S&T exchanges and cooperation were fully launched.

Restoring bilateral S&T cooperation mechanisms. Starting from July 1978, the governments of China and the US have engaged in space, aviation, education, basic science, agriculture, health, energy, geology, earthquake and atmosphere activities. An American Association for the Advancement of Science (AAAS) delegation visited China for the first time in November 1978, laying the foundation for the signing of the China–US Science and Technology Cooperation Agreement in 1979. From 1980 to 1989, China and the US signed cooperation agreements in 27 fields, including for exchanges of students, exchanges of scholars, agricultural technology, high-energy physics and atmospheric studies, and conducted nearly 500 intergovernmental S&T cooperation exchanges. These exchanges promoted the progress of China–US relations. China's S&T cooperation with European countries also achieved significant development. In January 1978, an S&T agreement between China and France was signed in Beijing. It was the first intergovernmental agreement on S&T cooperation signed between China and a Western country. Under the framework of the agreement, the China–France Joint Committee for Scientific and Technological Cooperation was established (National Energy Administration, 2011). After that, China's S&T cooperation with major European countries was restored and developed. Later, China signed intergovernmental S&T cooperation agreements with West Germany (1978), the UK (1978) and Italy (1978).

Organizing international S&T conferences. In 1980, CAST resumed its work on international S&T conferences. By the end of 1990, CAST and its affiliated societies had held more than 1300 international conferences in China, received more than 3000 visiting groups, and sent delegations to participate in more than 1500 academic exchanges, involving nearly 6000 people. The conferences and other activities enabled the Chinese S&T community to keep abreast of the latest S&T developments abroad.

Participating in the affairs of international S&T organizations. In 1979, the Chinese Chemical Society joined the International Union of Pure and Applied Chemistry. After complicated communication and coordination, at the 19th plenary meeting of the International Council of Scientific Unions (now the International Science Council) in September 1982, CAST was restored to its seat as a national member of the largest international non-governmental S&T organization. In November 1981, CAST joined the World Federation of Engineering Organizations. In 1988, the 22nd Congress of the International Council of Scientific Unions was held in China. By the end of 1990, the number of Chinese scientists serving in international organizations reached 350.

2.3 Difficult development in complex situations (1989–2000)

From the late 1980s to the early 1990s, the international diplomatic landscape changed. Throughout drastic changes in Eastern Europe, the disintegration of the Soviet Union and the end of the Cold War, China's diplomacy withstood enormous tests and safeguarded the overall situation of national stability and development. After Deng Xiaoping gave a speech during his tour of China's southern provinces in 1992, China's reform and opening-up reached a new level. Under the trend of world multipolarization and economic globalization, China's S&T diplomacy was proactive, playing the role of stabilizer, properly handling complex issues and opening up new areas of cooperation.

Stabilizing bilateral cooperative relations. In December 1992, China and Russia signed the Agreement on Scientific and Technological Cooperation. In 1994, China and Japan signed the Agreement on Environmental Protection Cooperation. In February 1995, China and the US signed the Agreement on Cooperation in Energy Efficiency and the Development and Application of Renewable Energy Technology. In June 1998, China and the US signed the Agreement on Cooperation in the Peaceful Use of Nuclear Technology. In May 1997, China and France signed the China–France Joint Statement, the

Agreement on Cooperation in Environmental Protection, the Agreement on Cooperation in the Development of Peaceful Use of Nuclear Energy, the Agreement on Cooperation in Health and Medical Sciences, and the Agreement on Cooperation in Research and the Peaceful Use of Outer Space. In 1999, the first Earth resources satellite—jointly developed by China and Pakistan—was successfully launched.

Carrying out multilateral cooperation. Economic and technological cooperation under the Asia–Pacific Economic Cooperation (APEC) mechanism is the focus of multilateral S&T diplomacy. In November 1996, Jiang Zemin pointed out at the Fourth APEC Leaders' Informal Meeting: 'An important aspect of economic and technological cooperation is cooperation in the field of science and technology.' He suggested that we should 'establish a network of science and technology industrial parks in APEC countries to encourage the exchange of experience and information among S&T industrial parks in the Asia–Pacific region' (Ministry of Commerce, 2002). Subsequently, China opened several S&T industrial parks in Beijing, Xi'an and Suzhou, expanded economic and technological cooperation with APEC members and promoted the development of high-tech industries. In April 2000, the World Business Incubation and Technology Innovation Conference was held in Shanghai.

Carrying out foreign exchanges. In April 1995, Tian Changlin, the Chairman of AAAS, sent a letter to Zhu Guangya, the President of CAST, stating that AAAS hoped to restore its cooperative relationship with CAST. In December of the same year, Tian was invited to visit China. Meetings of high-level people in S&T circles restored normal relations. In addition, mutual recognition of engineers between China and the rest of the world was launched. CAST signed cooperation agreements with the German Association of Engineers, the Romanian Federation of Engineers, the Polish Federation of Engineering Societies, and the Russian Federation of Engineering Societies. High-level international S&T conferences were held in China, including the 28th International Science Council Plenary Session, the 24th International Congress of Mathematicians, the 15th International Plant Protection Congress, and the 15th World Congress of Pharmacology.

3. Summary of the main contributions of China's S&T diplomacy in the twentieth century

After the founding of the PRC, the new people's regime needed the recognition and respect of the international community. Therefore, it needed to show, through various channels, that it was progressive and prosperous, and S&T was an important part of that effort. Chinese S&T organizations and people —through participating in international organizations' activities, developing relations with organizations in other countries and cooperating with other countries to hold large-scale international conferences—tried to shape the scientific image of China and its status as a major power, along with national S&T diplomacy. Through these activities, China achieved results in acquiring foreign S&T information, grasping the world's S&T development trends and promoting national S&T development.

China is also trying to contribute to the formulation of rules for international S&T cooperation and exchanges. In the early days of the PRC, China was relatively weak in S&T, and there were few rules for international S&T cooperation. But China held bilateral exchanges and academic conferences, hosted large-scale international S&T conferences and joined international S&T organizations. In these activities, China clearly expressed the 'One China' principle, which has always been the guiding principle and fundamental rule in China's international S&T activities.

After the reform and opening-up, China's socialist modernization drive entered a critical period, and the S&T awareness of the whole society was further enhanced. Chinese S&T workers focused on rejuvenating the country through science, education and sustainable development. They deepened bilateral relations and cooperation with S&T groups in various countries and further promoted non-governmental S&T exchanges by organizing large-scale international academic conferences. Many cooperation projects and exchange activities focused on the development of the national economy, technical exchanges, engineering education and certification. Much energy and resources were invested in these areas, which opened a new situation for bilateral S&T and economic cooperation. Many international academic conferences were held in China for the first time, which effectively promoted the development of academic exchanges and expanded China's influence in the international academic community. Overseas Chinese scientists were encouraged to return to China to participate in academic activities.

International exchanges also played a role in promoting the construction of domestic society. For example, to meet the needs of international exchanges, many disciplines established Chinese echelons of international academic organizations, and some of these groups have developed into national societies. To facilitate participation in the activities of the Lithosphere Federation Committee of the International Council of Scientific Unions, and to promote lithosphere research in China, eight societies (including the Geological Society) initiated the establishment of the 'National Committee of the China Lithosphere Plan' under the organization and promotion of CAST.

By the end of 1990, CAST had established S&T exchanges and cooperation with more than 40 organizations in more than 20 countries, and signed 36 bilateral cooperation agreements. CAST worked with its affiliated national academic groups and cooperated with national S&T diplomacy to fulfil its role as a non-government organization. The number of non-government international S&T organizations joined by CAST and its affiliated national societies increased from 71 in 1982 to 213 in 1990. The number of Chinese scientists serving in international non-government organizations increased, reaching 350 by the end of 1990. Several well-known Chinese scholars served as chairmen and vice-chairmen of international organizations. In 1980, CAST resumed holding international S&T conferences. By the end of 1990, CAST and its affiliated societies had held more than 1300 international conferences in China, received more than 3000 visiting groups and conducted more than 1500 academic exchanges with nearly 6000 people. These activities played an important role in keeping China's S&T community abreast of the latest S&T developments abroad. In October 1985, the Asian Symposium on Freshwater Fish Culture was held in Beijing. More than 100 experts from major fish-farming countries in Asia, the US, the Soviet Union and West Germany attended the meeting.

4. Discussion

4.1 Definition of S&T diplomacy

Considering the actual situation of China and the interrelationship between S&T and diplomacy in international organizations and academia, this paper defines S&T diplomacy as an important part of a nation's overall diplomatic strategy. Specifically, S&T diplomacy refers to international activities about S&T development and cooperation in order to achieve a nation's S&T strategy and foreign policy goals through bilateral, multilateral or other cooperation channels under a framework or treaty.

The core of this definition is that S&T diplomacy is a new dimension in the establishment of international relations against the background of S&T globalization, which requires the coordination of S&T policy and diplomatic policy. The definition includes governmental S&T diplomacy, public S&T diplomacy and people-to-people exchanges.

The subjects of S&T diplomacy include not only heads of state, heads of government, legislatures, government agencies, people's organizations and legal entities authorized by the government, but also non-governmental entities undertaking S&T diplomatic tasks, such as industry associations, S&T societies, enterprises, think tanks and media. People in S&T diplomacy include diplomats, public servants in international cooperation and professionals performing S&T diplomatic tasks, most of whom are scientists, engineers or researchers.

To summarize: the essence of S&T diplomacy is to apply appropriate rules to gain a leading position in international S&T affairs. The characteristics of S&T diplomacy can be illustrated as the in-depth participation of S&T personnel, flexible methods and measures and an organic combination of scientific principles and national interests.

4.2 Characteristics of S&T diplomacy

S&T diplomacy has the characteristics of other diplomacy in many aspects, such as principles, positions, methods and means, but it also has certain particularities.

Professional knowledge has a strong influence. Today's diplomacy involves economic, social, technological, cultural and other aspects, with more S&T content, which is in sharp contrast to the diplomacy of the past, which was limited to political issues. For example, climate change is one of the priorities of the international political agenda, and so climate knowledge and scientific data have become an important part of diplomatic relations. Diplomatic careers are largely determined by the approach and the qualities that should be possessed by those undertaking the career (such as negotiating skills, judgement and statesmanship). As the missions of diplomats have expanded to other areas, such as economics, technology, public health and the environment, successful diplomacy requires the participation of professionals in various fields. Many issues involve cutting-edge and uncertain S&T or need the professional knowledge and collaboration of engineers. Thus, expertise and diplomacy are becoming increasingly closely related.

In-depth participation of S&T personnel is essential. The essence of S&T diplomacy is to use proper rules to achieve a technological voice in the international community. In practice, S&T personnel are not only the proposers of advisory opinions but also the direct negotiators. For example, for technical standards and regulations, scientists and technicians are often workers or committee members negotiating scientific issues. Diplomats and international cooperation officials will also participate in related S&T diplomacy and play a policy-guiding role. When tensions arise in international relations, scientists can, to a certain extent, promote the improvement of relations between countries through dialogue and cooperation. A case in point is the Pugwash Conference on Science and World Affairs, which was initiated by physicists from the US and the Soviet Union. During the worst period of the Cold War, famous scientists from various countries, including the US and the Soviet Union, played an active role in preventing world nuclear conflicts and promoting nuclear disarmament. Chinese physicist Zhou Peiyuan participated in related activities. The Pugwash Conference and its organizer, Joseph Rotblatt, were awarded the Nobel Peace Prize in 1995.

The S&T diplomatic method is more flexible. Approaches to S&T diplomacy should combine flexible negotiating skills with fair, universal knowledge of technologies (Loriol et al., 2008). Unique adaptation methods include holding international S&T conferences. Many countries regard holding high-level international S&T conferences as an important means of S&T diplomacy; they are often called 'Olympic' international S&T conferences. The head of state of the host country often attends such conferences and delivers speeches, and the local government provides financial support for the conference. Out of the desire to enhance national prestige, some countries have established international S&T awards to gain recognition from the international S&T community. Examples include the Nobel Prize in Sweden, the Abel Prize in Norway and the Alvar Aalto Prize in Finland.

Adhering to scientific principles is combined with safeguarding national interests. S&T diplomacy involves science and diplomacy. Science knows no borders, but diplomacy is the art of negotiating national interests. The aim of the field of S&T is mainly the production of knowledge, and the main body of workers consists of scientists and scientific researchers. Norms formed in scientific research activities include the accepted beliefs, theories, patterns, cases, laws, applications and tools of the scientific community, including not only the theoretical frameworks and rules followed by the scientific community but also its promotion. People build cognitive values based on scientific values.

5. Conclusion

Although the main responsibility for dealing with diplomatic issues is rooted in the government, the means to solve these problems are not limited to the single way of the official administration. Non-governmental exchange and communication in S&T are considered a distinctive feature of S&T diplomacy. There are five main kinds of activities: expand the 'circle of friends' in the international S&T circle with a consensus towards cooperation; attract fellows from all over the world to jointly build and share an international S&T cooperation platform; actively participate and speak in global activities regarding S&T governance; provide public resources for popularizing science and promote mutual learning opportunities among different civilizations; and establish a mechanism of S&T exchange to gather strategic consensus.

To strengthen the strategic planning of S&T diplomacy, this paper provides some suggestions and proposals. First, a more clarified, strategic goal for future-oriented S&T diplomacy is required. Second, it is important to build a theoretical system for China to describe S&T diplomacy. Third, a global S&T cooperation map that adapts to the new type of international relations would be valuable. Fourth, fairness and justice should be maintained while a reform of the global S&T governance system is promoted. Finally, bottom-line thinking should be maintained, and the ability to predict risk and respond to emergencies should be strengthened.

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Appendix

A summary of the practical cases of China's S&T diplomacy and exchanges is provided in this appendix.

- 1964: Holding large-scale international academic conferences is an important way to unite the world's progressive scientists and highlight China's scientific image. An example was the 1964 Beijing Science Symposium, co-sponsored by the China Association for Science and Technology (CAST) and the Beijing Center of the World Federation of Scientific Workers. Scientists from various countries who participated in the symposium conducted exchanges and discussions on striving for and maintaining national independence, developing national economic, cultural and scientific undertakings, improving people's lives, and promoting S&T cooperation among countries.
- 1978: In the late 1970s, CAST worked together with its affiliated national societies to open up channels and establish friendly contacts with S&T groups in other countries, carry out international academic exchanges and cooperation, and facilitate the modernization of China. On 18 March 1978, the National Science Conference was held, and CAST formed a delegation to participate. Deng Xiaoping made an important speech at the opening ceremony, stating that 'science and technology are primary productive forces', 'the key to the four modernizations are the modernization of science and technology', and 'intellectuals are part of the working class'. On 30 March,

Zhou Peiyuan, on behalf of CAST and its affiliated societies, delivered a speech at the conference, proposing that 'CAST and various specialized societies should be more active in carrying out international academic exchange activities'. The resumption of international S&T exchanges provided a group of Chinese scholars with the opportunity to go abroad. In April, Chinese mathematicians Yang Le and Zhang Guanghou were invited to visit the library of the Department of Mathematics at the University of Lausanne, after attending the International Analysis Conference held in Zurich, Switzerland. Emilio Daddario, the President of the American Association for the Advancement of Science (AAAS), led a delegation to visit China in November.

- 1979: In May, CAST Vice President Pei Lisheng led a delegation to visit the US. Kerry Klein, the Executive Director of AAAS, welcomed the delegation. In September, Chinese scientists Lu Jiaxi and Hu Yadong signed to join the International Federation of Pure and Applied Chemistry on behalf of the Chinese Chemical Society in Davos, Switzerland.
- 1980: In March, the Second National Congress of CAST was held in Beijing and proved that the important tasks of CAST include carrying out non-governmental international S&T exchange activities, promoting international S&T cooperation and developing friendly exchanges with S&T groups and workers in other countries. In May, CAST Vice President Liu Shuzhou led a delegation to visit Australia and met with the President of Engineers Australia.
- 1981: To better serve international exchanges, CAST established the International Exchange Service Office in January. In September, the office and the Chinese Geophysical Society organized a China–US academic discussion on petroleum geophysical exploration. The conference won the praise of the participants for its thoughtful and meticulous management. A certificate of appreciation was issued by the co-organizer of the US side to the participants. In November, CAST joined the World Federation of Engineering Organizations (WFEO).
- 1982: In May, the Ancient Chinese Traditional Technology Exhibition was organized by CAST and attracted interest from overseas audiences. After complex communication and coordination, in September, Zhou Peiyuan led a delegation to participate in the 19th General Assembly of the International Council of Scientific Unions held in Cambridge, UK, restoring the national membership of CAST in this largest international civil S&T organization. Since 1982, the exhibition of ancient Chinese traditional technology has been shown in Canada, the US, China's Hong Kong and other places, attracting a cumulative audience of nearly 4 million people.
- 1985: CAST established the China Centre for International Science and Technology Conference (renamed as the China Centre for International Science and Technology Exchange in March 2016), the Association of China–Japan (International) Science and Technology Exchange (renamed the China Association of International Applied Technology Exchange in 1987) and the New Technology Development Center, thus forming a foreign affairs service system. In June, a CAST delegation went to Hong Kong to attend the inaugural meeting of the Hong Kong Association for the Advancement of Science and Technology. In July, CAST Vice President Wang Shuntong led a delegation to visit the Quebec Centre for Industrial Research in Canada.
- 1986: In January, CAST President Zhou Peiyuan led a delegation to visit Poland, Hungary and West Germany and signed a technical cooperation agreement with the Hungarian Association of Technology and Natural Sciences. In June, CAST hosted a banquet to welcome Hong Kong and Macao S&T workers who attended the Third National Congress of CAST. In July, the first China Youth Space Shuttle Scientific Experiment programme concluded, and foreign scientists attended the awards

ceremony. In September, CAST President Qian Xuesen and Vice President Zhang Wei met with representatives of the WFEO Executive Committee. The China Modern Science and Technology Achievement Exhibition was shown in Paris, France.

- 1987: In March, CAST President Qian Xuesen visited the UK and communicated with Sir George Porter, President of the Royal Society. Qian also visited West Germany and had talks with the German Research Association. In April, CAST Vice President Zhang Wei visited the Chairman of the Polish Federation of Technical Associations. The International Conference on Fluid Mechanics and the 11th Carboniferous Stratigraphy and Geology Conference were held in July and August, respectively, in China.
- 1988: On 11 September, the 22nd plenary meeting of the International Council of Scientific Unions opened in the Great Hall of the People in Beijing. Zhou Guangzhao, President of the Chinese Academy of Sciences (CAS), had a conversation with Ken Zhu, Chairman of the International Council of Scientific Unions.
- 1992: In the 1990s, CAST focused on the strategy of rejuvenating the country through science and education and the strategy of ‘going out’, actively participating in the activities of international S&T organizations, deepening cooperation with scientists from all over the world, enhancing China’s international influence, and serving the national strategy. In May, the Chinese Contemporary Physicists Fellowship Symposium, organized by CAST and the CAS, was held in Beijing. In June, the International Symposium on Fluid Mechanics and Theoretical Physics was held in Beijing.
- 1995: One thousand young scholars from home and abroad who attended the Second Youth Academic Annual Conference of CAST visited the Museum of the War of Chinese People’s Resistance against Japanese Aggression on 28 July. They expressed their wishes to not forget China’s national humiliation, as well as to rejuvenate the country through science and education. After the meeting, a proposal for ‘rejuvenating the country through science and education’ was issued to young S&T workers across the country.
- 1998: On 17 February, CAST was invited to send a delegation to attend the 150th anniversary of the establishment of the AAAS.
- 1999: On 5 July, Chinese Vice Premier Li Lanqing attended the 14th World Congress of the International Federation of Automatic Control and delivered a speech. In August, CAST held an international seminar with well-known experts and scholars to exchange in-depth views on how to promote the implementation of the strategy of ‘rejuvenating the country through science and education’. In August, the 9th National Youth Invention Competition and Scientific Symposium was held in Hong Kong.
- 2000: On 17 February, Li Peng, Chairman of the Standing Committee of the 9th National People’s Congress, met with internationally renowned agricultural experts Norman Borlaug and Zuo Tianjue, who were invited by CAST and accompanied by CAST vice presidents Wang Lianzheng and Zhang Yutai. On 22 March, CAST President Zhou Guangzhao met with Choi Hyung-sub, Chairman of the Korea Federation of Science and Technology. Also in March, CAST and the American Academy of Sciences signed an online science popularization cooperation agreement. In June, Li Zhengdao visited the China Science and Technology Museum to visit the popular science exhibition ‘Major S&T Achievements in the 20th Century and Prospects for S&T Development in the 21st Century’. In August, the China Electrotechnical Society held the 4th International Electric Power and Electronic Drive Exhibition. In September, Yang Zhenning attended the annual meeting of CAST held in Xi’an. In November, the first International Conference on Mechanical Engineering was held in Shanghai. A Chinese Physical Society delegation went to Taipei to attend the 4th General Assembly and the 9th Council Meeting of the Asia–Pacific Federation of Physical Societies.

