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Contents

From the editor

It is my great pleasure to be the invited editor of this special issue of *Cultures of Science*. And, as the co-editor-in-chief, I appreciate this opportunity to share my thoughts with you.

It has been one year since the inaugural issue of *Cultures of Science* was launched in 2018. Four issues have since included theoretical and empirical studies and papers on research policy and practice in the field of science culture. We have covered science culture, science education, science communication, public understanding of science, the cultural authority of science, and science and society. Our authors have come from China, India, Japan, West Africa, the Netherlands and Canada. We are most grateful to all those who have contributed their excellent work to this new-born journal. We are indebted to our invited editors, who have given us strong support during this start-up phase: Professor Li Zhengfeng, Professor Liu Dun, Professor Tang Shukun, Dr Cheng Donghong and Dr Yin Lin. And special thanks go to Ms Luo Hui, who served as the co-editor-in-chief during the very earliest phase of the journal and passed the baton on to me.

This year marks the 70th anniversary of the founding of the People's Republic of China. This is a significant milestone for our nation and for the development of science and technology in China. The editors-in-chief—Professor Bernard Schiele and I—agreed that two special issues would be dedicated to the progress of science culture in China to celebrate this important moment. The June issue focused on science communication research using evidence-based data. This September issue builds an overview of science culture and science popularization in China by reviewing the past, focusing on the present, and looking into the future.

Five papers are included in this special issue, which presents an overall picture of science culture and science popularization in China. The first paper is a brief review of the development of science popularization in China during the past four decades and the challenges facing China in the future. The second and third papers are revised versions of two academic reports delivered at the Inaugural Forum on Cultures of Science and the Inauguration Ceremony of the Department of Science, Technology and Medical History of Peking University. The forum was held on 26 April in Beijing and was co-sponsored by CAST-Peking University Institute for Cultures of Science; the Department of Science, Technology and Medical History of Peking University; and the National Academy of Innovation Strategy. Many distinguished scholars attended and gave lectures at the event. In this special issue, we have included edited versions of the special reports delivered by Professor Shang Zhicong and Professor Wang Xiaoming. Those two papers discuss the features of modern science culture and the impact of science popularization venues on the dissemination of science culture, respectively. The fourth paper discusses the traditional Chinese technological ideal and highlights its influence on the development of modern technology. The fifth paper presents some reflections on the transformation from an era of science popularization to a new era of science culture in China and sheds some light on relevant practice in the future.

In the upcoming December issue, *Cultures of Science* will establish cooperation with SAGE Publishing and adopt an international publishing platform. We will continue to publish special issues on exciting topics in this field. It's our sincere wish that more readers and authors will join us.

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Cultures of Science 2019, 2(3): 183–192

A brief review of the four-decade evolution of science popularization in China*

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Abstract

This article presents a brief review of the history, main achievements and challenges faced during the 40-year evolution of science popularization (SP) in China that began with the reform and opening up process. Four distinct phases are noted in the development of SP: institutional reconstruction, structural maturity, fast development of a legal system and comprehensive strategic upgrading. China has achieved much during these phases in the areas of SP mechanisms, funding, personnel, infrastructure, resources and civic scientific literacy. At the same time, it is also facing challenges in strategic positioning, the effectiveness of SP policies, internationalization, the construction of the SP system and scientific culture. Evidently, the government's prioritization of SP is critical for advancing this initiative. In the future, under the government's leadership, the following directions should be pursued: expanding and improving civic scientific literacy through a focus on internationalization; promoting scientific cooperation from a global perspective; establishing a long-term SP mechanism; and building a service platform to promote 'smart SP'. SP in China is clearly on the right track and will continue to advance in the future.

Key words

Science popularization, scientific literacy, science popularization policy, science and technology innovation

The National Science Conference in 1978 brought a 'spring of science' to China and prompted unprecedented opportunities for advancing science popularization (SP). In the 41 years since then, SP has assumed growing importance within China's national development strategy. China has strengthened its ability to develop SP, deepened its reform of the SP mechanism, improved the SP policy system, developed its SP forces and increased civic scientific literacy. These developments lay a solid social foundation for innovations in science and technology.

1. The development of SP in China over four decades

SP in China has made significant progress since its initiation in 1978. The country's achievements in this regard reflect an increasing commitment to promoting SP.

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*The Chinese version of this article was first published in *Chinese Science Bulletin*. Necessary edits are made to make it more suitable for republication in this journal.

1.1 Resumption of institutionalized SP (1978 to 1993)

At the National Science Conference convened in 1978, Deng Xiaoping proclaimed that ‘science and technology constitute a force of production’ and emphasized that ‘great efforts must be made to popularize science’. His speech provided a powerful boost for the resumption of SP. With the reinstatement of SP organizations, human resources in this field were strengthened and a number of influential SP initiatives were launched. Consequently, a systematic SP network was formed, which ushered in what has been referred to as ‘a spring of SP development’ (Shen, 2003).

1.2 Maturity of the SP system (1994 to 2001)

In the 1990s, SP received a high level of attention from the government. In 1994, the State Council issued Several Opinions on Strengthening the Popularization of Science and Technology (‘the Opinions’). This was the first programmatic document to be issued since the founding of the People’s Republic of China and elevated SP to the status of a national strategy (Tong, 2008). In accordance with the guidelines framed in the Opinions, the State Council established the National Joint Committee on Science Popularization in 1996 to coordinate SP efforts nationwide and provide institutional support for SP (Ren, 2008). Following State Council’s introduction of a strategy of rejuvenating the country through science education, a series of related policies were introduced. At the same time, numerous SP activities were launched, and local governments introduced their own regulations on SP. In 2001, SP was included in the Special Plan for the Development of Science Education under the 10th Five-Year Plan for National Economic and Social Development. Thus, SP in China entered a phase of overall development led by the government (Ren, 2009a, 2009b).