- 2001: In July, the China Committee of the International Science Council organized a seminar on S&T ethics and their impact on society. In August, Xu Shanyan, Vice President and Secretary of the Secretariat of CAST, led a delegation of Chinese science popularizers to visit the US and Canada. In November, the China Science and Technology Journalism Society and the China Centre for International Science and Technology Conference hosted the third Asia–Pacific Media and Technology and Social Development Seminar. In December, Zhang Yutai, Vice President and First Secretary of the Secretariat of CAST, led a delegation of science popularizers to Australia to conduct exchanges on science popularization facilities and venue construction and management.
- 2002: In May, CAST Vice President Zhang Yutai attended the signing ceremony of the cooperation agreement between CAST and the German Association of Engineers. In June, a delegation of Chinese scientists headed by CAST President Zhou Guangzhao visited Russia and attended the China–Russia Science and Technology Forum. The delegation took a group photo with Tereshkova, Director of the Russian Science and Culture Exchange Center. In August, the 24th International Congress of Mathematicians was held in the Great Hall of the People in Beijing. In September, the China Science and Technology Periodicals Exhibition Hong Kong Expo was held. In addition, CAST Vice President Wei Yu attended the CCBS Primary School Mathematics and Science Education Seminar held in Brazil, and CAST Vice President Zhao Zhongxian attended an environmental inspection in Switzerland.
- 2004: In May, the 15th International Plant Protection Conference was held. In July, CAST held the International Forum on Citizens' Science Literacy Construction in Beijing. Experts from Britain, the US, France, Japan, South Korea, India and other countries attended. During the forum, Chinese astronaut Yang Liwei and Japanese astronaut Maori Wei exchanged gifts. In August, the China International Hepatobiliary Surgery Forum was held in Chongqing. By promoting non-governmental S&T exchanges and cooperation with other countries, CAST strengthened its ties with overseas Chinese S&T associations and encouraged overseas Chinese experts and scholars to serve their country in various ways. In October, CAST President Zhou Guangzhao and Vice President Bai Chunli attended the 2004 Public Lecture of Outstanding Contemporary Chinese Scientists held in Hong Kong. In November, CAST members, including Zhou Guangzhao, Zhang Yutai (Vice President) and Deng Nan (Secretary of the Party Group), attended the symposium of overseas representatives of the Fifth Youth Academic Annual Conference of CAST. Also, CAST signed bilateral cooperation agreements with the Romanian Federation of Engineers, the Polish Federation of Engineering Societies and the Russian Federation of Engineering Societies. Chinese Vice Premier Hui Liangyu met with Axel Munack, President of the International Agricultural Engineering Society, during the International Agricultural Engineering Conference. The World Engineers Conference, with the theme of 'Engineers Shaping the Future of Sustainable Development', was held in Shanghai and was acknowledged as a most brilliant conference among the international engineering community.
- 2005: In May, Chinese Vice Premier Zeng Peiyan met with Chinese and foreign guests attending the 13th International Nuclear Engineering Conference. In October, the 28th International Science Council plenary meeting held in Suzhou was hailed as the 'most successful plenary meeting in the history of the meeting' by representatives of participating countries. In November, Deng Nan, Vice President and First Secretary of the Secretariat of CAST, met with George Atkinson, Science and Technology Advisor to the US Secretary of State. In December, the China–Germany Engineering Education

and Certification Cooperation Prospect Seminar was held.

- 2006: In April, CAST Vice President Zhao Zhongxian attended the 31st anniversary celebration of the Hong Kong Institution of Engineers. In June, the 2nd International Congress of Paleontology was held. In July, the 15th World Congress of Pharmacology and the 5th International Congress of Pathophysiology were held. In August, CAST Vice President Lu Yanchang attended the China International Power Supply Technology and Equipment Exhibition. In November, CAST President Han Qide met with Paul McManamon, Chairman of the International Society of Optical Engineering and Director of the US Air Force Laboratory.
- 2007: In June, Feng Changgen was elected as the Chairman of the Asian Science Council at the seventh meeting of the council. In July, the scientific and cultural inspection tour for the 10th anniversary of Hong Kong's return to the motherland set off in Beijing. In the same month, the Macau Association for the Advancement of Science and Technology visited CAST. Also, China and Russia held youth S&T cultural exchange activities. In August, the 22nd International Refrigeration Conference was held in Beijing. In September, the World Congress of Pharmacy, the Overseas Intellectuals Service Seminar and Joint Conference, and the China–US Scientist Symposium on Social Responsibility were held in Beijing. Deng Nan, Vice President and First Secretary of the Secretariat of CAST, also met with the AAAS delegation. In October, Chinese and foreign scholars attended a seminar on scientific exploration and human well-being. Deng Nan also met with the delegation of the American Museum of Natural History. Qi Rang, Vice President and Secretary of the Secretariat of CAST, visited the Japan Science and Technology Future Museum.
- 2008: On 15 December, a conference to commemorate the 50th anniversary of the founding of CAST was held in the Great Hall of the People in Beijing. Chinese President Hu Jintao delivered a speech at the meeting, encouraging the S&T community to study and absorb international S&T achievements, utilize global S&T resources, and contribute wisdom and strength to the construction of the national innovation system.
- 2009: On 19 February, Feng Changgen, Secretary of the Secretariat of CAST, held talks with Shi Lei, the editor-in-chief of the Asia–Pacific branch of the American *Science* magazine. From 2 to 6 March, Fu Congbin, Vice President of CAST and Chairman of the Pacific Science Association, led a delegation to the 11th Inter-Sessional Conference of the Pacific Science Association and the 2nd French Pacific Research Symposium. On 12 March, CAST Vice President Qi Rang met with the President of Engineers Australia and his delegation. The two sides signed a bilateral cooperation agreement. From 23 to 25 March, Cheng Donghong, Secretary of the Secretariat of CAST, led a delegation to Malaysia to attend the 2009 International Engineering Education Conference and the 50th Anniversary Celebration of the Malaysian Institute of Engineers. On 26 April, the commemorative meeting of the International Year of Astronomy was held. In August, the 22nd International Union of Biochemistry and Molecular Biology Academic Conference was held. CAST President Han Qide met with Chen Deliang, Executive Director of the International Science Council. In September, the International Conference on Information & Communication Technologies and Development was held. In October, the International Conference on Engineering Education and the China–ASEAN Engineering Project Cooperation and Development Forum were held. In November, the 13th World Lake Congress was held. Recommended by CAST, Professor Qian Yi from Tsinghua University won the 2009 Outstanding Engineering Education Award of the WFEO, and Bao Qifan, an expert in seaport construction and

port informatization, won the 2009 Hassib J Sabbagh Outstanding Engineering Construction Award of the WFEO.

- 2011: In September, Zhang Qin, Secretary of the Secretariat of CAST, met with the delegation from the Romanian Research Agency. Xu Yanhao, Secretary of the Secretariat of CAST, met with the Chairman of the Hungarian National Talent Council. CAST and the Institute of Electrical and Electronics Engineers held a cooperation exchange meeting.

Article

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Cultural studies in science education: A philosophical appraisal

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Abstract
The emergence of cultural studies as a scholarly programme and its adoption in science education are outlined; problems flowing from its commitment to Thomas Kuhn's epistemological relativism and ontological idealism are detailed; the gulf between the citing and the reading of Kuhn is noted; the malaise of obscurantist writing is documented; finally, problems of pursuing cultural studies research without philosophical input are indicated.

Keywords
Constructivism, cultural studies, Kuhn, philosophy, obscurantism, idealism

1. Introduction

The research programme of 'cultural studies of science' emerged in the 1980s.[1] The programme had been forming for some decades by gradually delineating itself from the long-established, institutionalized disciplines of philosophy of science and history of science, as well as from the less long-established discipline of sociology of science as exemplified in the work of Ludwig Fleck (1935/1979), Robert Merton (1942/1973) and Karl Mannheim (1952). Additionally, the programme gradually differentiated itself from the political economy of science (Rose and Rose, 1976) and the anthropology of science (Geertz, 1973; Latour and Woolgar, 1979/1986). In the end, and crucially, cultural studies differentiated itself from the Edinburgh-based 'strong programme' in the sociology of scientific knowledge.[2]

Understandably, the programme of cultural studies has some features of each of its parent disciplines. There is some philosophy, history, sociology, economics, politics and assorted inputs, such as feminism, queerism, post-colonialism and other epistemologies. Also understandably, from the outset, the new 'hybrid' programme faced the challenge of falling between disciplinary stools—a challenge not always well met.

There is a recurrent problem in any philosophical appraisal of cultural studies: the programme is, by its own admission, inherently ill-defined—not just, at its worst, unclear, ambiguous and confused but lacking both goals and method. John Frow, the founder of the cultural studies programme in Australia, candidly admits:

> 'Cultural studies', on the one hand, designates less a formed disciplinary space than a relatively formless potential which is taken up in different and often quite contradictory ways. (Frow, 2005: 1)

Ken Tobin, a co-founder of cultural studies in science education, wrote of the programme's constructivist foundation:

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> As we have thought about constructivism, we have come to realize that it is not a unitary construct. Every day we learn something new about constructivism. Like the bird in flight, it has an elusive elegance that remains just beyond our grasp. (Tobin and Tippins, 1993: 20)

Just how ‘a formless potential’ or anything that remains permanently ‘beyond our grasp’ can be the foundation of a research programme, the aim of which is knowledge of the theory and practice of science (either universal or local), is not explained. ‘Formless potentials’ and metaphoric ‘birds in flight’ present a challenge to philosophical appraisal; they do not auger well for the coherence of the cultural studies programme.

2. Beginnings of the cultural studies programme

The founding of the journal *Science as Culture* in 1987 can, for convenience, be taken as the birth year of the cultural studies programme.[3] The *Times Higher Education Supplement* opined in 1989 that ‘the journal could become a major new publication of the intellectual left—the first one truly to engage with the politics of science and technology’. The journal commenced publication to provide, among other things, ‘research space’ for anthropological studies of science of the kind that had been made famous, or, for many, infamous (Slezak, 1994), by Bruno Latour and Steve Woolgar’s study of laboratory life (Latour and Woolgar, 1979).

Just as the anthropology of religion is not concerned with the truth or falsity of religious claims, or even the strength or weakness of specific religious arguments, so too this approach to the study of science was consciously ‘truth neutral’. Truth or good warrant could not be appealed to as the explanation of the formation, and maintenance, of scientific consensus. Claims were not believed because they were true, and positions were not adopted because they were rational or there were epistemically good reasons for so doing. It was external pressures, social circumstances, or personal interests that shaped, powered, or caused scientific belief and change of belief.

Pierre Bourdieu (1930–2002), a French philosopher and sociologist of education, was a standard-bearer for this naturalistic methodology in science studies. The opening statement in his influential 1999 (originally 1975) paper on ‘The specificity of the scientific field and the social conditions of the progress of reason’ unfolded its banner:

> The sociology of science rests on the postulate that the objective truth of the product—even in the case of that very particular product, scientific truth—lies in a particular type of social condition of production, or, more precisely, in a determinate state of the structure and functioning of the scientific field. The ‘pure’ universe of even the ‘purest’ science is a social field like any other, with its distribution of power and its monopolies, its struggles and strategies, interests and profits, but it is a field in which all these *invariants* take on specific forms. (Bourdieu, 1999: 31)

Many adopted Bourdieu’s position. David Bloor titled one article ‘The sociology of reasons: Or why “epistemic factors” are really “social factors”’ (Bloor, 1984). Steven Shapin proposed a thoroughgoing sociological, and hence naturalistic, account of the history of science (Shapin, 1982). This was a 50-year echo of the Marxist Boris Hessen’s arresting 1931 article ‘The social and economic roots of Newton’s *Principia’* (Hessen, 1931).

The research avenues and questions in the new cultural studies field were signposted in the 15-chapter anthology *Science as Practice and Culture* edited by Andrew Pickering (1992). The writing style, or communicative tone, of the programme was, unfortunately, set from the top. Pickering crafted the following 80-word sentence:

> The dance of agency, seen asymmetrically from the human end, thus takes the form of a *dialectic of resistance and accommodation*, where resistance denotes the failure to achieve an intended capture of agency in practice, and accommodation an active human strategy of response to resistance, which can include revisions to goals and intentions as well as to the material form of the machine in question and to the human frame of gestures and social relations that surround it. (Pickering, 1995: 22)

The *cognoscenti* of the programme might understand what is written, but to outsiders, even sophisticated outsiders, it is, to put it mildly, a difficult passage. Disturbingly, it set the tone for writing in the new field. If this sentence, written by an acknowledged leader, gets through review, copyediting, and into print, what can be kept out? Basically nothing. Notwithstanding this, or maybe because of it, the book was a trailblazer; one commentator affirmed that:

> It stands as an encouraging sign of the continuing value of the relationship between history of science and constructivist sociology. (Golinski, 1998: 45)

The Sokal hoax demonstrated how easily incomprehensibility can be passed off as profundity. In Sokal's (1996) paper, hundreds of impenetrable sentences, such as the above, were strung together and published in *Social Text*, a leading cultural studies journal (Sokal, 1996, 2009; Sokal and Bricmont, 1998). The great pity is that it is from such sources that many educators drink.

3. Cultural studies of science education

Cultural studies soon found a home in science education, where its proponents have high hopes that its methodologies, questions and 'orientations' will become the disciplinary norm. The programme has been institutionalized, with doctoral degrees awarded, conference strands established, a journal founded, dedicated professorships created, and so on. The American Educational Research Association conference has a 'cultural and historical' research special interest group; the National Association for Research in Science Teaching (NARST) conference has a comparable strand.

As with all new 'guiding lights' in educational research—such as had been the case with behaviourism, positivism, progressivism and constructivism—the cultural studies programme in education warrants philosophical attention. It is noteworthy that, by the time the programme was taken up in science education, there were few disciplinary stools for its adherents to fall between. Notoriously, science educators have little training in any of the programme's parent disciplines (Matthews, 2021b).

This state of affairs is depressingly well documented in Peter Fensham's book *Defining an Identity: The Evolution of Science Education as a Field of Research*, in which he interviews 79 of the world's leading science education researchers (Fensham, 2004). He documents how the bulk of science educators have no formal training in philosophy, psychology, sociology or history, yet have to teach courses related to those fields and supervise graduate students. He finds that 'science educators borrow psychological theories of learning … for example Bruner, Gagne and Piaget', and that 'The influence of these borrowings is better described as the lifting of slogan-like ideas' (Fensham, 2004: 105). Jay Lemke, an educator interviewed by Fensham, well recognized this problem:

> Science education researchers are not often enough formally trained in the disciplines from which sociocultural perspectives and research methods derive. Most of us are self-taught or have learned these matters second-hand from others who are also not fully trained. (Lemke, 2001: 303).

The programme's first dedicated research journal commenced publication in 2006 when Kenneth Tobin and Wolff-Michael Roth founded *Cultural Studies of Science Education* (CSSE). The first editorial announced:

> The journal encourages empirical and non-empirical research that explores science and science education as forms of culture … It was anticipated that the forms of dissemination will make visible the nonlinearity of doing research and the recursive nature of delineating problems. (Tobin and Roth, 2006: 1)

The editors were dissatisfied with extant journals where:

> … the required format of manuscripts in standard journals assumes a linearity of method and incorporates many characteristics of positivism despite declared allegiances to (social) constructivism and postmodern, post-colonial and post structuralist theories. (Tobin and Roth, 2006: 2)

It is noteworthy that the editorial continues:

> A requisite for all published articles is, however, an explicit and appropriate connection with and immersion in cultural studies. (Tobin and Roth, 2006: 2)

It is left unsaid whether ‘connection and immersion’ means ‘agreement with’. If so, this certainly insulates its contents from outside critique, but it is a novel *policy* position for a research journal. It is the policy associated with sectarian or ‘closed-shop’ enterprises; it promotes an insular ‘silo’ research community. Even the scholastic journals—*Modern Schoolmen, New Scholasticism* and *The Thomist*—do not require ‘appropriate connection and immersion’ in either Thomism or Catholicism as a requisite for publication, just competence in the subject being addressed.

The foundation editorial of CSSE further announced that the journal encourages submissions that *present ideas radically departing from oppressive, hegemonic norms*. But the oppressive hegemonic research norms authors are encouraged to depart from are not spelt out. Are they: Measurement? Realism? Rationality? Universalism? Control groups? Literature reviews? Evidence? Objectivity? Clarity? Consistency? Statistics? Coherence? Or some other hegemonic failing not yet announced?

4. The impact of Thomas Kuhn

Kuhn’s epistemological relativism and ontological idealism have had an immense impact throughout the academy; cultural studies and science education are no exception. This is reflected in the opening sentence of a 2022 article by David Treagust, one of Australia’s foremost science educators:[4]

> Perhaps one of the major influences on our understanding of how scientific research and scientific knowledge evolves and develops was the publication of Thomas Kuhn’s *The Structure of Scientific Revolutions*. This small book really changed the way we look at the enterprise that is science. (Treagust, 2022: 16)

More is the pity, as many educators were ‘blinded’ by Kuhn’s supposed new shining philosophical light. Among other things, Kuhn provided a philosophical blessing to the whole constructivist programme in education. His imprint on nature of science (NOS), conceptual change, multicultural and indigenous science research is palpable (Matthews, 2023).

The founders of the cultural studies programme appealed to Thomas Kuhn’s texts, principally *The Structure of Scientific Revolutions* (SSR) (Kuhn, 1970), to anchor their relativism and idealism. Jan Golinski notes that Kuhn’s book ‘has come to be seen as the harbinger of the constructivist movement’ (Golinski, 1998: 13). Relativism has been the most-known public face of Kuhnianism in cultural studies, but Kuhn’s anti-realist idealism has had a more profound and insidious impact. Kuhn acknowledged this:

> Despite my critics, I do not think that the position developed here leads to relativism, but the threats to realism are real and require much discussion, which I expect to provide in another place. (Kuhn, 1990: 317)

Unfortunately, Kuhn never provided the promised defence of his anti-realist, idealist ontology. He died in 1996 aged 74 years. For some years he had worked on a manuscript, *The Plurality of Worlds: An Evolutionary Theory of Scientific Development*, that was published six years after his death (Mladenovic, 2022). Many reviewers saw that this decade-old manuscript amounted to a ‘walking back’ of his original revolutionary relativist and idealist claims. It was not ‘business as usual’ in philosophy, but it was far from the ‘anything goes’ reception that greeted SSR’s original publication. Kuhn had been ‘walking back’ for some many years and he had long been at pains to distance himself from his more enthusiastic followers. Hence there is a need to distinguish Kuhn from Kuhnianism.

Kuhnianism has been a significant factor in the rise of relativism (all views are equally good) and scepticism (we cannot know anything) concerning knowledge of the natural, social, cultural and moral worlds. Such relativism and scepticism are depressingly common in science education.[5] To be a sensible fallibilist, and to believe there is no perfect, cannot-be-improved knowledge, is not to be a relativist—a point often not appreciated. In Kuhn’s words:

> What occurred [when paradigms changed] was neither a decline nor a raising of standards, but simply a change demanded by the adoption of a new paradigm and it could be reversed. (Kuhn, 1970: 108).

And:

> We may have to relinquish the notion, explicit or implicit, that changes of paradigm carry scientists and those

> who learn from them closer and closer to the truth. (Kuhn, 1970: 170).

Kuhn's ontological idealism is written into what Rob Hagendijk labelled 'the first principle' of constructivism:

> Statements of fact in science are not so much descriptions of natural phenomena as notions fabricated by the scientists. (Hagendijk, 1990: 46)

That statements of fact—'the Earth orbits the Sun', 'photosynthesis produces oxygen'—are fabricated by scientists is a tautology. All statements are fabricated: that is what being a statement means. The move to idealism occurs when this tautology is taken as evidence that the statement cannot be related to the world; that it has no independent reference; that it cannot, in principle, be compared to any independent state of affairs because there are no such states of affairs. Consequently, for constructivists and cultural studies theorists:

> This circumstance leads to a preoccupation with colloquial talk and behaviour in the laboratories and the determination of what is to be considered evidence or fact as a consequence of such exchanges and activities. (Hagendijk, 1990: 47)

Their neutrality principle, coupled with idealism, rules out the selection among all the everyday, commonplace laboratory talk and activity—about lunch, football, the weather, a coming social event—of that talk and activity which specifically advances scientific knowledge. So, laboratory ethnography simply amounts to writing down everything said; principled selection is impossible. Without norms, the sociology of science amounts to describing everything scientists do; no lessons can be drawn.

Kuhn well exemplified the 'falling-between-disciplinary-stools' problem mentioned above. His PhD was in physics (from Harvard University in 1947), but he had no training in history, philosophy or sociology. Regarding philosophy, he admits to being 'an amateur' and reading very little of the philosophical literature (Kuhn, 1991/2000: 106). For sociology, he admits:

> I proceeded to make up the sociology of such communities as I went along … That is an abominable way to do sociology, and it did not occur to me that its outcome would, *qua* sociology, have a claim on the attention of members of that profession. (Kuhn, 1983: 28)

Little wonder his work was greeted with dismay by disciplinary specialists. Mario Bunge (1919–2020), a physicist and philosopher who published significant work in both fields (Matthews, 2019b), recounts in his autobiography that in 1966 he attended an influential colloquium on causality convened in Geneva by Jean Piaget. Kuhn, an admirer of Piaget, was a participant. Bunge observed:

> Kuhn's presentation impressed no one at the meeting, and it confirmed my impression that his history of science was second-hand, his philosophy confused and backward, and his sociology of science non-existent. (Bunge, 2016: 181)

This harsh judgement was made in 1966 after the first edition of SSR was published (1962) but before the second edition (1970). At the time of the symposium, Kuhn's most widely known historical work was *The Copernican Revolution* (Kuhn, 1957), which Kuhn acknowledged was entirely derivative and put together from secondary sources for the benefit of his Harvard General Education class. Bunge's judgement was harsh but shared by many contemporaries and, outside of education, is still endorsed.

And equal little wonder that Kuhn's work was so widely and enthusiastically embraced: seemingly, disciplinary knowledge was not needed to have strong opinions about historical and philosophical (HPS) questions.[6] This unfortunate state of affairs is manifest in many areas but especially in NOS research in education. Here, too commonly, researchers make assertions about NOS, and give direction to graduate students, without the benefit of any training in the field.

This is an institutional failing, not a personal one: HPS is rarely part of any programme for science teachers, and even less rarely part of graduate programmes for future professors of science education. Once appointed, new faculty are so overwhelmed with the teaching, supervision, service and administrative requirements for obtaining tenure that they have no time for serious HPS reading, let alone completing HPS courses. The latter ticks no tenure box. HPS is done, if at all, 'on the run'. More is the pity for the quality of science teacher education.

Subsequently, Kuhn did contribute to the history of science. In 1978, he published his acclaimed historical study of the development of black-body theory (Kuhn, 1978). But two considerations mean that this book gives no support to popular 'Kuhnianism'. First, *Black-body* did not utilize any of the famed conceptual apparatus of his revolutionary SSR; indeed the latter book, which hundreds of thousands were buying, reading and citing around the world, is never mentioned. Second, for example, Abner Shimony, the philosopher-physicist, in reviewing the book opined:

> On the whole, the intellectual processes of the few physicists immersed in black-body research seems to me to have been wonderfully rational. (Shimony, 1979: 436)

Many shared Shimony's estimation of the documentary evidence that was so well unearthed by Kuhn during his six months in the archives. This is a challenge to the lazy 'scientific change is irrational' thesis that so many expected to see in Kuhn's writing.

As evidence of Kuhn's impact, consider how in 2011 two CSSE researchers asserted the now cultural studies commonplace [sentences numbered for reference]:

> [1] Recent scholarship in science studies [STS] has opened the way for more thoughtful science education discourses that consider critical, historical, political, and sociocultural views of scientific knowledge and practice … [2] Increased attention to the problematic nature of western science's claims to objectivity and universal truth has created an educational space where taken-for-granted meanings are increasingly challenged, enriched, and rejected … [3] Thus, science's long accepted claim to epistemological superiority has now become bound to the consideration of cultural codes, social interests, and economic imperatives. (Bazzul and Sykes, 2011: 268)

Sentence [1] completely ignores the 150+ years of HPS scholarship that has richly documented the 'historical, political and sociocultural views of science'. And this scholarship has, for the same length of time, been utilized in European, UK and US science education programmes (Matthews, 1994, chapters 4, 5). Consider merely the Harvard Project Physics programme and its extensive support material (Holton, 1978). Sentence [2] is just hand-waving. Being challenged and enriched is not tantamount to being rejected; that is an additional step that may or may not be warranted for a particular concept and meaning. Sentence [3] is a hand-clapping conclusion that has not been entailed individually or collectively by [1] and [2].

5. Kuhn's idealism

Ontological idealism is the default position for cultural studies and constructivism. Rosalind Driver reminded readers that:

> science as public knowledge is not so much a 'discovery' as a carefully checked 'construction' … and that scientists construct theoretical entities (magnetic fields, genes, electron orbitals …) which in turn take on a 'reality' (Driver, 1988: 137).

This manifests the common linking of a tautologically-true premise—science is not a discovery but a social/cultural construction—with an altogether contentious and unproven idealist conclusion: scientific concepts have no existential reference. John Staver repeats the meme:

> For constructivists, observations, objects, events, data, laws, and theory do not exist independently of observers. The lawful and certain nature of natural phenomena are properties of us, those who describe, not of nature, that is described. (Staver, 1998: 503)

This indiscriminate running together of 'observations' and 'theory' that are, by definition, observer dependent with events and objects is indicative of generic philosophical indifference. And of casual, inattentive, writing. Both Driver and Staver were former presidents of the US National Association for Research in Science Teaching (NARST). Such ill-informed, casual writing 'from the top', supports denial of climate change, global warming, viral causation of COVID-19, and so on. For the ill-informed, these ‘threats’ are all just creations of the scientific mind and do not really exist. As so often, bad philosophy has bad social and personal consequences.

Michael Roth, the prominent constructivist, recipient of the NARST ‘Outstanding Researcher’ award and founder of the programme of CSSE, laid out the Kuhnian multi-world, idealist ontology:

> According to radical constructivism, we live forever in our own, self-constructed worlds; the world cannot ever be described apart from our frames of experience. This understanding is consistent with the view that there are as many worlds as there are knowers. (Roth, 1995: 13)

He continues:

> Radical constructivism forces us to abandon the traditional distinction between knowledge and beliefs. This distinction only makes sense within an objective-realist view of the world. (Roth, 1995: 14)

And concludes, for those who might not themselves draw the lesson:

> Through this research [sociology of science], we have come to realize that scientific rationality and special problem-solving skills are parts of a myth. (Roth, 1995: 31)

Then, later, he writes:

> Critiques of an observer-independent world also have been constructed in European phenomenology and existential and hermeneutic philosophy from Søren Kierkegaard through Edmund Husserl, Martin Heidegger, Hans-Georg Gadamer, Maurice Merleau-Ponty, Paul Ricœur, and Pierre Bourdieu … The observer and the observed cannot be separated. (Roth, 2005: 8)

It is noteworthy that the string of philosophers listed as refuting the realist claim of an observer-independent world does not include any with marked scientific or HPS competence.

6. Does quantum theory support idealism?

When philosophy fails to deliver the idealist, observer-dependent world, cultural theorists commonly ‘reach out’ to quantum theory to support their position. So, for instance, Wolff-Michael Roth writes:

> More serious is the critique that is associated with the Copenhagen interpretation of quantum theory. Here, the knowing observer is implicated in every observation without recourse; observer and observed are coupled and need to be accounted for in the mathematics which contains both a pan for the developing, but inaccessible system, and a part that accounts for the act of observation; observation is not passive but an active operation which determines both observational categories and the range of possible observables. (Roth, 2005: 8)

Characteristically, the meaning of ‘a pan for the developing, but inaccessible system’ is less than clear. Perhaps, as with much cultural studies writing, it has no meaning; it is just noise or hand-waving. Further, that ‘observation is not passive’ has been known at least since Plato, who recognized that ‘we see through the eye, not with the eye’. These considerations aside, the quantum argument, or variants of it, recur throughout the philosophical and educational literature. But it is not convincing; it does not bear scrutiny, much less warrant repeating.

Since Planck’s 1900 announcement of quantum theory, it has been seen by subjectivists and idealists as ‘manna from the laboratory’. Niels Bohr gave the first and most influential idealist interpretation—something that earned him a strong realist rebuke from Albert Einstein. This philosophical ‘clash of the titans’ has been well documented and copiously commented upon (Kumar, 2008).

Mario Bunge has long advanced, and defended, a version of Einstein’s realist arguments. This began with his 1967 edited book *Quantum Theory and Reality* (Bunge, 1967a) and his contribution to the collection, ‘A ghost-free axiomatization of quantum mechanics’ (Bunge, 1967b). In that paper, he axiomatized quantum mechanics and found no ghosts; everything was physical. In quantum mechanics, there were:

> no psychological concepts such as ‘observer’, ‘mind’, ‘subjective probability’, ‘expectation’, ‘uncertainty’, or ‘finding’; and no fictions such as ‘ideal

> measurement' and extra 'hidden variables' with no effects. (Bunge, 1967b: 274)

Forty-five years later, Bunge restated the argument in his *Science & Education* article 'Does quantum physics refute realism, materialism and determinism?' (Bunge, 2012). He points out that, no matter what Bohr, Born, Planck and other quantum physicists wrote, there is no subjective, observer, experiential, or even measuring-instrument term in their equations. Consciousness cannot cause a wave function, a mathematical operator, to collapse. Born's wave function gives the probability that the system is in this or that state when the equation is solved for this or that set of boundary conditions. Quantum mechanics proceeds without subjective, personal or observer terms, as they are not needed. Bunge writes:

> A semantic analysis of the basic concepts of the quantum theory, such as the energy operator (Hamiltonian) and the state vector or wave function, shows that they do not contain any variables referring to an observer. (Bunge, 2012: 1604)

Bunge celebrates the success and vindication of quantum theory, recognizing that, like all major advances in science, it does enlarge and transform our view of the world: it gives a deeper understanding of the world, its constituents and its processes. Accordingly, philosophical realism needs to be refined. Philosophical realism need not be tied to physicalism and the view that all objects have sharp properties; it should not be tied to classical mechanics. For Bunge, this was Einstein's big mistake in his famous co-authored 1935 paper (Einstein et al., 1935). The proper realist lesson is that quantum objects are not classical objects; the improper idealist lesson is that they are dependent upon us.

The quantum physicist Art Hobson (2017) and contributors to the French and Saatsi (2020) collection *Scientific Realism and the Quantum* have defended the realist interpretation of quantum mechanics. Hobson concludes his paper on 'A realist analysis of six controversial quantum issues' with the unambiguous assertion:

> The issues of quantization, field-particle duality, superposition, entanglement, nonlocality, and measurement present no barrier to a consistent and realistic interpretation based on standard quantum physics. At least to this extent, quantum physics is consistent with the scientific view as it has been known since Copernicus: nature exists on its own and science's goal is to understand its operating principles, which are independent of humans. (Hobson, 2019: 346)

The realist tradition in quantum theory is seldom mentioned in constructivist and cultural studies writing. Students are told that, after Bohr, realism is so yesterday. Supposedly, the philosophical world has swung over to observer-dependent idealism—the world announced in 1710 by Bishop Berkeley, Newton's trenchant critic:

> Some truths there are so near and obvious to the mind that a man need only open his eyes to see them. Such I take this important one to be, viz. that all the choir of heaven and furniture of the earth, in a word, all those bodies which compose the mighty frame of the world, have not any subsistence without a mind—that their *being* is *to be perceived or known* (Berkeley, 1710/1962: 67)

Critics of Berkeley, and of the idealist tradition, are ignored in cultural studies. Ernst von Glasersfeld, the doyen of educational constructivism and for whom Bishop Berkeley was the first philosopher he read, declared 1710 the greatest year in the history of philosophy.

The need for clarity about realism in science is well illustrated in a recent book, *Lightspeed*, by John Spence, the Australian physicist now at Arizona State University. The book traces the history, philosophy, sociology and physics of the determination of c, the foundational speed of light constant. In the introduction, Spence writes:

> The speed of light is one of a very small number of fundamental constants in physics which truly determines the nature of our universe and the form of matter within it. (Spence, 2020: 3)

Idealists and educational constructivists may agree, but realists can only shake their heads in disbelief when reading such a claim in an otherwise excellent book. Spence's assertion is the reverse of the truth. Our physical constants do not determine the nature of the universe and the form of matter within it; it is the latter that determine, or at least allow, the former. Dismay upon reading the above should be the reaction of anyone who has had a decent, HPS-informed, education—something not promoted in cultural studies nor, sadly, in much of science education.[7]

Educationally, the important thing is not that students become idealists or realists (this can simply be the outcome of effective indoctrination in which students have to believe what the teacher believes), but that they recognize that philosophy, especially epistemology and ontology, has been central to science (Matthews, 2022) and they develop an interest in appraising the strengths and weaknesses of philosophical positions (Matthews, 1997, 1998).

7. Reading versus citing Kuhn

It needs to be recognized that Kuhn is more cited than read in both cultural studies and science education. For many, the mere mention of Kuhn is considered to constitute an argument, or to provide evidence, for some philosophical view. Marilyn Fleer, a senior Australian science educator, writes:

> In recent years, the rational foundations of Western science and the self-perpetuating belief in the scientific method have come into question … The notion of finding a truth for reality is highly questionable. (Fleer, 1999: 119)

No evidence is adduced for these sweeping claims; no argument is provided for why 'finding a truth for reality is highly questionable'. The one piece of supposed evidence is an unpaginated reference to Kuhn.

The practice of having an unpaginated Kuhn reference substitute for evidence, or argument, is widespread in science education. It is almost the disciplinary norm. Merely putting the name 'Kuhn' in brackets after some claim is widely regarded as sufficient warrant for making the claim, no matter how outrageous, self-contradictory or ill-supported it might be.

Cathleen Loving and William Cobern, in a study of science education citations of Kuhn's SSR, found that, to the disgrace of the discipline, only 1.5% (144 out of 9715) provided a page reference. The rest were 'generic' references; merely using Kuhn's name was good enough for whatever claim was being advanced (Loving and Cobern, 2000: 194). Needless to say, those citing Kuhn paid no attention to the published arguments that challenge or refute the claim made on his behalf, even when the claims were refuted by Kuhn himself.[8]

Sal Restivo, a sociologist and former president of the Social Studies of Science Society (4S), identified this malaise:

> By the early1980s 'T.S. Kuhn' had become a cultural resource more or less detached from T.S. Kuhn, his writings, and the social contexts of his arguments. 'Kuhn' has served the interests of left, right, and center across the entire spectrum of intellectual discourse. (Restivo, 1994: 99)

8. Obscurantism

Obscure, difficult-to-understand writing is **c**ommon in constructivist and cultural studies literature. To his credit, Kuhn brought HPS in out of the cold and put 'paradigms' and 'incommensurability' into classrooms, living rooms, national papers and TV news, but he was not a good role model for clear writing. He too often needed to 'correct misunderstandings' and assert that 'I did not say that'. If he wrote clearly in the first place, such corrections would not be needed or would be minimized. Away from the top, writing got worse.

From the foundational 2006 editorial, the CSSE journal has provided a steady diet of difficult-to-read or, less kindly, obscure writing. There are technical terms in both natural and social science. They have specific meanings that serious readers can, with some effort, ascertain. But often enough in education, the supposed technical term is no more than a dressed-up everyday term. In which case, Eduspeak has replaced Plainspeak. Consider the examples in Table 1.

Have the plain-speaking translations missed anything worth having? Is whatever might be missing worth the time and effort to work out?

Table 1. Eduspeak vs Plainspeak.

Eduspeak	Plainspeak
Since co-participation involves the negotiation of a shared language, the focus is on sustaining a dynamic system in which discursive resources are evolving in a direction that is constrained by the values of the majority culture while demonstrating respect for the habitus of participants from minority cultures, all the time guarding against the debilitation of symbolic violence. (Tobin, 1998: 212)	Teach in a way that is sensitive to cultural values.
… speaking from the sociocultural perspective, [we] define negotiation as a process of mutual appropriation in which the teacher and students continually co-opt or use each others' contribution. (Cobb, 1994: 14)	Teachers and students can exchange ideas.
Activities, or rather, societally mediated motives do not get themselves realized; concrete goals are required for directing individual human subjects to realize the activities in which they participate and of which they are constitutive moments. (Roth, 2007: 165)	People act when they have strong motives to do so.
The synergism of the conversation between the research bricolage and critical theory involves an interplay between the praxis of the critical and the radical uncertainty of what is often referred to as the postmodern. (Steinberg and Kincheloe, 2012: 1492)	Education research is informed by postmodern critical theory.

Eduspeak, to put it mildly, is common in cultural studies. Roth and Tobin (2007) conjointly edited the programme's 'flagship' anthology: *Science, Learning, Identity: Sociocultural and Cultural-Historical Perspectives*. In their contribution, they crafted the following two sentences:

> If, on the other hand, we begin with the ontological assumption of difference that exists in and for itself, that is, with the recognition that A↓A (e.g., because different ink drops attached to different paper particles at a different moment in time), then all sameness and identity is the result of work that not only sets two things, concepts, or processes equal but also deletes the inherent and unavoidable differences that do in fact exist. This assumption is an insidious part of the phallogocentric epistemology undergirding science as the method of decomposing unitary systems into sets of variables, which never can be more than external, one-sided expressions of a superordinate unit. (Roth and Tobin, 2007: 99–100)

Do even the *cognoscenti* know what this means? Matters do not get any clearer when, on the following page, readers are told:

> Such alternative ways of 'w/ri(gh)ting' classroom research generally and science education research specifically allows us to institute much more substantive ruptures with the current homo-hegemony of the phallogocentric genres of science education and better come to grips with the multiplicity and plurality of experiences that exist in science classrooms. (Roth and Tobin, 2007: 102)

Does assimilating, or 'getting on top of', such text constitute good teacher education? These paragraphs were not written by a beginning student but by the two most published and most awarded researchers in international science education. Both are recipients of the coveted NARST 'Distinguished Contribution to Science Education Research' award: Tobin in 2007 and Roth in 2009. Combined, they have a Google citation count of 80,000+. What do these awards and citation counts say about the profession? The above texts suggest a clinical problem with the discipline; the paragraphs certainly say something about how much the discipline needs competent philosophy, alertness to nonsense, and commitment to clear writing.[9] And that just for starters.