1.3 Fast development of SP laws and system (2002 to 2015)

In the 21st century, public awareness of the importance of SP has increased, the tasks of SP have been clearly defined, and the legal system of SP has been improved. The Law of the People’s Republic of China on the Popularization of Science and Technology (the ‘Science Popularization Law’), which was promulgated in 2002, was the country’s first law that specifically addressed issues relating to SP, including organization, management, social responsibilities, measures for development and legal obligations. The law provided legal support for science popularization. It was followed by a succession of national and local regulations on SP, leading to the formation of a national system of SP laws, regulations and policies (Ren, 2009b; Zhang and Ren, 2012).

In 2005, the development of SP and an innovative culture was included as a special issue in the National Medium- and Long-Term Plan for Scientific and Technological Development (2006–2020). The plan explicitly expressed a commitment to a nationwide scheme for scientific literacy to strengthen China’s ability to develop SP and establish a sound operating mechanism for the SP cause (Ren, 2009a). In 2006, the State Council promulgated the Outline of the National Scheme for Scientific Literacy (2006–2020), marking another milestone in China’s SP cause by elevating civic scientific literacy improvement to the status of a national-level programme. The outline was followed by a spate of SP policies that were made to advance national scientific literacy. Those policies covered various aspects of SP, such as top-down designs and specific measures. Gradually, a national SP policy system was established, encompassing the state, ministries and local governments, with the Opinions, the Science Popularization Law and the National Scheme for Scientific Literacy at the core (Zhang and Ren, 2012). Guided by those policies, a multilayered network of SP organizations was formed at the central, local and grassroots levels, incorporating all sectors, including the countryside, cities, schools and enterprises. Thus, an SP mechanism involving all people and an atmosphere in which all people support SP were developed (Ren and Zhai, 2014; Ren and Yin, 2018; Ren and Zhai, 2018).

1.4 Comprehensive strategic upgrading (2016 to the present)

In May 2016, the State Council issued the Outline of the National Strategy of Innovation-Driven Development, which prioritized SP as one of the driving forces for the strategy. At a top-level science event that was held on 30 May 2016, President Xi Jinping importantly observed that scientific and technological innovation and SP are two wings of innovation-driven development, thus further highlighting the importance of SP and its role in supporting the national strategy and elevating SP to an unprecedented degree (Ren and Yin, 2018; Ren and Zhai, 2018).

In October 2017, in his report to the 19th National Congress of the Communist Party of China, President Xi noted the requirement of 'promoting the scientific spirit and making scientific knowledge widely attainable'. At the Meeting of Academicians of the Chinese Academy of Sciences and the Chinese Academy of Engineering held on 28 May 2018, President Xi called on scientists to 'continue to spread scientific knowledge and promote the scientific spirit' (Ren and Zhai, 2018). On 17 September 2018, President Xi sent a congratulatory letter to the World Conference on Science Literacy in which he strongly advocated strengthening civic scientific literacy to build a shared future for the community of humankind. With the Chinese Government's support, SP has entered a phase of unprecedented expansion and is assuming a new role in comprehensively supporting national development strategies.

2. China's main achievements in SP

In four decades of development, China has successfully established an SP mobilization mechanism, as evidenced by increases in funds, personnel, infrastructure, resources and public literacy relating to SP.

2.1 The formation of an SP mobilization mechanism led by the government and featuring public engagement

The institutionalization of SP in China has made giant strides. With the mushrooming of diverse and specialized SP organizations and the rollout of SP policies, laws and regulations, a comprehensive multi-tiered SP policy framework has been established, and an SP mobilization mechanism and SP forces have been developed at the central, local and grassroots levels and covering all regions and groups. These developments are indicative of the gradual formation of an SP system with Chinese characteristics (Ren and Yin, 2018; Ren and Zhai, 2018).

At the state level, the Science Popularization Law expressly stipulates the responsibilities of various levels of government, relevant departments, and associations of science and technology, as well as institutional mechanisms for advancing SP. In addition to the National Joint Committee on Science Popularization mentioned above, the Leading Work Group of Civic Scientific Literacy was established in 2006. This group has evolved into a body comprising 34 member organizations tasked with implementing the National Scheme for Scientific Literacy, which has effectively advanced civic scientific literacy within the country. SP in China has thus entered a phase of orderly and organized implementation, entailing goals, plans and priorities (Ren, 2009b; Zhang and Ren, 2012; Ren and Zhai, 2014; Ren and Yin, 2018; Ren and Zhai, 2018).

At the local level, under the guidance of local party committees and governments, all province-level divisions (provinces, autonomous regions and municipalities directly under the central government) and the overwhelming majority of prefecture-level cities and counties have established agencies responsible for implementing the National Scheme for Scientific Literacy along with corresponding working mechanisms. A total of 25 province-level divisions have included civic scientific literacy in their economic and social development plans. All province-level divisions have formulated their plans for implementing the National Scheme for Scientific Literacy during the 13th Five-Year Plan period. Among them, 16 have included civic scientific literacy in the performance evaluation system of party committees and government departments. In particular, the inclusion of civic scientific literacy in the government work evaluation system has effectively increased local governments' commitment to advancing civic scientific literacy (Ren, 2009b; Zhang and Ren, 2012; Ren and Zhai, 2014; Ren and Yin, 2018; Ren and Zhai, 2018).

The comprehensive implementation of the National Scheme for Scientific Literacy has led to a proliferation of SP initiatives along with widespread public awareness, support and engagement in this effort. In addition to relevant government agencies, many other organizations, notably universities, research institutes, science and technology related museums, grassroots organizations and the media, have been actively involved in SP activities. As a result of the government's promotion and widespread participation across sectors, a matrix of public social platforms demonstrating large-scale combination and collaboration has been established, creating favourable conditions for inclusive public engagement in SP (Ren, 2009b; Zhang and Ren, 2012; Ren and Zhai, 2014; Ren and Yin, 2018; Ren and Zhai, 2018).

2.2 Increase in SP funding

Nationwide SP statistics reveal that SP funding in China amounted to ¥16.005 billion in 2017, indicating an increase of 241.77% compared with funding in 2006. This amount included a sum of ¥12.296 billion appropriated by all levels of government, accounting for 76.82% of the total funds, which indicates an increase of 278.33% compared with the figure in 2006 (MST, 2008–2017). Of that amount, ¥6.269 billion was earmarked for SP, reaching¥4.51 per person (increases of 302.38% and 282.20%, respectively, compared with the figures in 2006). Thus, the total SP funding has shown a significant increase.

Private-sector donations to support SP amounted to ¥187 million, and self-raised funding amounted to ¥2.881 billion in 2017 (MST, 2008–2017), indicating increases of 139.74% and 171.28%, respectively, compared with figures in 2006 and pointing to increasingly diversified channels of SP funding. Figure 1 shows the structure and sources of SP funding.

2.3 Steady expansion of the SP workforce

The Science Popularization Law and various other policies have strengthened the SP workforce in China. This workforce mainly comprises administrators, professional workers and volunteers in this field. As Figure 2 shows, the total number of individuals involved in this sector reached 1,794,500 in 2017, which was an increase of 10.53% from 2006 (MST, 2008–2017). The number of full-time workers in 2017 was 227,000 (an increase of 13.56% compared with the figure in 2006), accounting for 12.65% of the total SP workforce. In terms of the workforce structure, there were 139,500 full-time SP workers with a mid-level or above occupational title or a bachelor's degree or above, indicating a rise of 53.80% compared with the figure in 2006 and accounting for 61.45% of all full-time workers engaged in this field.

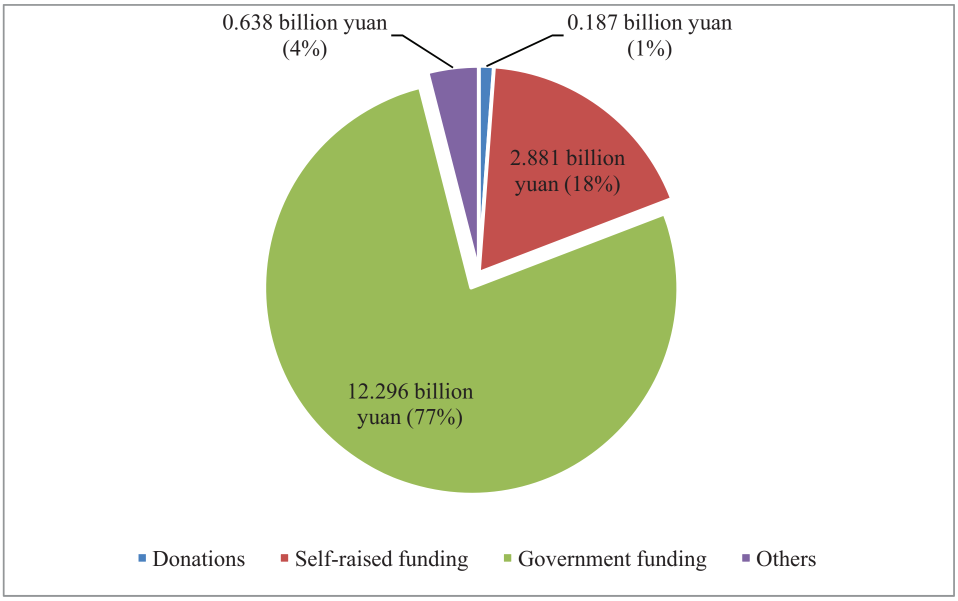

Figure 1: Funding sources and proportions relating to China's SP in 2017

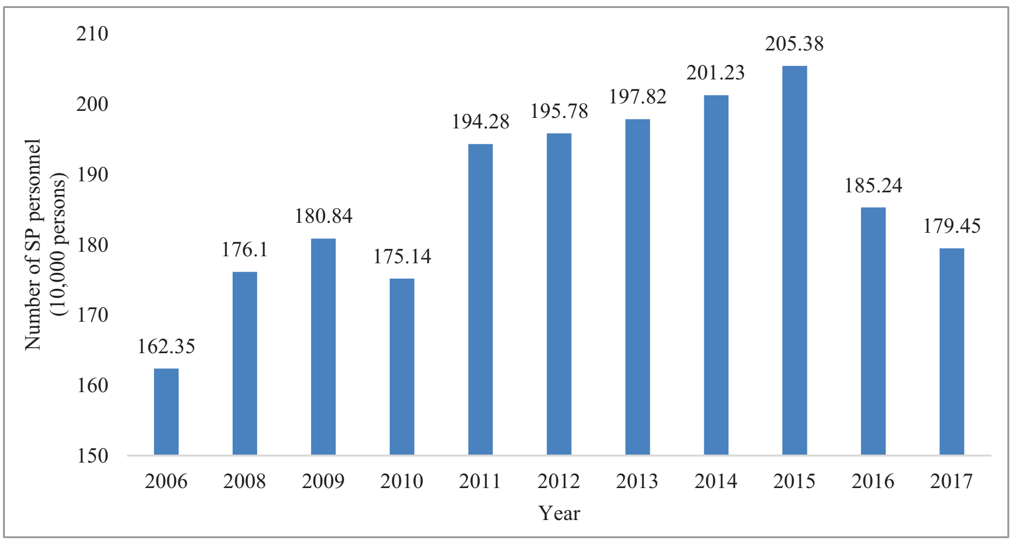

Figure 2: The development of China's SP workforce from 2006 to 2017

2.4 Significantly enhanced SP infrastructure

SP infrastructure includes science and technology related museums, specialized popular science museums, science education bases, grassroots popular science facilities, SP caravans, popular science websites, and digital science and technology museums. As shown in Figure 3, in 2017, China had 951 science and technology related museums nationwide with a total exhibition area of 3,199,900