Whereas natural science uses theoretical terms to simplify complex matters (many disparate movements can be unified as magnetic phenomena, many infections can be unified as bacterial, and so on), education commonly uses supposed theoretical terms to make simple matters more complex and less understandable. Isaiah Berlin (1909–1997) lamented:

> Pretentious rhetoric, deliberate or compulsive obscurity or vagueness, metaphysical patter studded with irrelevant or misleading allusions to (at best) half-understood scientific or philosophical theories or to famous names, is an old, but at present particularly prevalent, device for concealing poverty of thought or muddle, and sometimes perilously near a confidence trick. (Berlin, 2000: 221)

And Stephen Shapin warned:

> But the problem to which it is worth drawing attention is the particular species of bad writing that is, so to speak, institutionally intentional. Initiates learn to write badly as a badge of professionalism; they resist using the vernacular because it doesn't sound smart enough; they infer from obscurity to profundity. Some things are indeed hard to say in ordinary English, but not nearly so many as academics pretend. (Shapin, 2005: 239)

9. Philosophy-free cultural studies

Cultural studies' break from philosophy is institutionalized: there are no philosophers among the 40 or so members of the Editorial Committee of CSSE. This absence is apparent in published material. For instance, a recent article takes up the important topic of teaching non-epistemic values in science (Gandolfi, 2019). Much illuminating material has been written by philosophers on this subject,[10] but none is cited in the article—indeed, no philosophers at all are cited. Nevertheless, the author states that his research is:

> closely connected with the field of Post/Decolonial Science and grounded on the argument that modern Western Science is in fact a product of exchanges and collaborations between different cultures, and of the circulation of diverse types of knowledge around the world, all promoted by historical and geographical contexts (such as the trade in the Silk Road, and the European colonising and imperialist projects). (Gandolfi, 2019: 560)

Just how the achievements of Copernicus, Kepler, Brahe, Torricelli, Galileo, Huygens, Boyle, Newton and the other founders of early modern science (Wootton, 2015) are fitted into this picture readers are left to imagine—they certainly are not told. Galileo famously praised Archimedes, whose name, he said, 'should never be mentioned except in awe'. Galileo thoroughly utilized Euclidean geometry in his mathematization of physics, saying that the 'book of nature was written in geometric language'. Perhaps this is what is meant by cultural 'exchange and collaboration'. It is worth saying, but it is hardly novel. As with so much of cultural studies, problems emerge when one looks below the rhetorical, hand-clapping surface.

A fundamental problem with such philosophy-free 'externalist' programmes is well exhibited in the Gandolfi quotation. We know that for millennia there have been 'exchanges and collaborations between different cultures, and of the circulation of diverse types of knowledge around the world'. This throws no light upon, and indeed avoids, the question of why the scientific revolution occurred when and where it did. Of all the cultural exchanges that were going on around Tuscany in the seventeenth century, what did Galileo do that made *his* contribution to the exchange so dramatic and so epistemologically progressive (Matthews, 2023, chapter 3)? This is a question that all science students should be encouraged to answer. In cultural studies, the question is passed over: a case of 'nothing to be seen here', so to speak.

For all the millennia of trade on the Silk Road, it was not until the sixteenth-century Jesuit mission of Fr Matteo Ricci to Peking that modern astronomy and science began appearing in China, and this against the strident opposition of local mandarins. Education is enhanced if students learn the details of this debate. Dismissing it as an 'imperialist project' advances nothing, least of all good education (Matthews, 2019a, chapter 6). In the past 50 years, *feng shui* 'knowledge' has migrated out of China and settled, with significant local impact, throughout the world. If teachers have some philosophical acumen, this social reality can serve a deep educational purpose (Matthews, 2019a).

Cultural relativism is the foundation of the cultural studies programme; it is the ticket price for entry and for publication. The miserable consequences of cultural relativism are well known in areas such as modern slavery, the genital mutilation of women, the practice of *sati*, witch burning in New Guinea and many regions of Africa, continuing caste-based discrimination and violence in India, the promotion of voodoo medicine to deal with AIDS, COVID-19, and destructive environmental practices.

Meera Nanda, in many writings, has railed against the impact of 'progressive' philosophy and misplaced 'culturally sensitive' education in modernizing 'third world' countries. She fears 'the growth of local tyrannies, each justifying itself by culturally authentic standards' and warns that 'the postmodern elements of the constructivist science critique strengthen the *pre*modern elements of postcolonial societies' (Nanda, 1998: 289).

Twenty years later, Christine McCarthy, a philosopher, elaborated on this:

> Respect for persons does not entail respect for the belief-systems of those persons. Respect for persons entails respect for the capacity of those persons to engage in the fundamentally human activities, among which is the search for true belief. Respect for persons thus entails commitment to the support of each person in their quest for true belief; this means, in general, a commitment to the equal distribution of the social good of education. It means respectful, and mutual, critiques of one another's belief-systems, leading to mutual thought and the self-critique that is essential to the individual's growth in cognition and in all other capacities. It is also the *sine qua non* for social/cultural improvement, ethical, doxastic, and material. (McCarthy, 2018: 132)

10. Conclusion

The cultural studies programme acknowledges and deals with many of the serious curricular, pedagogical and policy questions that confront science education. Think of social justice concerns, indigenous education, justification of inquiry teaching, disciplinary versus integrated curricula, liberal versus technical objectives, value commitments and indoctrination, the legitimate boundaries of religion, politics, gender and culture in science curricula and classrooms, and much else. Informed considerations from both the philosophy of education and the history and philosophy of science are required when dealing with these issues. But cultural studies as a programme has largely ignored these disciplines. At best, such knowledge is made up 'on the run'.[11] Philosophy-free analysis does not advance solutions; it does not enlighten. Rather, it confuses and misdirects educational efforts.

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Notes

1. A useful history of the emergence of cultural studies is Dear (1995).
2. Some key texts are Barnes (1974) and Shapin (1982).
3. This was the first such-named research journal in the field. Robert M Young, the English historian of science, was the founding editor. The journal was initially published by Free Association Books and was subsequently acquired and published by Taylor and Francis.
4. David Treagust has 100+ publications and 36,000 citations and has supervised scores of doctoral theses. He is not a minor or peripheral figure in international science education. His quoted words indicate how normalized Kuhn's 'picture of science' has become among educators.
5. The unhealthy reach of relativism and idealism in science education is described in Matthews (2015, chap. 8 and 2021a, chap. 7).
6. For documentation and references on these claims, see Matthews (2023).
7. In private communication, Spence has said that the above sentence was poorly written and will be corrected in a subsequent edition. But that is too late for many present-day readers who will have had their idealism and constructivism confirmed by the claim. Spence, despite himself, will become yet another authority cited to support the idealist claim that the observer determines the world. This is yet another case of careless writing causing intellectual and disciplinary damage.
8. On Kuhnianism in science education, see Matthews (2023).
9. On the malaise of obscurantism or 'mumbo-jumbo' in culture and the academy, see Wheen (2004) and Frankfurt (2005).

10. See Carrier (2013), Couló (2014), Elliott (2017), Koertge (2005) and McMullin (1983).
11. For elaboration, and citations, see Matthews (2021b).

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Article

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Family visits to a biodiversity exhibit: An analysis of emotional responses during free visits and visits mediated by explainers

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Abstract

In this study, we analyse the role of emotion in the context of informal science education experiences, specifically seeking to understand: (a) which emotions can be stimulated in families visiting interactive expositions, and (b) the extent to which parents/caregivers and museum explainers engage the children's emotional expressiveness. To this end, a protocol based on the core affect model was employed to examine the visits of 10 family groups (26 individuals) who visited an exhibit on biodiversity in a science museum in Rio de Janeiro, Brazil. Five families went on free visits and the other five had their visits mediated by explainers. We observed that, in general, positive emotions, such as excitement and surprise, were among those most often expressed. Negative emotions, such as disagreement and doubt, also stood out in this study, but they were not exclusively associated with the negative aspects of the experience, and were instead linked to challenging moments that facilitated the construction of meaning by the families. The data suggest that visits mediated by explainers occasioned more frequent emotional displays than free visits, indicating the importance of explainers in families' interactions and emotional responses.

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Keywords
Science museums, emotions, family visit, exhibit explainers, conversations

1. Introduction

Museum experiences evoke a number of emotional responses that are capable of influencing the public's involvement and engagement with exhibits and educational initiatives (Marandino et al., 2018). Moreover, emotions are responsible for stimulating the interest necessary for the learning process to occur and can provide memorable experiences that lead visitors to think and feel differently after their visit (Falk, 2009).

In the words of Wagensberg (2005: 11), 'emotions, not anything else, are the most important elements of museographic language', allowing visitors to experience a museum in its totality. When proposing that communication in science museums must involve touch (hands-on), reflection (minds-on) and emotion (hearts-on), Wagensberg (2001: 346) highlights that 'stimulus and emotion are the key words for the zero point of all knowledge'.

Several authors have defended the impossibility of understanding why people visit museums and engage in related activities when emotions are removed from consideration (Gregory and Witcomb, 2007; Smith and Campbell, 2016). From this perspective, understanding how emotions affect interactions and conversations can contribute to a better understanding of visitor experiences at museums, among other things. In this study, specifically, we investigated how exhibits can influence the emotional responses of family groups and how emotions are expressed in social interactions between adults and children. In particular, we considered whether differences exist in emotional responses between free visits and visits guided by museum explainers.

1.1 Emotional responses during the visit experience

Emotions play an important role in visitor behaviour (Camarero-Izquierdo et al., 2009). Del Chiappa et al. (2014) analysed whether emotions influence visitor satisfaction and observed that groups demonstrating positive emotional responses reported higher satisfaction with their visit and evaluated the museum in question more favourably in terms of its attractiveness and singularity. Ruiz-Alba et al. (2019) and Palau-Saumell et al. (2016) verified that positive emotions are an indicator of visitors' intentions to revisit a museum and recommend it to others.

In general, the emotions that are most strongly associated with museum visits are positive ones (Falk and Gillespie, 2009; Mastandrea and Maricchiolo, 2016). However, this varies according to the type of museum visited. Mastandrea and Maricchiolo (2016) carried out a survey in several countries and regions (Austria, France, Hungary, Italy, New Zealand, Portugal, China's Taiwan and the United States) on motivations, attitudes, emotions and learning processes in three types of museums: ancient art, modern art and the sciences. In this investigation, curiosity was the most frequently cited emotion in science museums, while art museums were more strongly associated with aesthetic pleasure.

Emotions such as excitement and pleasure have been associated with better long-term learning outcomes in science (Falk and Gillespie, 2009) and conservation (Ballantyne et al., 2007). Piscitelli et al. (2003), in their investigation of the interactions of young children at science museums, affirm that emotions such as excitement, anxiety, happiness, frustration, empowerment, success and pleasure are experienced as children interact with exhibits. Other studies (Evans et al., 2018; Rappolt-Schlichtmann et al., 2017) have also discussed the role of negative emotions in learning processes in museum spaces, showing that emotions such as frustration and confusion are associated with periods of high activation. The authors describe this state as one of 'productive struggle' in which children exhibit more concentrated and engaged behaviour, suggesting a relationship between feelings of 'struggle' and significant learning. On this topic, Falk (2009) states that the stronger the emotional 'value' of an experience, the higher the probability that relevant sensorial information will be committed to memory. Emotion can be interpreted in this context as a signal of the event's significance.

Luke et al. (2022) analysed social and emotional behaviour during the interactions of 606 4- and 5-year-old children at 14 children's museums and 12 community playgrounds. In their analysis, the authors made use of categories centred around four socio-emotional abilities: (a) emotional expression, which registers instances of positive and negative feelings; (b) emotional regulation, which registers instances of positive and negative reactions to frustration; (c) behavioural regulation, which registers positive and negative involvement with age-appropriate activities; and (d) relational abilities with peers. Noteworthy among these results is the observation that social emotions (those demonstrated during play with other children) and emotional regulation were expressed with more negativity at science museums than at playgrounds. Luke et al. (2022) suggest that this may be a reflection of museums as spaces constructed for play that allow children to make (and fail) multiple attempts at completing tasks, becoming frustrated in the process. As such, science museums provide opportunities for children to practise these important social abilities.

In Brazil, there have been few studies completed to date that specifically focus on investigating emotions during museum visits. Among the studies that investigate the visiting public and provide data on the role of emotions in their experiences, we highlight Leporo (2015), who analysed how children share their perceptions through spoken interactions with objects and knowledge on display at an exhibit on micro-organisms. Leporo repeatedly identified expressions of pleasure, displeasure and surprise in the children's conversations, which were the third most frequent conversation type among those identified by Leporo during the visit, and the most frequent conversation type during the interview. Cerati (2014), who investigated family visits to a botanical garden exhibition using scientific literacy indicators, showed that the aesthetic/affective indicator was the second most prevalent indicator in the families' speech, supporting the assertion that personal affinities with the natural environment favoured aesthetic/affective experiences over the course of exhibit visits. Freitas et al. (2018) investigated how learning conversations were presented during explainer engagement with students on a visit to an itinerant marine biology museum. This study ranked affective conversations—represented by verbal expressions of students' emotional reactions in the categories of pleasure, displeasure, surprise and intrigue, among others—as the second most frequent conversation type.

These studies demonstrate that emotion plays a crucial role in visitor motivation, engagement and behaviour. However, the way in which emotion affects people of different demographic backgrounds is not yet well understood. To contribute to this understanding, this study focuses on the experiences of families with children on free and mediated visits to a science exhibition. The exhibition fits into the typology of collections on the natural sciences, according to the Brazilian Institute of Museums (Instituto Brasileiro de Museus—Ibram, 2011), and therefore is situated in the broad category of science museums.

1.2 The role of social interaction in children's emotional responses during the visit experience

Museum visits are inherently social activities. Children, especially those of preschool age, do not customarily visit museums alone (Jensen, 1994). On the contrary, they are typically accompanied by adult family members—usually parents and/or other caregivers, such as grandparents, aunts, uncles and so on. Studies have shown that, in these types of groups, parents/caregivers direct children's attention during interactions (Bamberger and Tal, 2007; DeWitt and Storksdieck, 2008; Povis and Crowley, 2015), guiding their behaviour (Crowley and Callanan, 1998; Falk and Dierking, 2000), encouraging reading (Borun et al., 1996; Massarani et al., 2021b) and contributing to learning conversations (Fender and Crowley, 2007; Siegel et al., 2007). Additionally, parents/caregivers have been recognized as emotional support systems for children, facilitating conversations about memories, making personal connections and developing joint understanding of the museum experience (Hein, 1998).

Koron et al. (2022) analysed the ways in which parental instructions moulded children's attention and focus in terms of the emotional and elemental content of paintings (e.g., colours, lines, devices, techniques). The results showed that, in groups in which parents were instructed to ask their children specific questions, the children's focus and attention were more directed, and the children were encouraged to think about the emotional and elemental content in more detail. During interactions without directed guidelines, children chose emotional words less frequently in their descriptions of the works of art observed. These results suggest, according to Koron et al. (2022), that parents/caregivers dampen children's emotional experiences when they provide educational instructions.

Another noteworthy point addresses the role that explainers can play in family interactions with children by facilitating (or not) their emotional engagement during visits. Norris and Tisdale (2013) show that explainers, when well prepared, are capable of engaging visitors with the exhibition content, themes and design elements that have the largest emotional potential. Shaby et al. (2019) also demonstrate that explainers are fundamental in the potentiation of visitors' emotional responses. Similarly, Rodari and Merzagora (2008) argue that explainers are the only truly bidirectionally interactive museum element, as they are able to listen to visitors and respond to their reactions, questions and emotions. This ability allows explainers to adapt their responses and presentations to different audiences and contexts, making their activity dialogical. The explainer team's conversations and behaviour are also considered to influence the cognitive and emotional interactions of visiting groups (Macías-Nestor et al., 2020).

1.3 Theoretical background

Employing the sociocultural perspective found in Vigotsky (1999, 2004), we define mediation as a process of intervention in a relationship by intermediate elements, in which these elements potentially take the form of instruments and/or symbols (e.g., tools, conversations, written texts or images, among other possibilities) and human action (e.g., interaction with others). As such, both interventions function as mediators of emotions. For Vigotsky (2004), emotion is a concomitantly biological and social phenomenon that can be understood as a process that develops and transforms over time. In alignment with this perspective, we define emotion as:

> a complex and pluralistic set of interactions between objective and subjective variables, mediated by neural and hormonal systems, that motivate and organize cognition and action. Moreover, emotions include an aspect of interpretation on the part of the subject in terms of their own lived emotional state, as well as the cognitive evaluations of socio-communicative signs and expressions that, in turn, are capable of motivating behavior. (Scalfi et al., 2022)

Therefore, we envision emotions as possessing additional characteristics beyond the biological (hormones, connections, cerebral structure) in order to study emotions in informal spaces, choosing to include relationships with other individuals and elements, the environment and lived experiences in this operational definition (Fredricks et al., 2004; Pekrun and Linnenbrink-Garcia, 2012; Rowe et al., 2023). Emotions can therefore be defined for the purposes of this study as being based in two fundamental dimensions: valence and arousal (Russell, 1980; Russell and Barrett, 1999). These form a bidimensional 'core affect model', the various combinations and degrees of which result in affective experiences. Here we consider valence (positive and negative experiences) and arousal (level of activation or deactivation; for example, feeling energetic versus feeling sleepy) as emotions that sustain a direct relationship with (a) epistemological aspects of learning and construction of meaning, (b) social relations, and (c) previous experiences and memories. These emotions can be expressed through behaviours (e.g., gestures and/or facial expressions) and through conversations with other individuals and interactions with exhibition elements during the visit experience. This conception allows for a more detailed description of emotions in which any emotion can be assigned to one of four categories: weak positive emotions, strong positive emotions, weak negative emotions or strong negative emotions.

2. Methodology

This study is part of a larger research project being carried out by the National Institute of Public

Communication of Science and Technology (INCT-CPCT), the objective of which is to understand visitor experiences at scientific-cultural spaces in Latin America (Massarani et al., 2019a, 2019b, 2021b). This project was approved by the Joaquim Venâncio Polytechnic School Research Ethics Committee (EPSJV/Fiocruz), case number 466/2012, and under National Health Council/ Ministry of Health operational norm n°001/2013.

In this study, we investigate the emotions experienced by family groups during visits to an exhibit on biodiversity. Two questions guided this investigation: (a) Which emotions can an interactive exhibit stimulate in visiting families? (b) To what extent do parents/caregivers and explainers stimulate children's emotional expressions? Specifically, we examined whether a difference in emotional responses exists between free visits and visits guided by museum explainers.

This study adopted a qualitative approach, is exploratory in character, and can be categorized as a case study. These choices are justified by the fact that case studies allow for the close examination of data in situations in which the separation of a phenomenon of interest from its context is unfeasible (Yin, 2014).

2.1 The 'Forest of the Senses' exhibition

The interactive 'Forest of the Senses' (*Floresta dos Sentidos*) exhibition was developed as a science communication strategy designed for 5–8-year-old children; it focuses on topical biodiversity issues, such as animal trafficking, biopiracy, resource disputes between native and invasive species, and conservation.

The exhibit simulates a 42-square-metre nanoforest in which printed images, objects, textured materials, sound effects and scenic illumination immerse the visitor in the forest environment (Figure 1). At the entrance, there are two scenographies of trees that envelop a touchscreen computer. The exhibition associates the three-dimensional nanoforest with 'gamified' language in which visitors are invited to participate in a search that is completed by obtaining clues. In summary, the visitors could (a) use the computer to obtain instructions in the form of clues, which are delivered by a sloth mascot; (b) enter the forest and complete an activity within the stipulated time of 180 s in order to find a clue; and (c) return to the computer to answer a question and obtain a new clue. To assist in the discovery of clues, visitors receive a kit of curiosity-stimulating, low-cost objects, such as magnifying glasses and flashlights.

This exhibit was produced by the Museum of Life (*Museu da Vida*), which is an interactive museum associated with the Oswaldo Cruz Foundation/ Fiocruz and the Federal University of Rio de Janeiro, and was supported by the Rio de Janeiro Research Foundation Carlos Chagas Filho. At the time of data collection, the exhibit was located at the Science and Life Museum (*Museu Ciência e Vida*; MCV), which was supported by the CECIERJ Foundation (Rio de Janeiro State Centers for Science and Higher Distance Learning; *Centros de Ciência e Ensino Superior a Distância do Estada do Rio de Janeiro*). The MCV is located in downtown Duque de Caxias, in the metropolitan region of the state of Rio de Janeiro; this area was assessed with one of the lowest Human Well-Being Index scores in the country (Observatório de Metrópoles, 2010, 2013). The Duque de Caxias municipality has been considered an area of high economic growth in recent decades, but little social benefit has resulted from this growth when analysed in terms of regional per-capita gross domestic product and/or human development indices (Camaz, 2015).