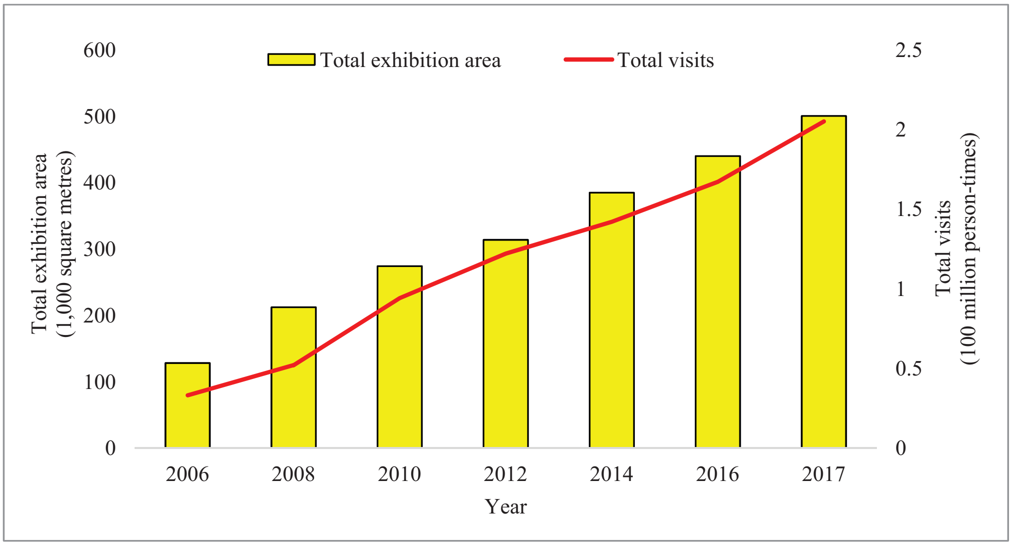

Figure 3: Exhibition areas and visits to science and technology museums and science and technology related museums

square metres (an increase of 373.35% compared with the figure in 2006) and 488 science and technology museums with a total exhibition area of 1,800,400 square metres (a 198.97% increase compared with the figure in 2006). In 2017, science and technology related museums and science and technology museums received total visits of 205 million person-times (an increase of 520% compared with the number of visits in 2006) (MST, 2008–2017).

The formulation of the National Scheme for Scientific Literacy has promoted the development of a system of SP public service. For example, there has been steady progress in the development of modern science and technology museums with Chinese characteristics. A new structure comprising four types of venues has been formed. It includes general and specialized science and technology museums; mobile science and technology museums; SP caravans and science and technology rooms in rural middle schools; and digital science and technology museums. The new structure has promoted the sharing of high-quality SP resources.

2.5 The augmentation of SP resources and progressive informatization

Mass media are an important means of promoting SP as well as the main channel through which the Chinese public can access information on science and technology. In 2017, 14,100 popular science books were published in China, which was an increase of 344.62% compared with the number of books published in 2006. A total of 112 million copies were printed, accounting for 1.21% of all books printed nationwide in 2017. In the same year, 491 million science and technology newspapers were distributed nationwide, and 89,700 hours of TV programmes and 73,700 hours of radio programmes were devoted to science and technology (MST, 2008–2017).

The rapid informatization and increased diversity of the media, which encompass the internet and new media, have increased scientific literacy among the public. Social media platforms, including WeChat accounts, Weibo accounts and mobile reading apps, are the primary channels through which the public can access information on science and technology.

Initiatives such as 'Internet + SP' and SP programmes to promote informatization have promoted the integration of traditional SP with modern means of communication, resulting in a steady increase in up-to-date coverage of popular science. Internet-based SP represented by leading platforms such as China Science Communication and Guokr has gained traction. In 2017, a total of 2,570 popular science websites published 1,367,100 articles and 49,700 videos and received 921 million visits. Further, 2,065 SP Weibo accounts published a total of 664,500 posts and received 4,409 million views (MST, 2008–2017).

2.6 Steadily increasing public scientific literacy

The promotion of civic scientific literacy has become an important responsibility and mission of China's SP workforce. With the development of SP, and especially since the introduction of the National Scheme for Scientific Literacy, China's civic scientific literacy has been steadily improving, and the percentage of scientifically literate citizens increased from 1.44% in 2001 to 8.47% in 2018 (see Figure 4).

The Chinese public has shown increasing interest in and support for science and technology development. According to the findings of the 2018 Chinese Civic Scientific Literacy Survey, the most aspired professions in China are the teaching, medical and scientific professions; 83.7% of respondents agreed that modern science and technology will create more development opportunities for future generations; and 77.3% endorsed the view that, although basic research cannot generate immediate results, it is necessary and should be supported by the government. Thus, an environment that is conducive for science and technology innovation is being fostered.

3. Challenges facing China's SP endeavour

While China has made giant strides in promoting SP over the past four decades, various constraints and deficits have also been evident.

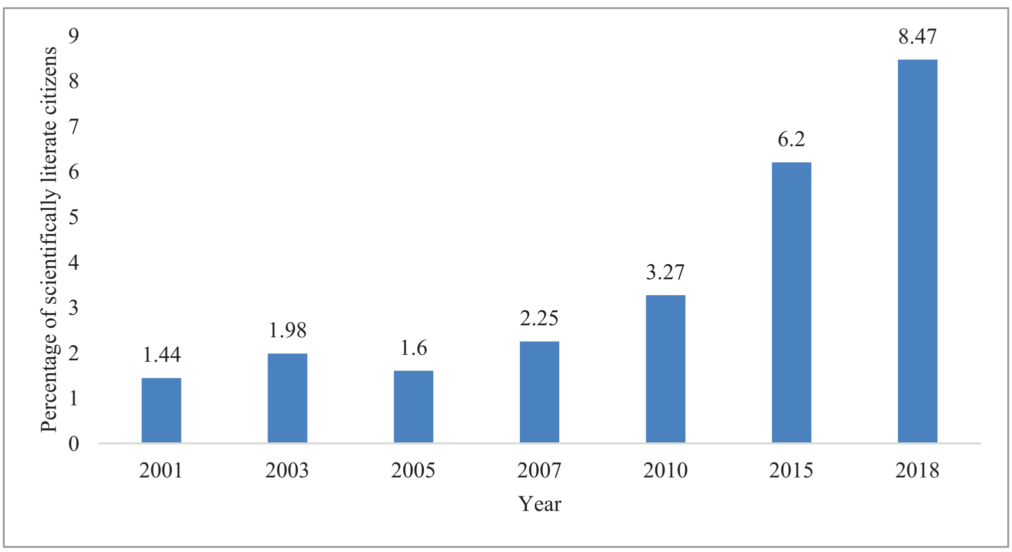

Figure 4: The evolution of civic scientific literacy in China from 2001 to 2018

For example, less attention is paid to promoting the scientific spirit and scientific thinking compared with scientific knowledge; and imbalanced development between SP and scientific innovation will continue. There is significant room for improvement in various areas, including strategic positioning, theoretical development, practices, the policy framework and international expansion. Therefore, reflections on the current challenges facing China's SP endeavour are crucially important for sustaining the future development of SP in this country.

3.1 Weak strategic positioning and imbalanced development of SP and scientific innovation

Although scientific innovation and SP are emphasized as two wings of innovation-driven development in China's national strategy, the latter currently takes a backseat and receives less support in the national innovation ecosystem than the former. Governments at all levels generally accord more attention to scientific research than to SP. In 2017, SP funding accounted only for 0.9% of the funding allocated for R&D and for 1.4% of fiscal expenditure on science and technology. These figures are indicative of a significant funding deficit relating to SP. A mechanism for converting R&D results into SP resources is yet to be established, and the incentive mechanism for promoting SP requires further improvement. The SP workforce also needs to be strengthened, given that the number of full-time writers in this field has remained constant at around 10,000 for some years now, while there has been a decline in the total SP workforce in recent years. Given the massive demand for SP, there is a major shortage of science popularization workers (MST, 2008–2017). Moreover, concerned actors, notably scientists, enterprises and the mass media, have been less than enthusiastic in supporting SP.

3.2 Low effectiveness of SP policies and long-term operating mechanisms

While China has established a comprehensive SP policy framework and SP mechanism, the role of long-term mechanisms still needs to be strengthened, and relevant policy measures need to be more effectively implemented.

Some key issues need to be addressed in relation to those constraints:

- There is a need to develop an improved mechanism for leveraging the market to enable the broad-based mobilization and participation of social actors in SP activities.
- A lack of supporting regulations and detailed rules for implementing the Science Popularization Law and other policies has resulted in their limited effectiveness.
- Existing mechanisms for promoting interdepartmental coordination and local coordination should be strengthened.
- There is a need to establish a standard, institutionalized and long-term evaluation mechanism.

3.3 Low level of internationalization and open cooperation

Currently, China's SP has a low level of internationalization, and the aspiration of building a shared future for the community of humankind remains a distant goal. Theories on public understanding of science and science communication are developing vigorously in the international academic community, but only a few researchers in China have paid attention to this field, and there is a need to learn from internationally advanced theories and practices relating to SP. International cooperation and exchanges in this field are yet to be strengthened, and there is still considerable scope for sharing SP resources among the countries involved in China's

Belt and Road Initiative. Moreover, efforts to internationalize the SP industry, improve innovative SP services and import and export SP products remain at a preliminary explorative stage (Ren et al., 2018).

3.4 Inadequate and imbalanced development of the SP system

China is yet to establish a comprehensive system integrating SP theories, practices, policies, markets and internationalization and to develop a systematic synergy of SP efforts and resources, as evidenced by varying degrees of inadequate and imbalanced development in different fields, sectors and regions.

Some key issues need to be addressed to accomplish this synergy:

- The position of SP within the national innovation system needs to be defined more clearly in a way that enables it to play an effective role in supporting an innovation-driven development strategy.
- The supplyside of SP cannot meet rapidly growing demand from the public, and the SP industry remains undeveloped. Therefore, there is a need to improve the mechanism of private-sector investment in SP (Ren et al., 2018).
- The overall level of the country's civic scientific literacy is still relatively low, and there are significant urban–rural and regional differences; for example, the percentages of scientifically literate citizens in first-tier cities such as Beijing and Shanghai are nearly five times higher than those in the western provinces. Significant developmental imbalances between urban and rural areas and among regions are indicative of the prevalence of inequality relating to SP, which is considered a public good.