2.2 Procedures and participants

Data collection occurred from March 2015 to June 2015 on Saturdays, which are the day of the week when the MCV has the highest number of spontaneous visitors. To participate in the study, family groups were required to have at least one adult and at least one child between 5 and 8 years old, with a maximum of six members to allow for adequate multimedia data collection. This age range was aligned with the exhibit's target audience. Families were approached at the exhibit entrance by researchers who explained the study's general objectives and verified whether the groups adhered to the selection criteria.

Point-of-view cameras were deployed for observation and visit recordings (Burris, 2017; Glăveanu

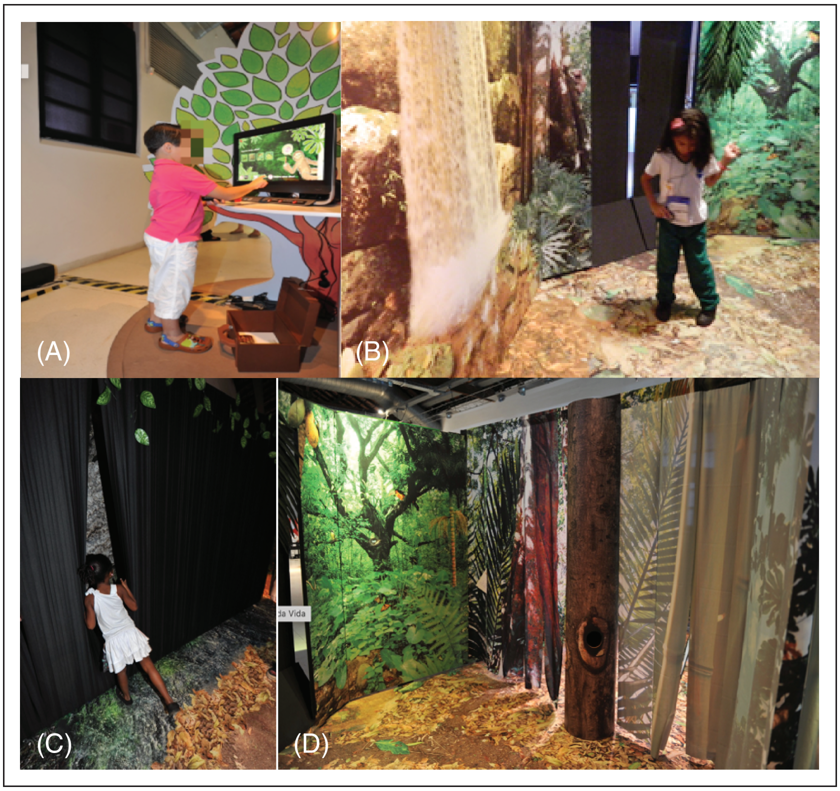

Figure 1. Forest of the Senses. (A) Computer with instructions; (B) and (C) Children performing activities; (D) An area of the 'forest'. Credit: Peter Illiciev.

and Lahlou, 2012; Massarani et al., 2019a, 2019b, 2021b); specifically, a *Looxcie* camera was attached to helmets worn by the participants to document their interactions with the exhibit and other individuals. One limitation of the study was that people knew they were being watched, which may have made them self-aware and led them to modify their behaviour. Glăveanu and Lahlou (2012), Burris (2017) and other previous studies developed by our research group (Massarani et al., 2021a; Scalfi et al., 2022) show that, when recording the visit, some children tend to initially focus their attention on the camera. However, this behaviour is reduced and even disappears during the visit. The 10 participating family groups were composed of 14 adults (10 women and 4 men), 12 children (9 boys and 3 girls) and one teen. Five families were accompanied by exhibit explainers, and five went on free visits.

2.3 Analysis protocol

Previously described procedures were adopted in this study for the analysis of emotional experiences in public scientific-cultural spaces (see Massarani et al., 2022b; Scalfi et al., 2022; Rowe et al., 2023). After collection, audiovisual data was loaded into Dedoose 8.0.23 software, and significant events and conversations were selected using a methodology similar to those proposed in Ash et al. (2007), Rowe and Kisiel (2012), Rowe et al. (2023), Massarani et al. (2022b) and Scalfi et al. (2022). Events were considered significant if they (a) had a clear beginning, middle and end; (b) contained spoken content related to the exhibit; (c) contained externalized conversations among participants or carried out by one speaker with themself or an imagined individual; and (d) contained linguistic emotional descriptors (spoken or gesticulated).

Later, appropriate emotional descriptors were assigned to each event using the proposals found in *Emotion Annotation and Representation Language* (EARL) and *Wheel of Emotion* (Plutchik, 2001) as references; this allowed us to categorize positive and negative emotions (valence) and their degrees of activation or deactivation (arousal). To gain a better understanding of these emotions, the EARL and Wheel of Emotion emotional descriptors employed in this study were grouped into larger categories based on their degree of arousal (activation or deactivation) and valence (positive and negative) proposed by the core affect model (Russell, 1980, 2003; Russell and Barrett, 1999), as shown in Figure 2. The model consists of two bipolar, independent dimensions. The valence dimension is interpreted as reflecting the aspect of emotion that offers information on well-being, for example, by attributing a good or bad meaning to an experience. Arousal, in turn, is the dimension of experience that corresponds to the mobilization or expenditure of energy; that is, it is represented as a continuum from relaxation (e.g., sleep state) to activation (e.g., vigilance) (Russell and Barrett, 1999). In this model, the four diagonally arranged variables are not dimensions in and of themselves, but rather assist in the definition of the quadrants in the core affect model (Russell, 1980). Thus, the proposed structure avoids reducing the complexity of emotions to a small number of basic emotional labels. This approach allowed for clearer visualization of differential prevalence among quadrants during the families' visits.

Then, the sections of the visits containing significant events were transcribed using a detailed transcription code (Kasper and Wagner, 2014; Perakyla and Sorjonen, 2012). The use of the transcription code (Figure 3) contextualized dialogue with temporal and sequential elements, such as superimposed conversations, sentences combined by speakers without pausing, silence, intervals and pauses, as well as intonation, volume, variations in tone or speed, laughter, and breathing, all of which are essential to refining the emotional analysis process.

3. Results and discussion

3.1 Which emotions were evoked during the visits?

In total, 192 min of recordings were produced, of which 18.7% (35 min 59 s) were characterized as significant events. Next, 18 emotional descriptors

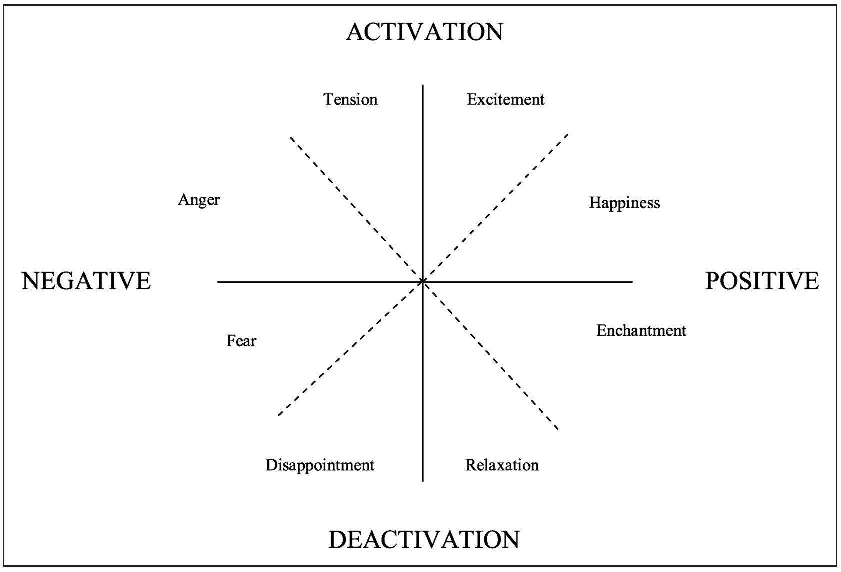

Figure 2. Examples of EARL and Wheel of Emotion descriptors. Source: Author compilation; adapted from Russell (2003).

Adult speaker: ex. A1, A2 / child speaker: C1, C2 / Sloth character (computer): S / Pause (.), (0.4) / audibly: AAfrica / Breath: h / Laughter: [laughter] / superimposed speech: [] / ascending intonation: ? / continuing in tone: , / Speaking more softly: “word” / Laughter in words: (h) / Descending intonation . / Elongation of word elements: : / Continuous speech without pauses: = = / Speaking while smiling: ☺palavra☺ / Speech accompanied by the sound of inhaling/exhaling: Hhhhhh / Text read audibly: “word” / Emphasis on a certain syllable: emphasis

Figure 3. Transcription conventions employed.

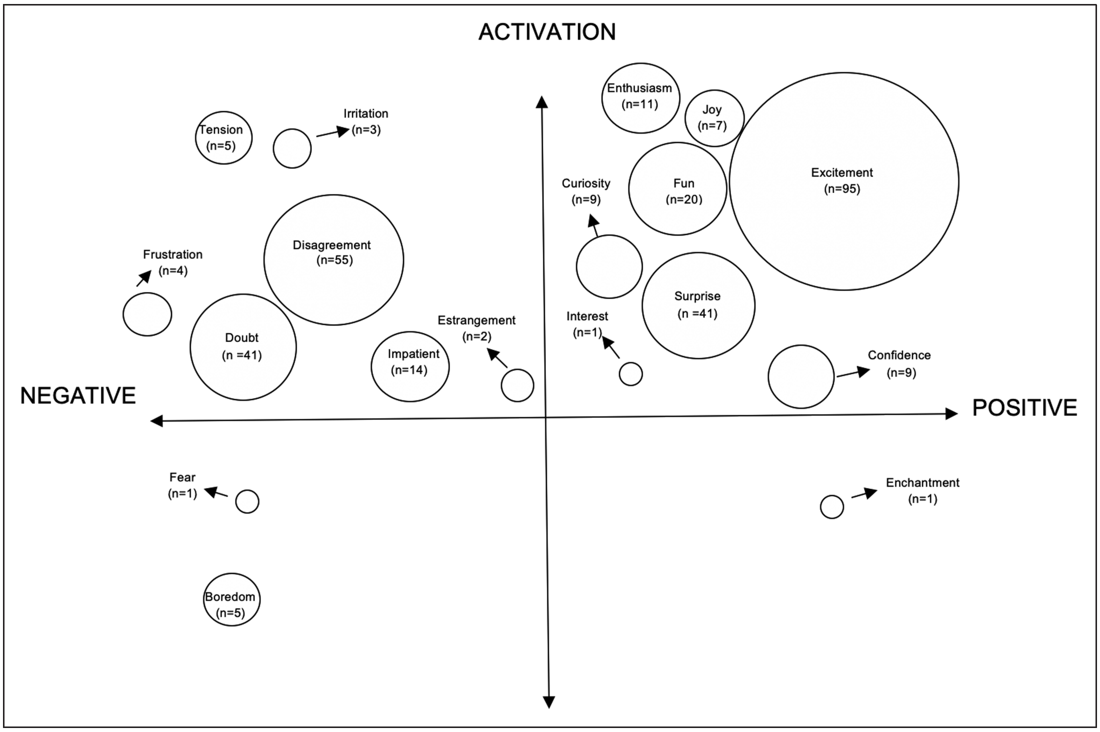

Figure 4. Descriptors identified in this study. Source: Author compilation. Note: Circle size reflects the number of occurrences of each descriptor.

were identified. Visitors’ emotional data were grouped and sorted by quadrant according to the core affect model (Russell, 2003); 193 occurrences of high activation and positive valence were recorded, along with 124 occurrences of high activation and negative valence. Low activation was identified in six occurrences of negative valence and one occurrence of positive valence, as shown in Figure 4.

In Figure 5, free and mediated visits are separated to visualize their potential similarities and differences. Free and mediated visits had similar mean durations of 17 and 16 min, respectively. Eight descriptors in the high activation, positive valence category were identified (curiosity, surprise, fun, excitement, enthusiasm, confidence, interest and joy), with a greater number occurring during mediated visits (n = 113) than free visits (n = 80). Seven high activation, negative valence descriptors were identified (doubt, disagreement, estrangement, frustration, irritation, tension and impatience); these

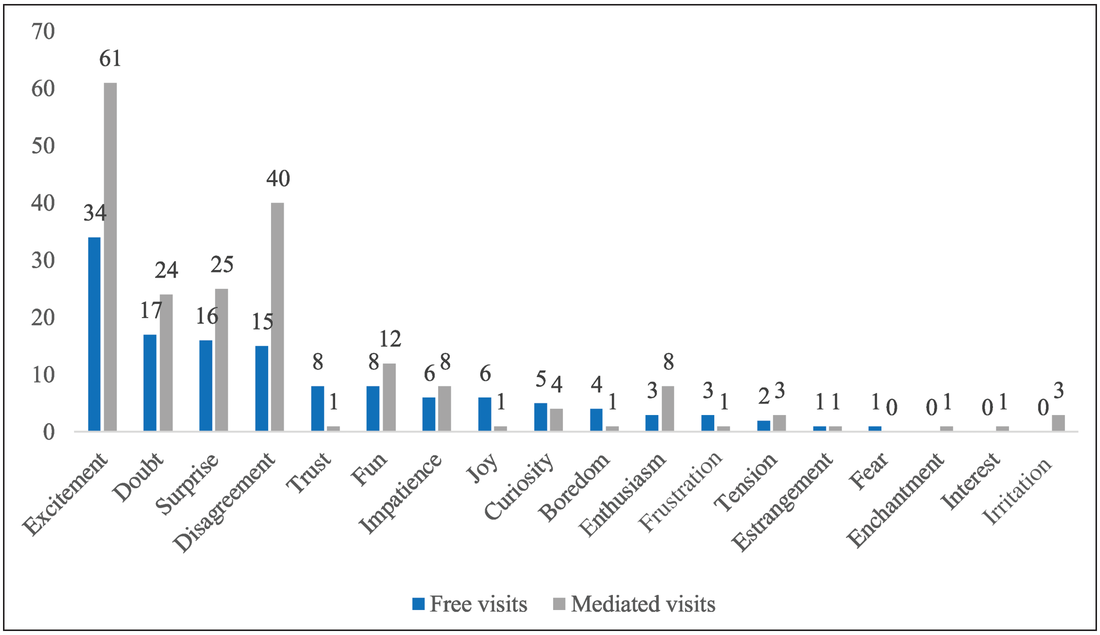

Figure 5. Occurrence of emotions in free versus mediated visits.

also occurred more frequently in mediated visits (n = 80) than in free visits (n = 44). Among the low activation descriptors, two negative valence descriptors were identified (boredom and fear), which occurred more in free visits (n = 5) than in mediated visits (n = 1). One positive valence descriptor (enchantment) occurred only during mediated visits.

The results demonstrate that the exposition offered positive experiences to the families, given that positive valence descriptors were more common. Excitement (n = 61, n = 34) and surprise (n = 25, n = 16) stood out more prominently in mediated than in free visits, respectively. Among the negative valence emotions experienced by the families, disagreement (n = 40, n = 15) and doubt (n = 24, n = 17) were prominent in both mediated and free visits, respectively.

In general, mediated visits garnered more descriptors, indicating that greater stimulation was achieved in the presence of these professionals in terms of the families' interactions and emotional responses, as discussed in Emotions present during children's social interactions with parents/caregivers and explainers. In the following sections, we consider the data generated in this study in the light of academic literature on the subject, beginning with general reflections concerning the emotions presented during the families' interactions with the exhibit, illustrated by example observations.

3.2 Emotions observed during family–exhibit interactions

From an experiential perspective, the presentation of inspiring stimuli to visitors is an inherent part of museum design. Numerous authors maintain that an exhibit's arrangement is a potentially emotion-evoking element for visitors (Legrenzi and Troilo, 2005; Norris and Tisdale, 2013). Similarly, Joy and Sherry (2003) and Wang (2020) highlight the capacity that exhibit atmosphere and arrangement have to engage visitors and elicit reactions that stimulate all five senses. In this study, numerous elements of the investigated exhibit were identified as being fundamental in stimulating visitor emotions, connecting families to their senses, and creating a meaningful experience.

The Forest of the Senses exhibit thematically implements gamified language to incentivize children to interact and have fun, and to engage the family as a whole. Lazaro (2004) explores this topic, arguing that the gaming experiences, in general, include adrenaline rushes, a sense of adventure and mental challenges. The data generated in this study demonstrate that the exhibit was exciting (activation) and evoked high levels of energy and enthusiasm. These emotions were observed during two instances in particular. The first was that of searching for clues in the forest. Searching for and getting close to answers excited children and parents/caregivers, as can be observed in Example 1.

Example 1. The flower clue.

A1: It's close to the anteater! It's close to the anteater! = [EXCITEMENT]
C1: = Run [EXCITEMENT]
C1: = Close to the anteater.
A1: Where's the anteater? Here's the anteater (.) is this here an anteater? [DOUBT]
C1: [inaudible]
A1: [Where is] (0.2) Come on
C1: HERE::! [EXCITEMENT]
A1: Found it?
C1: HERE:: (.0.2) RIGHT HERE = [EXCITEMENT]
A1: = N::o (.) I think this one here's the anteater (.) look (.) it's
Here (.) look (.) isn't it?
A1: The flowers =
C2: = Aaah this bag? [SURPRISE]
A1: The flowers (.) they're these ones [here (.) look?] [DOUBT]
C2: [The::y are] (.) I think so =
A1: = from the bee = [DOUBT]

Note: A = adult, C = child.

In Example 1, the family (G5) is searching for a clue about bees. The father/caregiver guides the children, who rush to find the clue before the allotted time expires. They search for, select and define which flowers are the correct ones to bring back to the computer. This interaction elicited a high degree of excitement from them. The other instance in which excitement was prevalent in the families' emotional responses was during their interactions with the computer; specifically, when they chose the correct answers, as narrated by the sloth mascot (illustrated in Example 2).

Example 2. Fruit texture clue.

S: It's rough like the skin [of a kiwi]
C1: [IT'S ROUGH!] [EXCITEMENT]
A1: It's rough =
E: = It's rough
S: It's [slimy like jelly]
A1: [It's rough (.)
C1: [HERE!] [EXCITEMENT]
S: If you want a hint (.) press here =
C2: = It's this one! [CONFIDENCE]
S: Congratulations (.) you got it right =
C1: =YEA::::[EXCITEMENT; JOY]
S: The fruit's peel is rough
A1: So coo::l [ENTHUSIASM]

Note: S = sloth, C = child, A = adult, E = explainer.

Examples 1 and 2 demonstrate how families had fun during their experiences. Lazaro (2004), who observationally analysed the emotions of 34 adults playing video games (by studying their behaviours and facial expressions), shows that the participants mentioned excitement as one of the positive emotions that they experienced, associating it with moments of adrenaline, novelty and challenge. Although excitement was positive in this context, we observed a collateral effect on family interactions in which members became more concerned with finding the correct answer before the allotted time expired than with reflecting on biodiversity issues.

Surprise was another high activation/positive valence emotion that appeared during the families' experiences. Generally, surprise is an emotion experienced in short durations as a prologue or prelude to other emotions (Ramachandran, 2012). In other words, a person often feels happy or angry shortly after feeling surprised. In this study, surprise was observed as a sudden change associated with positive emotions upon seeing objects or animals in the nanoforest, as illustrated in Example 3.

Example 3. Visiting forest spaces.

A1: This here [inaudible] look, poop! (0.2) [laughter] [SURPRISE; FUN]
C: Look mom! A caterpillar! [SURPRISE; EXCITEMENT]
A1: A caterpillar, baby! [SURPRISE] (0.2) Aaah [Spi::der = [SURPRISE]
A1: [inaudible] this helmet, love]
C: [LOO:::K]= [SURPRISE]
A1: = I don't know why I have it
C: Look here! [SURPRISE; EXCITEMENT]

Note: A = adult, C = child.