3.5 Inadequate theoretical research on SP and a lack of support for the development of scientific culture

More efforts are needed to expand innovative theoretical research on SP in China and to provide theoretical support for the development of scientific culture.

On the one hand, SP is an emerging interdisciplinary field of study that is not yet well established in China. For example, there is no single published book that provides a systematic overview of SP history, and academic interest in and research on related frontier topics, such as scientific culture, open science and scientific ethics, remain limited.

On the other hand, the existing SP theoretical framework is a conventional one that is not well informed by insights derived from other disciplines, such as sociology, psychology, pedagogy, management science and communication science. The development of SP-related theories remains weak because of the lack of support from first-level disciplines and lack of funding from national research programmes.

3.6 The future of SP in China

In conclusion, this review of China's SP development over the past four decades has revealed that government support is a key factor in the advancement of SP. Looking forward, as socialism with Chinese characteristics enters a new era, China should, under the leadership of the government, strengthen civic scientific literacy by improving internationalization, promote open cooperation from the perspective of a global horizon, establish a long-term SP mechanism through the collaboration of all forces, and introduce new service models and platforms of civic scientific literacy through informatization. SP in China is sure to be more prosperous in the future.

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Author biography

Fujun Ren, Professor, PhD supervisor, is an expert enjoying the State Council Special Allowance. He is the general director of the National Academy of Innovation Strategy and the chief editor of *Modern Science* and *Cultures of Science*. He holds a PhD from the Harbin Institute of Technology and a postdoctoral degree from Tsinghua University. He previously served as the director of the China Research Institute for Science Popularization; as the vice president of the China Science Writers Association and of the Beijing Association for Science and Technology; and as the chief editor of *Studies on Science Popularization.* His areas of expertise include science popularization, innovative culture, scientific culture and scientific policy.

Cultures of Science 2019, 2(3): 193–202

On the distinctive features of the modern scientific culture

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Abstract

Remarkable strides have been made in science ever since the scientific revolution in the 17th century, and the scientific community continues to prosper today. In its professional activities and social life, this community has created a scientific culture that is increasingly prosperous and is having a significant impact on the development of human culture. The scientific culture has distinctive features that are different from those of the literary culture. For example, it emphasizes the decisive role of objective examination in the course of enquiry to reduce the impact of the subjectivity of researchers on the results. It also stresses the objectivity of knowledge and testing that objectivity through reproducibility. It favours experimental and mathematical approaches while underestimating the roles of imaginal and intuitive thinking, and advocates the values of utilitarianism. This paper concludes that the distinctive features of the scientific culture should be examined in the course of its current development to eliminate the negative impact of utilitarianism.

Key words

Scientific culture, distinctive features, objectivity, mathematical approach, experimental approach, utilitarianism

1. Introduction

Since the scientific revolution in the 17th century, science has developed remarkably, and our knowledge in the scientific disciplines has grown to form a significant part of human knowledge. Scientific research methodologies featuring experiments and mathematical deduction have evolved into fundamental approaches used by humans to understand the world. Whether it is in the exploration of nature or in research on human society and human awareness, scientific approaches are used extensively. Science has become a remarkable symbol of modern society.

With the development of science and the growing number of scientific professionals, the scientific community has become a strong force in social development in the 21st century. The scientific culture, which has been developed by the scientific community in its professional activities and social life, is becoming more conspicuous. It is different from the other subcultures of human society but also integrates with them to promote the progress of human culture.

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This paper is intended to illustrate the special qualities of the modern scientific culture, with a focus on key points of concern in promoting the progress of the scientific culture in China today.

2. The separation between the two cultures

The scientific culture is different from the literary culture, which has been created by scholars in the field. The differences have resulted in separation between practitioners of the two cultures. The earliest statement noting that was made by British scholar Charles Percy Snow (1905–1980).

Snow had undergone rigid scientific training and, upon receiving his PhD in 1930 from the University of Cambridge, was engaged in research, teaching and administrative duties. As he loved literature and had a strong passion for great writing, he maintained close contact with both scientists and researchers in the humanities. During World War II, Snow was in charge of scientific resource administration in a committee under the British Royal Society. He once also served as director of technical personnel at the British Ministry of Labour, helping select professionals for the Manhattan Project. More importantly, he was a scientific adviser to the British Government for a long time. From 1964 to 1966, he served as a parliamentary secretary in the House of Lords to the Minister of Technology. In recognition of his outstanding contribution and extensive social influence, Snow was awarded the title of Baron of Leicester in 1957.

Snow's academic and professional experience enabled him to nurture a deep understanding of the cultural separation between the communities of science and the humanities. He found that scientists and humanities scholars often disagreed with each other about concepts, failed to understand each other, had a poor opinion of each other's area of research, and even engaged in verbal attacks. He described this separation as follows:

> For constantly I felt I was moving among two groups—comparable in intelligence, identical in race, not grossly different in social origin, earning about the same incomes, who had almost ceased to communicate at all, who in intellectual, moral and psychological climate had so little in common that instead of going from Burlington House or South Kensington to Chelsea, one might have crossed an ocean . . . by and large this is a problem of the entire West. (Snow, 2012, p. 2)

Regarding the degree of separation, Snow (2012, p. 4) said:

> Between the two a gulf of mutual incomprehension—sometimes (particularly among the young) hostility and dislike, but most of all lack of understanding. They have a curious distorted image of each other. Their attitudes are so different that, even on the level of emotion, they can't find much common ground. Non-scientists tend to think of scientists as brash and boastful.

In 1956, Snow published an article in the *New Statesman* titled 'The two cultures', which pointed out for the first time the separation between the scientific culture and the literary culture and prompted considerable discussion. In 1959, he expanded on the article and delivered a lecture titled 'The two cultures and the scientific revolution' at the University of Cambridge, making the separation between the two cultures a hot topic.

Lionel Trilling (1962) from Columbia University and Frank Raymond Leavis (2013), a literary critic from the University of Cambridge, subsequently expressed their views on the issue. They stressed that science and the humanities are different in approach and discourse. The statement of 'two cultures' simplifies the complexity of the humanities, they noted, and does not hold water.

John Brockman promoted the concept of the 'third culture'. He claimed (1996) that the wide dissemination of scientific knowledge has led to a change in the role of intellectuals in modern society, as more and more scientists assume the role of general intellectuals. Science has an increasingly profound influence in policymaking and philosophical argumentation, and both government and society value it more than ever. In Brockman's view, the 'third culture' acknowledges the rapid development of the scientific culture and its quickly growing influence on social culture since the mid-20th century.

Thus far, the discussion of the two cultures has continued for about six decades. During that period, because of developments in science and technology and significant changes in social life, the meanings of the two cultures have undergone enormous changes. Due to globalization and the ubiquity of science, the separation between the two cultures is no longer typical of Western society but a common phenomenon worldwide. Over a span of 60 years, the two cultures have integrated and clashed with each other.

The Sokal affair showed the separation between the communities of science and the humanities. In November 1996, New York University quantum physicist Alan Sokal submitted to *Social Text*, a famous journal of cultural studies, a disingenuous article titled 'Transgressing the boundaries: Toward a transformative hermeneutics of quantum gravity' to test the editors' academic ability, but none of the five editors identified that it was a parody. Within a month of the publication of the article, Sokal published another article titled 'A physicist experiments with cultural studies', revealing that the article in *Social Text* was a hoax. This event shocked the academic community and sparked a global 'science debate' between self-proclaimed guardians of science, who included scientists and positivist philosophers, and postmodernist thinkers.

During the debate, scientists declared to humanities intellectuals that 'I can read your paper, but you can't read mine.' In the face of this arrogant challenge, some humanities intellectuals evinced a lack of confidence, while others went to the extreme of attacking the authority of science in the name of the humanities. The conflict between the two sides then evolved into a matter of 'pride and prejudice' in which each side defied the other.

The debate reveals that, by the end of the 20th century, a vast separation persisted between the two cultures. On the one hand, some humanities intellectuals misused concepts and knowledge from natural science, while some others devised unreasonable and surprising theories. This practice aroused the doubt and scorn of scientists. On the other hand, some followers of science hoped to expand the use of scientific approaches to the more complex phenomena of society at large. They expected to include all earthly activities in science and convert science into a new type of belief. Science, which should be based on rationality, is thus misusing the authority of rationality and turning into a new sort of superstition. Friedrich August Hayek (1982, p. 176) claimed that 'In this sense the twentieth century was certainly an outstanding age of superstition... where the application of the techniques which proved so helpful with essentially simple phenomena has proved to be very misleading'.

Modern science made a late start in China but, once it had established itself in the 20th century, a separation between the scientific culture and the literary culture appeared here as well. This can be seen from the debate between scientists and metaphysicians in the 1920s. After the First Opium War, progressive Chinese intellectuals turned for inspiration to Europe, which had advanced science and technology and developed industries. In 1918, under the leadership of Liang Qichao, a group of seven, including Zhang Junmai and Ding Wenjiang, travelled to Europe in order to learn. However, their hope of Europe representing the triumph of science, and a path for the future for China, was destroyed when they saw the violence and destruction of World War I. In 1923, Zhang Junmai gave a lecture titled 'The outlook on life' at Tsinghua University. The lecture ignited a widespread science–metaphysics debate between conservative cultural forces and the Westernized school that was then prominent.

The conservative school, headed by Zhang, held that science concerns physical things, and thus cannot satisfy the spiritual needs of humankind. Therefore, it cannot help with the spiritual life of humanity in any way. It was the progress of science that had resulted in the evils of modern civilization in the West and the enormous damage of World War I. The Westernized school, headed by Ding Wenjiang, claimed that science promotes spiritual life and intellectual development; science can train people's intellect, enhance spiritual contentment and, moreover, serve as an important instrument for personal cultivation and moral edification.

Since the 20th century, China has made tremendous progress in science, and the scientific culture has come to have an increasing impact on society. But we have not managed to bridge the divide between the scientific culture and the literary culture. Technology-minded governance and scientific hegemony are evident sometimes in the course of national policymaking and social governance. This separation hinders the development of science and prevents humankind from making social progress. It is thus important for China to develop a positive culture of science.

3. The distinctive features of the scientific culture

Created by men and women of science, the scientific culture constitutes the form of life and attitude towards life consciously or unconsciously followed by people involved in scientific activities. It is a type and an important element of human culture, and one of the subcultures of humankind. As Snow (2012, p. 9) said:

> At one pole, the scientific culture really is a culture, not only in an intellectual but also in an anthropological sense. That is, its members need not, and of course often do not, always completely understand each other; biologists more often than not will have a pretty hazy idea of contemporary physics; but there are common attitudes, common standards and patterns of behaviour, common approaches and assumptions. This goes surprisingly wide and deep. It cuts across other mental patterns, such as those of religion or politics or class.