As shown in Example 3, upon observing individual elements in the scenario, the mother/caregiver and child demonstrate surprise, followed by excitement or fun. For Valdesolo et al. (2017), an unexpected event may be surprising even when it is easily explainable. This result suggests that the exhibit arrangement, designed with interactivity and immersion in mind, exerted a positive influence on the visitors' capacity to notice and be spontaneously surprised by exhibit elements.

Mazzanti (2021) states that museums employing multisensory and multimedia approaches represent a new experiential trend that promotes dialogue between exhibits and visitors. Mazzanti discusses the importance of designing exhibits with emotional stimuli in mind in order to engage visitors and motivate them to interact with the content while also taking care to allow free visitors to choose their own emotions. This is underscored by Rappolt-Schlichtmann et al.'s (2017) insight that different visitors value different emotions during their experiences. While some prefer strongly positive stimulation and feelings, others prefer to feel challenged, which can involve negative feelings, such as confusion, difficulty and frustration. Therefore, a diverse array of emotional responses must be considered and supported during exhibit design (Mann and Cohen, 2017).

Although the Forest of the Senses exhibit incentivizes a playful approach, its content covers serious and topical biodiversity issues with the intent of engaging families in scientific discussion, particularly in the area of biodiversity. This juxtaposition inherent in the exhibit's design accentuated the duality between positive and negative emotional expressions. Themes such as biopiracy, resource disputes between native and invasive species and concerns regarding wildlife conservation all carry the potential to cause discomfort in visitors. Hayes (2016), for example, argues that such discomfort, evoked by exhibits, allows for a meaningful dialogue to take place and a more grounded, significant understanding of the theme by the visitor. Mann and Cohen (2017) also extol the potential of exhibits that allow visitors to experience complex and negative emotions that lead to reflection. Nonetheless, the significant events analysed in this study, even those that occurred in the presence of explainers, indicate that families engaged only superficially with this type of content, given the presence of only a single example (see Example 11) of a more reflective discussion on the themes addressed.

Another aspect that we observed was that of cognitive effort during the search for clues. Studies have demonstrated that, during play, children practise cognitive skills including language, problem solving, creativity and divergent thinking (Russ, 1988; Vigotsky, 1999). The game in the Forest of the Senses exhibit was fundamentally based on the use of problem-solving skills, favouring the expression of emotions that typically arise during this type of activity. For example, disagreement—a high activation/negative valence emotion characterized by conflicting ideas—was observed during interactions with the sloth at the computer station in which the family was asked to choose between several clues, as illustrated in Example 4.

Example 4. The jackfruit clue.

S: What's the fruit's skin like (.) it's soft like a baby's skin
C1: No = [DISAGREEMENT]
A1: = No = [DISAGREEMENT]
A2: = No [DISAGREEMENT]
S: It's smooth like a piece of paper
C1: [No::] [DISAGREEMENT]
A2: [No::] = [DISAGREEMENT]
A1: = No [DISAGREEMENT]
S: It's rough like kiwi skin
A1: Yea
C1: [Yea]
A2: [Yes]

S: It's slimy like jelly
A1: No:: [DISAGREEMENT]
C1: [No] [DISAGREEMENT]
A2: [No::] [DISAGREEMENT]
S: If you want a hint (.) press here
A2: press the [hint]
S: [Congratulations!] (.) [you got it right (.) the fruit's skin is rough]
A1: [Alri:::ght C1::] [ENTHUSIASM, EXCITEMENT]

Note: S = sloth, C = child, A = adult.

During this interaction, family members were demonstrably motivated to engage in learning opportunities. Russ (1988) states that the divergent thinking ability can play a role in helping children to consider different ideas on how to regulate their emotions. Doubt was another frequently observed emotion during gameplay. Although doubt is classified in the field of psychology as a high activation/negative valence emotion (as it typically causes confusion, resentment and defensiveness), the field of education regards it positively in teaching and learning processes (Schuck and Buchanan, 2012). Dewey (1930), Schön (1995), and Freire and Macedo (1987) are among the authors who consider doubt to be an important process in problem solving, generating new questions and a critical perspective. In the words of Schechter (2004: 172), 'doubt is the necessary spark for the beginning of a learning process'. In Example 5, we present an episode that illustrates the presence of doubt during the families' conversations.

Example 5. Getting to know the forest.

A1: That there's a sloth =
C2: Antea … (.) anteate … =
A1: No = [DISAGREEMENT]
C2: = It's a tapir! [no] [DOUBT]
A1: [It's the one that eats the little ants] (.) what's its name [DOUBT]
C2: AH anteater? [DOUBT]
A1: Anteater (.) right? [DOUBT]
C2: The anteater [inaudible] (.) [it's a] =
C1: [MOM LOOK OVER THERE] [EXCITEMENT]
A1: mhm
C2: It's a tapir mom! [EXCITEMENT]
A1: Let's go there now (.) it's a tapir

Note: A = adult, C = child.

Example 5 illustrates an episode in which the family was still familiarizing itself with the nanoforest space. On viewing one of the animals in the scenario, the family members displayed doubt as to whether it was a tapir (C2) or an anteater (A1). The adult, in this case, recalled the animal's characteristics but not its name, after which the child stated that it was an anteater. This stretch demonstrates the fact that doubt is often erroneously interpreted as a lack of knowledge. Nonetheless, this episode shows that previous experiences—that is, tests of previous knowledge—contribute to learning experiences, demonstrated here by the correct identification of the animal in question.

In summary, doubt and disagreement are not exclusively related to negative experiential aspects. As in the studies performed by Evans et al. (2018), doubt and disagreement are evidence of 'productive struggle'. For Rappolt-Schlichtmann et al. (2017), challenging experiences, reflected in negative emotional expression, can help pave the way for collaboration and the construction of meaning. Although few museums presently encourage negative emotional responses in their visitors, pressure is mounting for museums to recognize and incorporate the fact that exhibit narratives are imbued with meaning, and that emotions, be they positive or negative, must be capitalized on to achieve inspiration, reflection, effective proposals of significant engagement, and lasting impressions (Mann and Cohen, 2017; Watson, 2021).

3.3 Emotions present during children's social interactions with parents/caregivers and explainers

Parent/caregiver interactions with children in this study were characterized by moments of support and stimulation, in which adults incentivized children verbally and through affectionate touches and gestures (for details, see Neves, 2019). Some of these interactions generated positive emotional responses; for example, when a child answered a question correctly, they might receive a kiss from their parents and give them a kiss back. Another example would be a child in the same situation receiving a pat on the back or the hands and responding with a smile. Other parental behaviours evoked more negative responses from children. For example, holding a child's hand to guide them or control them in some way generated frustration and irritation.

At distinct junctures, parents and caregivers attempted to guide and aid children in identifying clues. However, as they themselves were not yet familiar with the environment, the groups on free visits took indirect or confused trajectories through the forest and experienced difficulty in completing the game's tasks, as illustrated in Example 6.

Example 6. The bird egg clue.

A1: Yellow parrot (.) where's the parrot (.) look for it, hey (.) let's look for it (0.1) No (.) not there (.) here it is = [EXCITEMENT; DISAGREEMENT]
C2: = here
A1: See if it's here (.) it's not here (.) oh (.) no, it isn't
C2: It ISN'T (.) Let's get out of here! [EXCITEMENT]
A1: Over here (.) It's counting, you see (.)
C2: THERE! I FOUND IT! [EXCITEMENT]
A1: You did? =
C2: = MHM [EXCITEMENT]
A1: Is it the parrot?
C1: Yea
A1: No (.) it's not a parrot [DISAGREEMENT]
C1: OH NO! (0.3) [INAUDIBLE] [EXCITEMENT]
A1: Where's the parrot?
C1: WHERE'S THE PARRO::T [EXCITEMENT]
A1: (0.5) Geez it's hard [SURPRISE]
C1: [INAUDIBLE]
A1: (0.2) They're here
C2: Look over there C1 (0.3) [inaudible] =
A1: = it's around there
C2: It's around here =
A1: More to the le::ft
C2: To the left? [DOUBT]
A1: Yea (.) left is the other side (.) here, look (.) it's right around here
C1: NO THAT'S A SNAKE! [DISAGREEMENT]
A1: Ye::s (.) but it's around here
C2: It's a goat[1] [laughter] just kidding [FUN]
A1: A snake here look =
C1: AH WHERE IS I::T = [EXCITEMENT; IMPATIENCE]
A1: =PSH relax! Here look (.) le::ft (.) oh ma::n (.) see if it's on the other side (0.3) look at them here! [IMPATIENCE; SURPRISE]
C2: AHA!(.) GOT IT! [EXCITEMENT; ENTHUSIASM]
A1: Now come back
C1: [laughter]
A1: [Press the button there] (.) ma::n! What = [EXCITEMENT]

Note: A = adult, C = child.

In Example 6, both positive emotions (excitement, surprise, enthusiasm, curiosity and fun) and negative emotions (impatience, disagreement and doubt) were identified. The parents/caregivers gave spatial instructions to help their children find the clues, but they were not always in agreement, demonstrating doubt and disagreement. A1 also corrected one of the children's erroneous identifications of an animal: 'A1: Is it the parrot? / C1: Yea. / A1: No (.) it's not a parrot [DISAGREEMENT]'. Such corrections occurred in other instances as well, as can be observed in Example 7, in which a child, unsure as to whether they have found the correct clue, asks, 'Is this it? [DOUBT]', and A1 disagrees, saying, 'No (.) it's not that o:ne (0.3) no: [DISAGREEMENT]'.

Example 7. The toad clue.

C1: Is this it? [DOUBT]
A1: No (.) it's not that o:ne (0.3) no: [DISAGREEMENT].
C1: Let's go then
A1: It's close to the waterfall (.) HERE C1:: (.) See if it's this one here Gi (0.2) there's this one close to the waterfall.
C1: Ok (.) but let's go
A1: Well I'm lost too
S: Next to the waterfall you found the animal you were looking for
A1: Mhm =
S: = what animal was it again?
A1: Let's see: =
S: = It's the parrot
A1: Hm:: [DOUBT]
S: It's the chameleon (.) it's the fish (.) it's the toad
A1: O::h man! (.) [none of them] [SURPRISE; EXCITEMENT]
S: [If you want a hint (.) press here]

A1: Ask for a hint
S: (0.2) The animal is really small
A1: really sma:ll (.) really sma::ll? [DOUBT]
C1: Maybe this one (.) or this one
A1: Choose, then (.) choose that one
S: Congratulations =

Note: A = adult, C = child, S = sloth.

Although the assistance received by the children while identifying clues about animals or plants appeared consistently throughout the conversations, the parents/caregivers were not always well versed on the content in question; nor did they always understand the clues and hints correctly, as Example 7 demonstrates.

Another frequently observed aspect of family visits, as Whitaker (2016) highlights, is that some parents/caregivers are not predisposed to engage with the visit. This was not observed in our study. Even when unfamiliar with the space, the game and/or the content, the parents/caregivers generally made an effort to be involved in the children's experiences by playing together, allowing for varied emotional expressions during these familial interactions.

Regarding the role of explainers in the interactions of children with their families, we observed that the explainers, due to their previous knowledge of clues and familiarity with the space, provided hints, offered assistance in finding clues and oriented the children to help them complete the activities within the time limit, as Example 8 demonstrates.

Example 8. The giraffe clue.

E: [A::h ok] I'm going to give you guys a hint (.) there's a hidden photo here
A1: He:ere?=
E: = it's hanging (.) yea
A1: There's a photo here! Where's C1 (.) [SURPRISE]
E: Move it around (.) move it around
A1: You have to move it C1 (.) where's the photo? Here C1!
(.) Here C1 [EXCITEMENT]
E: Come here see which little animal it is
A1: This one's the intruder (.) this isn't where it belongs.
E: Do you know this little animal's name?
C1: Giraffe [CONFIDENCE]
E: It's a giraffe (.) Do you know where it came from? No? You're gonna find out now (.) let's go
A1: Let's go

Note: E = explainer, A = adult, C = child.

In Example 8, C1 confidently names the animal when prompted after receiving the explainer's help. In general, the explainer had the effect of expanding and amplifying emotional situations, which is also depicted in Example 9, in which the explainer encourages the child to put their hand in a box to feel a sensory clue about a fruit, as well as in Example 10, in which the explainer encourages the child to search for a clue on the ground and incentivizes them to respond correctly, which the child does with enthusiasm.

Example 9. The fruit texture clue.

E: And then you put your little hand in here and you fe: el (.) is that ok? (.) you put [your hand here and you'll feel it]
A1: [But it's (.) it's C1 turn (.) C2 (.) go ahead honey]
C1: Oh my God (.) [I'm afraid (.) can you help me] [FEAR]
A1: [Go ahead (.) hold out your hand] [laughter] [FUN]
E: It's just so you can feel it (.) to see what (.) what the fruit's skin is like
A1: Is there fruit in here? [CURIOSITY; DOUBT]
E: Just feel it
A1: [A:::h]
E: [You'll feel it (.) this fruit's skin has that texture]

Note: E = explainer, A = adult, C = child.

Example 10. The leaf clue.

C1: You're not seeing it =
E: = No, right (0.2) You don't see anything green on the [ground]?
A1: [Leaves] (.) they're leaves
E: A::h = [EXCITEMENT; SURPRISE]
A1: =A::h

E: Where's the little piece that the animal ate? (0.2) look he took a piece didn't he? (.)
Let's go (.) so what does he eat?
A1: He e:ats:
C1: Green leaves [ENTHUSIASM]
E: He eats green leaves (.) well done! [ENTHUSIASM]

Note: E = explainer, A = adult, C = child.

Examples 9 and 10 demonstrate how the explainers facilitated the families' emotional relationship with the exhibit to engage them as much as possible and keep them interacting. To accomplish this, they employed strategies such as the use of open questions, the direction of the children's attention, and the stimulation of their curiosity. Some studies (see Kamolpattana et al., 2015; Massarani et al., 2022a; Pattison and Dierking, 2012; Shaby et al., 2019) show that explainers create the space for deeper science-related discussions. In this study, there was only one example of a significant event that qualified as a deeper discussion of the exhibit's themes. This discussion was about the conservation of a certain toad species (Example 11).

Example 11. The toad clue.

C2: It's a toad isn't it mom}
A1: It is (.) Let's see, right
S: Congratulations (.) you got it right (.) [it's the toad]
A1: [Ah see! That's what I'm saying] (.) Me here without my glasses I only saw the chameleon [laughter] [EXCITEMENT; FUN]
S: Congratulations guardians of the forest =
C1: =Congratulations! [ENTHUSIASM]
S: [You [found the animal and now you know which animal to protect (.) but the mission in the forest isn't over yet (.) many animals and plants are in the same situation as the toad (.) and it is your duty [inaudible] to them (.) stay alert for dangers around the forest (.) and have a good adventure]
E: [Ok so (.) the toad (.) it's an animal that is in danger right [inaudible] because
It's hunted (.) because it produces a substance that's used for (inaudible) kind of =
A1: = [hm:] = [SURPRISE]
E: = [It's so you can learn right] =
A1: =[That was why when they made the Metropolitan Arc] =
E: = [Hmm::] = [SURPRISE]
A1: = [Tha::t's why (.) now I get it] They were making the Metropolitan Arc (.) that one that goes to Itaguaí = [SURPRISE;INTEREST]
E: =Right
A1: But they went into a reserve that had a lot of toads =
E: = Mhm
A1: And people were joking about how ['construction was halted because of a toad!']
E: [Yes (.) ri::ght it makes all the difference]
A1: I didn't know! = [SURPRISE]

Note: C = child, A = adult, S = sloth, E = explainer.

In Example 11, the explainer directs and applies information about a species and its conservation; this information became meaningful to the mother, who had previous knowledge regarding the interruption of an important infrastructure project in Rio de Janeiro due to the animal in question, though she did not know exactly why. During the dialogue, the mother surprisedly states: 'A1: I didn't know! = [SURPRISE]'. In summary, these results demonstrate that explainers stimulate the visiting families to interact with the exhibit by employing stimulating phrases, interesting facts and assistance, consequently creating emotional stimuli as well as supporting learning experiences.

Shaby et al. (2019) analysed the potential of explainers to stimulate visitors' emotions during a visit to science museums, investigating the interactions between students, museum explainers and the physical exhibit environment. Their results show that explainers used emotional engagement—understood as interest, curiosity, feelings, guidance, and positive and negative affects inherent in the learning process—to engage the students with the exhibit in numerous instances. The results generated in the present study are similar to those observed by Shaby et al. (2019).

3.4 Contrasting roles: Parents/caregivers and mediators, and children's emotional responses

Comparing how parents/caregivers and explainers interacted with children and stimulated their emotional responses indicates that both behaviours created pleasurable and fun moments, and provided assistance in clue discovery. During this process, positive emotions, such as excitement, surprise and fun, are notably more prevalently expressed. Although the roles of both types of adults (parents/caregivers and explainers) involve supporting the children, we suggest that this constant facilitation may also have inhibited moments of frustration or irritation when people were faced with incorrect answers or failure to find a clue.

Adults' specific activities while interacting with the children, which incidentally implied affective attachments, elicited greater cooperation, as parents actively engaged in play and affectionately incentivized their children with words and gestures. These behaviours were associated with moments of confidence (n = 8) and joy (n = 6), and occurred more frequently on free visits.

Family intimacy also produced a greater incidence of disagreements over child behaviour, specifically in terms of moral conduct. For example, some parents/caregivers showed feelings of irritation or impatience when children did not do what they had previously agreed to do, or when they did not do what their parents/caregivers requested, as demonstrated in Example 12.

Example 12. The lion tamarin clue.

A1: = That's not it (.) hold on it's (.) it's close to the =
C1: = [IT'S THIS ONE!] [Excitement]
A1: No it's not (.) it's close to a person with a hat [DISAGREEMENT]
C2: Hat (.) where is i::t [DOUBT, EXCITEMENT]
A1: C2 (.) Geez man I already asked you (.) stay close to me (.) otherwise we're leaving [IRRITATION]
C1: [inaudible] the hat here

Note: A = adult, C = child.

Example 12 demonstrates how emotions shape people's actions. In the phrase 'A1: C2 (.) Geez man I already asked you (.) stay close to me (.) otherwise we're leaving [IRRITATION]', the mother warns her son, in an irritated tone, about what might happen if he doesn't respect their agreement. For Rowe et al. (2023), specific social institutions (such as scientific, educational or familial institutions) and culture shape 'what' is felt and 'how' during interpersonal interactions. Similarly, Illouz (2007: 3) observes that emotion reveals as much 'about the self as it does about the relationship with others in a cultural context'. In Example 12, demonstrating alignment with this argument, the mother elicits a high activation/negative valence feeling (irritation) from her child that may or may not result in a behavioural change on the child's part. Emotions are indeed, as argued by Morton (2013), central factors in individuals' moral lives.

The explainer can be conceptualized as fulfilling the role of a catalyst, assisting families in effectively explaining information that otherwise would have remained inaccessible to the children. As previously discussed in Emotions present during children's social interactions with parents/caregivers and explainers, the explainers' support elicited both positive emotional responses (such as excitement and surprise) and negative emotional responses (such as disagreement and doubt) in the children. The experience of tension represents a noteworthy divergence between parent/caregiver and explainer interactions with children. While tension was typically associated with conflict during familial interactions, it was associated with fun or excitement during interactions with explainers upon encountering the unknown, as shown in Example 13.

Example 13. The animal body sensory clue.

E: Close to the little hole there's a cica:da (.) A:::h it's there, ok (.) you're gonna put your little hand in there and you'll fe:el it [SURPRISE]
C1: Is it re::al? [EXCITEMENT; TENSION]
E: No:: (.) [it's just for you to feel here] (.) I'll put it here so you can see
A2: [It's make-believe]
E: There's no little animal there at a::ll (.) It's just for you to feel what it's like =
A1: =Yea:: like it were a = Right
C1: It's a ru::g! = [ENTHUSIASM; SURPRISE]
E: =a::h how is it now? (.) does it feel like a rug?
C1: Mhm
E: So this little animal (.) that we don't know who it is yet (.) it's like this (.) it's nice and soft

Note: E = explainer, C = child, A = adult.

In Example 13, the explainer incentivizes the children to affectively engage with the activity, think logically about the clue object, and play. Using the

Vigotskyan perspective as a framework, Colliver and Veraska (2021) demonstrate that mediators contribute to the intellectual comprehension of the emotions of children at play. They suggest that explainers have the duty of helping children identify and experience their emotions in the context of cultural learning and thus facilitate their learning about culture and the value of emotions. Our study presents corroborating observations, supporting the fundamental role that explainers play in facilitating children's construction of their own emotions.

It is also noteworthy that explainer activity can be used to guide family groups to answer questions correctly, restricting the group's ability to find clues and construct solutions themselves. Another important aspect is that, as Massarani et al. (2022a) indicate, there is a tendency for explainers to focus their attention on the children in the group, excluding adults from the museum experience in certain respects. As it happens, the explainer in this study also directed the most of their speech towards the children, often leaving adults in a passive role during their interactions.

4. Final considerations

Studies on emotions in scientific and cultural spaces offer an opportunity to construct more meaningful interpretations of visitor experiences. In this study, the objective was to understand which emotions the Forest of the Senses interactive exhibition stimulated in family groups and to what extent the parents/caregivers and museum explainers elicited these emotional responses.

Our analysis indicates that the exhibit's structure as a 'treasure hunt' game, as well as the design of the space, allowed the visitors to become immersed in a representation of forest spaces that stimulated a variety of emotional responses and incentivized families to participate actively. This suggests that the sensory dimension of the exposition was directly related to the emotional responses that occurred during visitor–exhibit interactions. Therefore, it is important to consider that the objectives, narratives and design of an exhibit affect the ways in which visitors respond emotionally. Different types of expository projects offer distinct emotional experiences to their visitors. Moreover, knowledge of visitors' principal emotional experiences can be used to orient exhibit design to meet visitor expectations and support significant visitor engagement.

Among the emotions observed during the family visits analysed in this study, those denoted as high activation/positive valence were the most prominent, followed by high activation/negative valence. These results suggest that, although the extant literature has documented that positive emotions are more strongly associated with museum visits, analysis of visitor satisfaction studies generally indicates that both positive and negative valence emotions experienced during the visit play an important role in the understanding of visitor engagement and learning experiences. In particular, results related to relatively high levels of negative emotional experiences reinforce the importance of understanding that negative emotional expression is a legitimate and valuable form of learning for families and an opportunity for building emotional regulation skills.

Exhibits that deal with topical, quotidian themes that are covered in the media are of redoubled importance to socially fragile locales, such as the community investigated in this study, due to their significant potential to attract local populations to museums and promote scientific culture—a process permeated by a set of emotions that occasion the visit itself and emerge during it.

This study generated supporting evidence regarding how parents/caregivers and explainers contribute to children's emotional responses during social interaction. The analysis of the mediated visits, for example, revealed that museum explainers employ strategies to guide the visit experience and, as a result, elicit emotional responses from children and their families. Consequently, we confirm that the presence of educators on such visits attributes an additional dimension to emotions in which they become not only feelings but also an educational tool employed to guide the visit, stimulate curiosity and engage families on scientific issues (in this case, Brazilian biodiversity). Our observations with respect to parents/caregivers support the assertion that they experience the emotions elicited by the game together with their children; therefore, their role is better characterized as a chaperone of child conduct than as one of gameplay orientation.

The emotional experiences of museum visitors are still far from completely understood. The identification of trends in these complex phenomena and the contextual factors associated with them are fundamental for the creation of efficient and resonant learning experiences for all of the diverse audiences who visit museums. More studies are necessary to deepen and extend the discussions on emotions in museums, as the focus on visitors is the predominant lens for studies in this area. Understanding how these emotions are expressed and how exhibits direct visitors to feel certain things are lines of investigation that will generate important contributions for the design of more meaningful and inclusive visit experiences.

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Note

1. In Portuguese, the word for goat ('cabra') differs in only one letter from the word for snake ('cobra'); hence C2's play on words.

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From affordances to cultural affordances: An analytic framework for tracing the dynamic interaction among technology, people and culture

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Abstract

This paper proposes a novel framework called 'cultural affordances' to examine the dynamic interplay among technology, users and culture, as multilevel and multidirectional interactive networks. The framework includes three dimensions. 1) Cultural affordances of technology describe what technology can offer users and culture in terms of behavioural or cultural changes. 2) Cultural affordances of users describe what users can offer other users, technology and culture in terms of behavioural, technological or cultural changes. 3) Affordances of the cultural describe what culture can offer users and technology in terms of the design and use of technology as well as related changes. To establish the need for a culturally oriented extension to affordance theory, we first revisit Gibson's original definition of affordances of the environment and discuss its significance and limitations, including the need to understand the interplay between technology and users in the digital era. We contend that culture, as an assemblage of all relations and practices, should be included as an indispensable part of affordance theory, and we provide a detailed explanation of the novel, three-dimensional framework of cultural affordances. We then apply the framework to three prior empirical studies and one ongoing study to demonstrate how the framework can be used as an analytic tool to deepen our understanding of the multilevel and multidirectional interplay among technology, users and culture, and we identify related changes, focusing on WeChat. We also discuss how the framework can provide directions for designing new technologies to improve collaborations among users, between users and designers, and between an online platform and the offline world.

Keywords
WeChat, social media, affordances, cultural affordances, cultural studies

1. Introduction

The notion of affordances has been widely used to understand and design for the interaction between

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technology and users (Bucher and Helmond, 2017; Davis and Chouinard, 2016; Gaver, 1992; Hartson, 2003; Kaptelinin and Nardi, 2012; Norman, 2013). American psychologist James Gibson first introduced the concept: 'The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill' (Gibson, 1986: 127). Later, scholars from various fields, such as design, human–computer interaction, computer-supported cooperative work, computer-mediated communication, information and communication technologies (ICTs), and social media studies, have conceptualized various kinds of affordances (Bareither and Bareither, 2019; boyd, 2010; Costa, 2018; Nagy and Neff, 2015). Some of these conceptualizations have demonstrated an inclination towards technological determinism (such as physical or technological affordances), some have shown a tendency towards social constructionism (such as social normative or imagined affordances), and others have endeavoured to integrate the technological and the social by stressing the context (such as affordances-in-practice or *ad hoc* affordances). Significantly, these studies have either excluded or downplayed the cultural aspect while developing affordance theory, and have sometimes limited agency to human actors and maintained a static view of culture. These limitations constrain us from comprehensively understanding the interplay between technology and users in the digital era.

To further develop the theory of affordances and improve its application in empirical research, it is essential to include the cultural aspect as an indispensable part. In the rest of this paper, we first examine the significance and limitations of Gibson's affordances of the environment and establish that this cultural aspect is excluded from his theory. Then, we briefly review the development of affordance theory in ICT and social media studies, identifying the remaining limitations in addressing culture. To overcome these limitations, we define culture as the sum of all relations and practices that are constantly changing and evolving in a particular sociohistorical context, and we offer a detailed explanation of our novel, three-dimensional framework of cultural affordances. We then demonstrate how this framework can be applied in empirical studies as an analytical tool to investigate the interplay among technology, users and culture; to identify the behavioural, technological and cultural changes that are derived from within that interplay; and to provide directions for designing new technologies that permit better collaborations among users, between users and designers, and between an online platform and the offline world. Finally, we conclude with an invitation for further empirical research on cultural affordances in related fields.

2. Revisiting Gibson's affordances of the environment

2.1 Significance

Gibson's notion of the affordances of the environment is significant in at least two ways. First, it aims to transcend subjective–objective dichotomous views by perceiving animals and their situated environments as complementary through possible relationships. Gibson (1986) contended that an absolute boundary between the objective and the subjective is a fallacious notion. Instead of examining separately the properties of objects and subjects, one should focus on affordances or the relational properties that emerge from the interaction between animals and their environments (Gibson, 1986; Heft, 1989). Second, the concept endeavours to free people from the bondage of second-hand or mediated knowledge, such as 'images and writing' or 'past experiences and memory', that could limit people's ways of thinking and doing (Gibson, 1986: 42, 254).

2.2 Limitations

Despite its significance, Gibson's notion of the affordances of the environment has limitations, as it excludes the agency of the environment and culture. Specifically, Gibson (1986: 135) contended that humans and animals can offer 'the richest and most elaborate affordances of the environment' to other humans and animals. However, he refrained from mentioning that humans and animals could offer something to the environment in return. That omission might have been due to his restricted view of the environment as stable and lacking agency—a view that is untenable in the age of digital environments. It is questionable to state that a technological platform (such as a social networking site) as a particular environment can offer affordances to users, whereas users cannot offer anything back. In contrast, Despret (2016) maintained that the natural environment has its own agency. Kaptelinin and Nardi (2006) extended the scope of agency from human actors to non-human entities (such as bears, fax machines, or the World Trade Organization). Neff et al. (2012: 301) argued that technology can make social changes and it has 'technical agency'.

Second, Gibson's description of the affordances of the environment tended to prioritize the natural world and deprioritize the cultural world. For Gibson (1986), the ecological approach of perceiving the affordances of an object starts from the natural environment. This understanding fails when applied to an object designed and utilized in the cultural environment. For example, Heft (1989) stated that the affordances of an object are applicable in the human world and they are sociocultural in origin. Costall (1995) stated that the natural environment we confront nowadays is already humanized.

Third, Gibson (1986) suggested that affordances are derived from knowledge received first-hand (such as direct experience) rather than that attained second-hand (such as stories, images or texts). According to Gibson, the latter is less reliable since it can be factual or fictional. Nonetheless, this prioritization faces an immediate challenge, as the two knowledge types are not always separable. Moreover, second-hand knowledge not only facilitates but also affects how we experience first-hand knowledge (Miyamoto et al., 2006; Zheng and Yu, 2016).

Fourth, Gibson's explanation of the concept of invariance was incomplete. At the end of *The Ecological Approach to Visual Perception*, Gibson (1986: 310–311) attempted to describe what invariants are and offered examples, including invariants that underlie changes in the optic array and invariants for perceiving the surfaces, their relative layouts and reflectances, saying, 'they are not yet known, but they almost certainly involve ratios of intensity and color among part of the array … The study of invariants is just beginning'. Nonetheless, no clear definition of invariants was given. Furthermore, Gibson (1986: 13) stated that permanence is relative: 'the "permanent objects" of the world … are actually only objects that persist for a very long time'. If invariants are relatively persistent, then enduring cultural values and practices should also be considered invariants in the cultural environment, and they can be experienced through direct activities as well as through words and images.

To overcome these limitations, our understanding of environment and agency should be extended in at least four ways. First, the environment, including the natural and the cultural environment, is neither static nor nonresponsive. Instead, it has agency and can respond to what is offered. Second, having agency means having the capacity to act upon oneself regardless of the type of actors (such as human or technological actors). Third, it is problematic to understand environmental agency by simply replicating the ways we understand human agency. Fourth, agency is intrinsically related to culture. In this paper, we recognize the agency of both human and nonhuman actors (Latour, 2005). Such agencies have different characteristics, and they cannot be understood using the same standards (Rose et al., 2005). What users can offer to a technological platform is affected by specific cultural values and practices, and the realization of one's own agency is directed culturally (Campbell, 2009). The agency of nonhuman actors also has a cultural aspect since it involves designers' values, and a platform can encourage or discourage specific behaviours.

3. Developing affordance theory: Divergence and convergence

The subsequent development of affordance theory in ICT and social media studies can be categorized into three approaches: platform-centered, user-centered and context-centered approaches. However, these approaches provide little explanation for the cultural dynamics at play in the interaction between technology and users. These dynamics may involve: 1) the cultural aspect that is embedded in a technological platform; 2) the differences in users' values, practices and sociocultural norms compared to the cultural values of the platform and its designers; and 3) the multidirectional and multilevel interplay among technology, users and culture.

3.1 Platform-centred affordances

Prior studies of affordances in ICTs and social media studies have demonstrated a tendency to centralize technological properties and focus on how they affect users and their related social interactions. For example, Gaver (1991) defined technological affordances as an object's independent, inherent and physical properties that are compatible with a user for possible action. Gaver excluded culture as an integral factor when developing affordances theory. boyd (2010) provided an insightful analysis of the structural affordances of networked technology for networked publics, including persistence, replicability, scalability and searchability. This understanding of affordances focuses on the properties of social network sites or a technological platform (boyd and Ellison, 2007; Marwick and boyd, 2014), treats affordances as universal, and does not highlight the unique design of a technological platform or what users can offer in return as a different type of affordance. Later, boyd (2013) acknowledged culture primarily as a contextual factor, documenting, for example, how individuals from distinct socioeconomic classes prefer different social-networking environments. This analysis can be expanded to include culture in the network of agency both as an acting agent and as offering affordances for other human and technological agents.

Technology has a cultural aspect, as it can request, demand, encourage, discourage, allow and refuse (Davis and Chouinard, 2016). Meanwhile, users do not use ICTs and social media only in various ways but also return affordances to affect the design of a technological platform. For example, the student backlash against Facebook's News Feed in 2006 forced the platform to modify the function to allow users to control their own privacy settings (Sanchez, 2009; Schmidt, 2006). Bareither and Bareither (2019: 15) proposed the notion of the emotional affordances of digital media as 'its capacities to enable, prompt and restrict the enactment of particular emotional experiences unfolding in between the media technology and an actor's practical sense for its user'. Again, it is problematic to assume that digital media can provoke users' emotional reactions unanimously, since users' personalities and sociocultural contexts vary.

3.2 User/social-centred affordances

Some scholars have placed users' needs at the centre of their discourse and stated that the affordances of a group of people can encourage specific ways of using ICTs while discouraging others. Nonetheless, that perspective falls short of discussing how users' needs are affected by the cultural environment in which they live. To elaborate, Dinsmore (2019) introduced the concept of contested affordances, describing how smartphone affordances become embedded in power relationships between teachers and students to show that social relationships shape technological affordances. In this research, technological affordances have been contested with the affordances of social norms, and, sometimes, the latter constrain the former. Dinsmore's study is inspiring since it described affordances in a multidirectional manner. However, it failed to discuss the cultural aspect of smartphones or the cultural values and practices of students and teachers. Similarly, McVeigh-Schultz and Baym (2015) proposed the notion of vernacular affordances, arguing that users can invent new practices and rules unanticipated by designers. Nonetheless, the culture that affects users' practices remains undiscussed. Lo Presti (2020) noted that people's offerings to each other with or without technology are socionormative affordances.

These approaches concentrate on how users and social norms affect ways of using technologies in particular contexts. Nonetheless, these understandings overlook the role of culture in terms of the use and design of a technological platform.

3.3 Context-centred affordances: Integrating the technological and the social

Several scholars have developed versions of affordance theory to integrate technological features and social aspects by focusing on contexts and practices. For example, Van Osch and Mendelson (2011) suggested a typology of affordances to uncover the complex interactions among developers, users and an artefact. In their typology, designed affordances are perceived and recognized by designers, improvised affordances are recognized and improvised upon by users, and emergent affordances are neither perceived by designers nor recognized by users but can still influence the interactions between artefacts and actors. Arguably, designers and users are not always situated in the same culture, leading to different understandings of an artefact. Similarly, Costa (2018: 3651) proposed the notion of affordances-in-practice as 'the enactment of platform properties by specific users within social and cultural contexts'. Additionally, Costa (2018) claimed that structural affordances (boyd, 2010) and the phenomenon of context collapse (Marwick and boyd, 2011) are not found in some non-Western contexts. These two notions disapprove of the prevailing understanding of affordances as stable and invariant as well as the dominant, platform-centred approach. Instead, the notions include sociocultural aspects as part of the concept of affordances and recognize the agency of human actors. However, it is problematic to understand culture as conventional and stable.

In summary, a unidimensional or unidirectional approach of understanding affordances is insufficient as technology and culture continue to evolve, and access to computers, the internet and mobile phones increases. Meanwhile, it is unsatisfactory to simply involve all technological, social and cultural aspects in the theory of affordances. There is a lack of an analytical tool that allows researchers, practitioners and designers to understand how technology affects people and culture, how culture affects the use and design of technological platforms, and how users' ways of perceiving and using technologies affect their design and the culture within which they are designed and used.

4. Cultural affordances revisited

4.1 Prior studies

Scholars from design, human–computer interaction and communication studies have introduced the notion of cultural affordances on their own terms. For example, Turner and Turner (2002) stated that the notion of cultural affordances is a set of unique attributes developed from a group's daily practices, and users perceive cultural affordances based on objectified and historically developed meanings and values. Costall (2012) argued that affordances in general differ from canonical affordances, which are the particular, normative meanings of an object. For example, the canonical affordance of a chair is that it is for sitting, yet people can use a chair in multiple ways (Costall and Richards, 2013; Cranz, 2000). Similarly, Solymosi (2013: 594) described cultural affordances as 'symbols, words, [and] images'. These notions of cultural affordances are inspirational but insufficient because they tend towards cultural constructionism and apply a restricted view of culture as stabilized and representational. In addition, these perceptions imply a culture–technology dichotomy. Hence, the discussion about the interaction among technology, users and culture remains incomplete.

4.2 Cultural studies perspective: A novel approach

Despite the absence of a settled definition, culture is widely understood in the field of cultural studies as an assemblage of all relations and practices that are constantly changing and evolving (Barker and Jane, 2016; Hall, 1980, 1986; Slack and Wise, 2002; Williams, 2011; Willis and Willis, 1981). Williams (2011: 93) contended that culture is 'ordinary' and a 'whole way of life'. Hall (1980, 1986) described culture as the sum of all conventional and unconventional social practices and their interrelations that are grounded in a particular sociohistorical context. Slack and Wise (2005: 126) proposed that 'culture is a complex set of connections or relations'. This definition is similar to actor–network theory's contention that the social is 'a type of connection between things' (Latour, 2005: 5). Scholars from cultural studies understand culture as having the characteristics of inclusiveness, ordinariness, contingency, network, relation, practice and process.

Rather than perceiving technology as an objective and independent entity, cultural studies researchers see technology as 'a relationship' and 'a connection' (Williams, 1981: 227), 'forms of life' (Winner, 2010: 3), 'an assemblage' (Wise, 1997: 137), 'a cultural form' (Williams, 2003: 86), and 'an articulation'; that is, technology is a form of connecting different elements as a whole (Slack and Wise, 2002: 488). These descriptions show that the nature of technology is about relation, connection and process, and they remind us of Kling's (2000: 247) claim in a distinct body of literature that information technologies are 'socio-technical networks'. Thus, the relationship between culture and technology is convergent rather than divergent. Technology is 'integral to culture' and 'integrally connected to the context within which it emerges, is developed and used' (Slack and Wise, 2005: 5, 26). Moreover, technology has a cultural aspect as it can request, demand, encourage, discourage, allow and refuse (Davis and Chouinard, 2016). Thus, cultural studies provide a novel perspective to study affordances. The field overcomes the culture–technology binary view and integrates the two.

Having clarified our understanding of culture, technology and their relationship, we offer a novel framework of cultural affordances that aims to integrate the cultural and the technological.

4.3 A novel framework of cultural affordances

To develop the theory of affordances further, we propose a novel framework of cultural affordances that enables us to investigate the interaction among technology, users and culture from multiple perspectives at multiple levels. The framework includes three dimensions.

1. *Cultural affordances of technology* describe what technology as a particular environment can offer to users and culture, and such affordances may or may not affect users' ways of thinking and doing as well as culture. For example, a technological platform can encourage, strengthen, discourage or refuse certain behaviours or cultures. Cultural affordances of technology recognize the agency of users and culture in engaging in these possibilities.
2. *Cultural affordances of users* describe what users as a particular environment can offer to other users, technology and culture. Such offerings may or may not affect other users' ways of doing and thinking, technological platform designs, or culture. Cultural affordances of users acknowledge the agency of other users, technology and culture in choosing how to respond to users' actions. For example, posting, liking or commenting on a social networking site offers affordances to other users, technology or culture. Users' actions do not have to be significant. Even the simplest actions, such as clicking, can be aggregated and re-presented by technology to offer potential actions to other users. Such actions reveal users' personal values that are either in line with cultural norms or not and can affect cultural and technological changes. When these aggregations and re-presentations form a cycle, it increases the chance of community formation and value formation within the community (Joseph et al., 2007). Thus, cultural affordances of users can be utilized to examine the process of emerging and forming communities, contextual meanings, or new norms.
3. *Affordances of the cultural* describe what culture as a particular environment can offer to users and technological platforms, and such offerings may or may not affect the ways technologies are designed and used. Affordances of the cultural recognize the agency of technology and users in responding to culture. They explore the invisible and ambient culture. Like a fish starting to notice that it lives in water, they pay attention to what and how collective ways of doing and thinking that we take for granted can affect our ways of using and designing technologies. Such affordances also reveal the unnoticed and the subconsciousness or unconsciousness and identify looming norms and the unknown.

This framework aims to investigate the kinds of affordances that are offered by technology, users and culture and to identify the behavioural, cultural and technological changes derived from their interplay. The cultural affordances of technology examine how technology can affect users' ways of doing and thinking as well as their culture. The cultural affordances of users investigate how users can affect other users, technology and culture. The affordances of the cultural explore how culture can affect the use and design of a technological form. This framework enables us to examine further the power dynamics of an interactive network that involves various actors, including human and nonhuman actors. The agencies associated with the different types of cultural affordances can be divided into three kinds: those associated with technology, with users, and with culture. The three types of agencies are related but not symmetrical or determinate. Trying to use the same standard to understand each of them would be unsatisfactory and implausible.

This new framework of cultural affordances is assembling and revealing. It avoids either cultural or technological hegemony. There is never one overarching cultural affordance: it is always plural and open to integrating more dimensions (such as cultural affordances of designers). The three dimensions can be contradictory and sometimes competing. The framework aims to bridge technology and culture, online and offline worlds, and users and platforms as well as to reveal the limitations of technology and culture.

The following discussion uses three prior empirical studies and one ongoing study as examples to demonstrate why investigating the interplay among technology, users and culture from one direction or at one level is insufficient. The results show why we need this novel framework of cultural affordances to examine the complex and dynamic interplay of the three at different levels as well as from multiple directions simultaneously. We also demonstrate how this novel framework can identify behavioural, cultural and technological changes and provide directions for designing new technologies.

5. Applying the framework of cultural affordances

To illustrate our theory, we apply the framework of cultural affordances to three empirical studies and an ongoing study of WeChat as a digital technology having rich relationships with its users and Chinese culture. The focus on WeChat addresses the lack of research on social media affordances in non-Western contexts (Costa, 2018). The three prior empirical studies were chosen purposefully since they each examined the interplay of WeChat, users and Chinese culture from the perspective of either a technological platform, its users, or a culture. Taken alone, each perspective is insufficient to demonstrate the complex and dynamic interplay among the three. By applying the framework to the three prior studies and comparing them with an ongoing study, we demonstrate how those studies can be further developed to obtain a comprehensive understanding of the interplay among WeChat, users and Chinese culture; identify behavioural, cultural and technological changes that are derived from the process; and provide directions for designing new technologies.

5.1 Cultural affordances of technology

Holmes et al. (2015) examined WeChat as a case study during the 2014 Chinese Lunar New Year and argued that WeChat supports traditional Chinese values. Specifically, major attributes of Chinese culture, such as filial piety, social connections (*guanxi*), reciprocal favours (*renqing*) and face (*mianzi*), are demonstrated and practised on WeChat through digital red packets (Holmes et al., 2015). Traditionally, during the Chinese Lunar New Year, elders put money in red packets, give them to children and unmarried family members, and wish the recipients another healthy and safe year (Wirth, 2017). In contemporary China, people have extended this ritual gifting practice to other special occasions, such as weddings, birthdays, household moves and anniversaries (Mack, 2019). WeChat launched digital red packets immediately before the 2014 Chinese Lunar New Year. The feature attracted more than 8 million users, and the payments made totalled approximately 400 million *yuan* (85 million US dollars) via 40 million messages within nine days (Holmes et al., 2015). Consequently, millions of new users signed up for WeChat and voluntarily subscribed to the WeChat payment system by linking it with their bank accounts (Yin, 2015; Xu, 2021).

Holmes et al.'s study can be further developed by applying our proposed framework of cultural affordances. Indeed, WeChat's digital red packets enable users to practise the cultural tradition of giving red packets more easily in the absence of spatiotemporal constraints (Xu, 2021). The digital feature reveals a cultural aspect of the design and is a cultural affordance of WeChat. However, digital red packets have their own cultural values and practices embedded in the platform. The packets have a maximum amount of 200 *yuan* (approximately 29.85 US dollars) (Custer, 2016). In the offline world, the amount of money in a red packet depends on the relationship between the giver and the receiver, and it generally varies from 150–2000 *yuan* (20–300 US dollars) (Wirth, 2017). When explaining the reason for setting this limitation, WeChat founder Zhang Xiaolong said that people should not use this feature to compete with others or to show off their wealth on WeChat:[1]

> We have noticed that giving red packets is increasingly becoming a purely monetary transaction. It's just sending out money without any emotional attachment. The larger amount you send, the more love you have. This is not right. How can money measure the world? (Tencent, 2019)

This statement demonstrates how digital red packets have their own cultural value. The maximum amount of money in a digital red packet is the same for everyone, regardless of whether they are rich or poor. It is fair to everyone, and WeChat leaves no space for privilege.

Additionally, the digital red packets come in two types. One can either send a digital red packet to another individual or designate an amount of money to give to a group of people (Liu et al., 2015; Xu, 2021). The former bears a resemblance to the traditional practice, but the latter is a gamified version of red packets. A sender first sets how many people can receive the packet within a WeChat group. The potential receivers are then expected to grab or open the packet as soon as possible, and the amount of money that one can receive is randomly assigned, as in a lucky draw (Liu et al., 2015; Xu, 2021). This feature offers users a new way of giving red packets, and it enables participants to not always follow the established, unspoken rules in terms of who shall give to whom, when to give, and how much to give in a red packet (Wu and Ma, 2017). Thus, the cultural value of the digital red packets may not always be in line with the established social hierarchy.

To answer the question about whether WeChat supports Chinese traditional values, one cannot ignore the users' role. Traditionally, red envelopes are given only on special occasions, such as Chinese Lunar New Year, weddings, or birthdays (Wirth, 2017). In contrast, WeChat users give digital red packets more frequently and have extended this practice to new scenarios (Wu and Ma, 2017; Xu, 2021). For example, digital red packets can be given to start a conversation in a quiet WeChat group, reconcile conflicts among group members, remind colleagues to check and respond to work-related messages, ask for a favour from an acquaintance, pay a talented writer for online content as a digital reward (*dashang*), split a bill between friends, or express love and care to family members and partners on special days, such as Mother's Day and Chinese Valentine's Day (Xu, 2021; Weng et al., 2020; Wu and Ma, 2017). Consequently, the original cultural meaning of exchanging red packets between family and friends has become blurred through the monetized connectivity of all kinds of relationships. Overall, relationships (*guanxi*) have become quantifiable, impersonal, more short term, and even disposable with an obligatory expectation of immediate reciprocity (Xu, 2021). Users feel social pressure and competition after seeing others frequently give or ask for digital red packets within a WeChat group (Wu and Ma, 2017). Thus, *guanxi* culture has not been strengthened on WeChat since what users offer to other users does not improve their relationship with others in the long term; nor does it deepen their mutual understanding and emotional connection.

Since 2016, WeChat has increased the upper limit for each digital red packet to 520 *yuan* (75.6 US dollars) for 24 h on some special days, such as 20 May, Valentine's Day, and Chinese Valentine's day (*Qixi*).[2] These days are 'considered fit by young people for saying "I love you"' (Xinhua, 2017; Shen et al., 2020). In Chinese, '520' and 'I love you' are homophonic, and lovers tend to give red packets with an amount of 520 *yuan* to express their love and later post screenshots of either receiving or giving this special kind of red packet (Weng et al., 2020; Xinhua, 2017). WeChat may have modified the feature temporarily to respond to the needs of younger users or the cultural affordances of users, allowing them to use digital red packets to express their love at a particular moment. Hence, it is incomplete to conclude that the platform alone either strengthens or destabilizes traditional Chinese culture. Meanwhile, the upper limit for a digital red packet changes back to 200 *yuan* the next day. This example reveals the agency of the platform/designers as well as their cultural values.

To deepen our understanding of why certain cultural affordances of users and WeChat are offered rather than others, we need to examine what the cultural offers users and the platform. Instead of stating that WeChat supports traditional Chinese values, Xu (2021) stated that being polite and sending blessings through a red packet are some of the reasons for the popularity of WeChat among Chinese users. That is, traditional Chinese cultural values and practices enable WeChat to be adopted more quickly and easily because the platform offers values and practices that resemble the traditional ones. Additionally, Chinese cultural practices and values would affect users' practices on WeChat. For example, in some WeChat groups, only supervisors, rather than the team members, give out digital red packets to boost the team's morale; people of equal positions normally give each other similar amounts of money when exchanging digital red packets (Xu, 2021). Therefore, people still follow certain hierarchical orders when using the digital red packets. A prior study showed that users feel competitive pressure when giving digital red packets since people can 'see who sends or receive Red Packets with the highest monetary value' (Wu and Ma, 2017: 2245). Such pressure can be caused by the culture of face and reciprocity (Wu and Ma, 2017). Hence, what the cultural offers can play an essential role in terms of the design and use of WeChat, as well as what WeChat offers and what Chinese users offer in return. Examining either the platform or users alone leaves us with an incomplete understanding of these behaviours and their mechanisms.

Certain behavioural, technological and cultural changes are derived from the interplay among WeChat, users and Chinese culture. Furthermore, the interplay among the three is multidirectional at different levels, including direct and indirect interactions. The interplay can be competitive and even contradictory. For example, the affordances of digital red packets allow users to practise the cultural ritual more conveniently, while the original cultural meaning of giving a red packet as a blessing has been altered to a combination of expressing love and care to loved ones and achieving instrumental goals (Wu and Ma, 2017; Xu, 2021). This change may guide society to become more goal-driven and monetized.

On the one hand, users quickly adopted the new technology and became more comfortable using digital red packets to manage various relationships in their own social networks (Xu, 2021). On the other hand, users still had to follow certain hierarchical orders when giving or receiving digital red packets. What users offer to other users can both strengthen and dissolve the traditional culture. WeChat modified the digital red packets to enable younger users to express love by sending more money (Xinhua, 2017). This change allowed users to strengthen relationships with their loved ones, but users might feel that intimate relationships can now be replaced with monetary value. These tensions or contradictions can be used for further direction when designing the platform. For example, the WeChat design team can ask what can be done so users can enjoy the technology's convenience and express their love and care by giving digital red packets without feeling competitive pressure. One possible solution could be giving the users control over the decision to show the amount of money they receive.

The interplay among WeChat, users and Chinese culture resulted in the following changes: 1) from giving red packets to relatives and friends only on special occasions to giving digital red packets more frequently to people in various relationships; 2) from expressing love and care to achieving an instrumental goal; and 3) from setting 200 *yuan* as the maximum amount for each digital red packet to setting a maximum of 520 *yuan* on some special days. An examination of these changes from the single perspective of WeChat, its users, or the Chinese culture alone is insufficient.

5.2 Cultural affordances of users

After conducting a qualitative study with 30 participants, Zhou et al. (2017) concluded that younger

WeChat users innovatively use culturally relevant emojis and stickers to modify meanings and express their own identities and feelings. A new subculture has emerged on WeChat in which users use seemingly consenting emojis or stickers (such as a smiling face) to express dissent. For example, younger WeChat users replace the traditional meaning of a smiling face with new connotations such as being speechless with scorn, having a mocking attitude, or expressing the idea that 'I don't want to talk to you' (Zhou et al., 2017: 752). Meanwhile, users create their own stickers based on the new connotations of a smiling face (Zhou et al., 2017). These practices enable younger users to share a sense of closeness with other users who understand the new connotations, emerging as a cultural affordance of users: what users offer cultivates new cultural meanings and practices on WeChat.

We can apply the framework of cultural affordances to develop Zhou et al.'s study further. As early as 2012, WeChat included emojis and stickers on its platform, and, as early as 2014, it offered users the ability to create customized stickers by using personalized images with a simple tab, making it one of the first companies to offer such features (De Seta, 2016; 2018). These new functions led to an explosion of users' creating personalized stickers on the platform (De Seta, 2016). Importantly, this feature reveals its own cultural value, which is to support personalized expression in a non-traditional way. In June 2021, WeChat founder Zhang Xiaolong mentioned that the emojis and stickers on WeChat were mainly provided by users:

> WeChat has not updated its *biaoqing*/facial expressions (e.g., memes, stickers and emojis) repertoire for a couple of years. Thanks to our users, we can have the latest *biaoqing* circulated on our platform … based on a small sample of users' data, I found that users tend to express their feelings in a more extreme manner recently, such as using the smiley-face-split-in-half emoji more often. (Zaobizagang, 2021)

In parallel with the WeChat founder's comments, WeChat launched version 8.0, in which a new feature enables users to update their personal status on their profile page by using 21 new emojis (such as happy, broken, zoning out, luck come to me, etc.), one of which was the animated emoji of a smiley-face-split-into-half, which was added in January 2021 (Dao Insights, 2021). Thus, the emoji culture that has emerged on WeChat is a combination of what the platform offers users as well as what users offer other users and the platform.

The affordance of the cultural should be considered in this case since an important question is why users alter the meaning of a smiling face rather than simply using an angry face emoji. One possible explanation is that the behaviour is culturally related. People are expected to be polite and respectful to others and those in positions of authority, such as teachers and supervisors (Liu, 2004; Yau, 1988). Thus, one needs to take special care when expressing disagreement (Liu, 2004). This cultural norm still affects users' communication modes on WeChat, especially when they engage with senior users. In parallel with this cultural norm, prior reports have found that older WeChat users still used the smiling emoji with its original meaning, and younger users were not concerned with whether older users, such as their senior family members, understood the emoji's newer meaning (Borak, 2019; Zhou et al., 2017). Thus, this emerging emoji culture on WeChat should be examined by including all three dimensions of cultural affordances to obtain a more comprehensive understanding of the phenomenon and related changes.

5.3 Affordances of the cultural

Chen (2018) conducted a qualitative study by interviewing 42 college students studying in China and concluded that traditional Chinese cultural concepts, such as filial piety, social ties (*guanxi*) and face (*mianzi*), still affect how young Chinese students use WeChat. 'They could be seen to carry out filial piety by creating virtual co-presence with their parents on WeChat … they remained aware of the necessity to present themselves in the online environment according to their parents' expectations' (Chen, 2018: 254). This research demonstrates what traditional Chinese culture offers Chinese college students and how it affects their ways of using WeChat.

Similarly, Chen's study can be further developed by applying the framework of cultural affordances to deepen our understanding of the interplay among

WeChat, college students and Chinese culture. WeChat is built on users' acquaintance networks and can reveal users' actual relationships in real life (Chen et al., 2019; Wang and Gu, 2016). Hence, the followers of a Chinese college student on WeChat are people whom he/she knows in real life, such as his/her parents, teachers and classmates. This reveals the platform's cultural value, which is to encourage certain practices that are acceptable in an acquaintance's social network in comparison to other practices that are acceptable in a stranger's social network. Additionally, the platform requires users to link a bank account with a verified real name if they want to use WeChat for any financial services, such as giving red packets, ordering a taxi or purchasing a train ticket (Xu, 2021). This design feature reveals another cultural value of WeChat: prioritizing trust and reducing uncertainty among users. Thus, WeChat's cultural affordances play an essential role in terms of Chinese college students' ways of using it.

What users offer other users on WeChat, such as comments on a post, direct messages or likes, affects Chinese college students' practice on WeChat as well. Some college students expressed that they needed to learn how to communicate with others on WeChat:

> How people communicate with each other on WeChat is different from how we communicate on QQ. In the teacher–student WeChat group, I usually let others respond to messages first, and I will do what others do, like saying 'thank you' or sending a flower emoji to my teacher.[3]

Other students expressed that they changed their ways of using WeChat after receiving text messages from friends or parents. For example, a student mentioned that he/she received some comments from friends, complaining that he/she posted too often and too negatively:

> Whenever I want to post something, I think of those comments from my friends. They have a reason: I shall consider the feelings of others who will read my post rather than just posting something for myself. Sometimes, I decide not to post what I want to say on WeChat after giving a second thought or post it on QQ if I really need an outlet.[3]

Other college students expressed that their parents reminded them to study harder after seeing what they post on WeChat:

> I posted some pictures when traveling with my friends, and the next day, my mom texted me on WeChat, telling me that I come to college to study rather than just for fun. I did not think about blocking her before and now I always hide the posts from my parents if I post something that can be worrisome for them.[3]

Thus, not only Chinese cultural values but also the cultural affordances of WeChat and the cultural affordances of users influence college students' ways of using WeChat. Examining the three dimensions of cultural affordances together might improve our understanding of users' behavioural and cultural changes on WeChat. Specifically, many users who want to post something personal, such as feelings and opinions, return either to QQ (an instant messaging software service for younger users in China) or to other platforms, such as Sina Weibo (a Chinese microblogging website). Thus, WeChat's culture becomes more professional and formal. Equally importantly, examining these dimensions offers us some direction for designing new technologies. For example, designers must find solutions to mitigate, if not resolve, the tension between the need to obtain trust and convenience and the need to express oneself without too much pressure.

6. Conclusion

Understanding the use and design of ICTs and social media requires an analytical tool that examines technology, culture and users as multiple interactive networks with intertwined relationships and multiple directions. As technology and its application continue to evolve and as access to computers, the internet and mobile phones increases, researchers, practitioners and designers must understand simultaneously and holistically how technological platforms affect people and culture, how culture affects the use and design of technological platforms, and how users' ways of perceiving and using technologies affect their design and the culture.

This paper provides a novel framework of cultural affordances as an analytical tool that can support such inquiries with a focus on relationships and networks as a whole rather than on them as single dimensions. *Cultural affordances of technology* refer to what technology (such as ICTs and social media) can offer users and culture, leading us to examine how technology can affect users' ways of thinking and doing as well as culture. *Cultural affordances of users* refer to what users can offer, enabling us to investigate how users' behaviours can affect other users, technological designs and culture. *Affordances of the cultural* refer to what cultural values and practices can offer, allowing us to explore how culture can influence technologies' design and ways of using them. An additional contribution of the theory is to acknowledge the agencies of technology, users and culture in responding to the affordances of the other two. Several empirical cases exemplify how this novel framework can be applied to deepen our understanding of the interplay among technology, users and culture; to identify behavioural, technological and cultural changes during such interactive processes; and to provide directions for designing new technologies. This paper also demonstrates the insufficiency of examining only one dimension of the interplay among technology, users and culture. Instead, multiple dimensions must be investigated simultaneously.

The three dimensions of cultural affordances function interdependently, and they proceed simultaneously and continuously. This framework offers us an unprecedented opportunity to investigate the uncertainty and spontaneity of the interactions among technology, users and culture and each's agencies. We hope this paper can be considered an invitation for further empirical research on cultural affordances in ICTs, social media studies and other related fields.

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Notes

1. WeChat Open Class PRO, Tencent's annual event, has been held since 2016 by the WeChat team to release its annual report. The primary yearly audiences of this event include merchants, developers and the public in China. Over 13-hour-long video recordings are available online. This video is from WeChat Open Class PRO 2019.
2. *Qixi* is also known as the Chinese Valentine's Day (the 7th day of the 7th Chinese lunar month). It is based on a romantic legend about a weaver girl and a cowherd. See more details at: https://www.chinahighlights.com/festivals/double-seventh-festival.htm.
3. This direct quotation is obtained from the first author's dissertation project, *Exploring cultural affordances on WeChat*. The dissertation project is a qualitative study that is currently in the data-analysis stage. It includes 30 semistructured interviews, online observations and follow-up discussions with participants in three groups: users who use WeChat as their main social media app, college students who use multiple social media apps, and WeChat team members.

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