The scientific culture embodies the spirit of the scientific community. Compared with other subcultures, such as those of art and religion, it has a shorter history, but it has experienced rapid development and has an increasingly significant impact on modern society. The meaning of the scientific culture concerns both cognitive principles (such as logical consistency, simplicity and testability) and social norms for scientific activities (such as Robert K Merton's universalism, communism, disinterestedness and organized scepticism and John Ziman's innovation ethos). Starting from the 20th century, the scientific culture has unconsciously shaped the thought and mentality of humankind, fostering the modes of thinking and psychological patterns of people, and has become an indispensable element of a person's basic qualities.

However, the distinctive features of the scientific culture are relative to other forms of subcultures, especially the literary culture. The following is a comparison between the two cultures.

3.1 The historical origin of the separation between the two cultures

According to Snow (2012, p. 17), a major factor in the separation between the two cultures is 'our fanatical belief in educational specialisation'. Knowledge of nature, society and humans themselves is a prerequisite for understanding the living environment and for controlling and harnessing environmental factors. Humankind in primordial times gradually accumulated knowledge in life and production activities before developing cities and civilizations.

At present, human civilization is thought to be roughly 8,000 years old. During that period, humans' cognitive activities gradually became independent from other production activities, allowing the emergence of intellectuals engaged in cognitive work. The history of cognitive workers is only more than 2,000 years long, if we calculate from the time of the classical Greek intellectuals and the scholars of China's Spring and Autumn period.

Later, the Renaissance in the 16th century accelerated further division and segmentation of cognitive work, eventually bringing about the scientific revolution. So far, large-scale scientific cognitive activities have a history of no more than 500 years, but in that period humankind has experienced an exponential growth in knowledge.

The division and segmentation of cognitive work is a requirement for the growth of knowledge, because of which specialized education has grown into a necessary means of training intellectuals for modern society. This is the historical origin of the separation between the two cultures.

3.2 The epistemological origin of the separation between the two cultures

From the perspective of philosophy, David Hume's fact–value dichotomy in *An Inquiry Concerning Human Understanding* can be viewed as the epistemological origin of the separation between the scientific culture and the literary culture. Science deals with facts, while the humanities deal with values. When answering the scientific question of 'yes or no', the value-based answer of 'should or should not' can hardly be satisfactory for people. In making value judgments about 'should or should not', the scientific answer of 'yes or no' can be invalid as well. Furthermore, Immanuel Kant's division between natural law and moral law in *The Critique of Pure Reason* strengthened the differentiated modes of thinking of the two cultures. The former concerns the question of 'what is it?', which belongs to the problem of natural philosophy of the 'fact world', while the latter concerns 'how should we act?', which is a problem of moral philosophy of the 'value world'.

3.3 The differences between the two cultures

The two cultures have significant differences in their epistemology and methodology.

3.3.1 Differences in epistemology

The scientific culture is based on knowledge of nature and focuses on the objective external world. Science is about discovering the truth. Scientific activities are ideally experimental, logical and neutral. Scientific theories should be reproductions or reflections of the objective world, with a focus on the uniformity of subjectivity and objectivity. Such a representationalist view of science shows that scientific activities are one type of objective practice, and thus scientific knowledge generated from that practice is objective.

By contrast, the ideas advocated by the humanities, such as a 'people-oriented ethos' and 'man as yardstick for everything', constitute a warm and friendly cultural system created by humankind that is different from the natural order. Although the objects of research in the literary culture are also from the natural world, they are personified. Under the framework of human subjective consciousness, the system of knowledge in the humanities exhibits a stronger degree of subjectivity, casualness and conventionality and falls into the relativist standpoint in terms of epistemology.

3.3.2 Differences in methodology

Typical scientific methods are experimental and mathematical. The experimental method involves observing and analysing the regularity of changes pertaining to the object of study by controlling and purifying its status. This method seeks to eliminate differences brought about by individual senses and to ensure the objectivity of the research findings by repeated experiments. The mathematical method uses quantified expressions to accurately describe the features of the object of study. This method makes scientific knowledge systematic, theoretical, more generalizable, and predictive, and renders logical reasoning and prediction more procedural, strict and accurate.

The literary culture favours imaginal, intuitive and logical thinking. For example, art, literature and history are mostly perceptual, because of which knowledge of those areas is acquired through description, experience, reflection and intuition; philosophy emphasizes logical thinking, with a focus on the analysis of concepts and propositions. The literary culture does not exclude individual subjective factors, and does not stress the reproducibility of findings or knowledge.

3.4 The features of the scientific culture

In summary, the scientific culture possesses three distinctive features. First, it stresses the decisive role of objectivity in the course of cognition, avoiding the impact of individual subjectivity on the results of cognition. Second, it focuses on the objectivity of knowledge and emphasizes testing that objectivity with reproducibility. Correspondingly, it favours experimental and mathematical methods, downplaying the roles of imaginal and intuitive thinking. Third, it advocates utilitarianism, which subscribes to the basic principle that if one kind of behaviour is conducive to enhancing happiness, then it is correct; if it leads to something contrary to happiness, it is wrong. Here, happiness involves not only the actor but also every individual affected by the relevant behaviour.

The scientific sociologist Robert K Merton noted that utilitarianism had ignited the propagation of modern science. In the 17th century, many Protestants broke away from the restraints of the church to explore natural laws and mysteries. They regarded this as a new approach to understanding the omniscient God and fulfilling their duty of self-redemption. With utilitarian purposes, such activities of natural exploration became accordant with Protestant values, attracting more people to join the ranks of scientific researchers.

Later, there was a growing trend of secularization in science, which is closely related to the utilitarian assessment of science (Merton, 1938). As an advocate for modern science, Francis Bacon heralded the advancement of learning to benefit humankind. The idea of making use of scientific knowledge to benefit humankind reflects the utilitarian value of the scientific culture. The utilitarian assessment of science allows science to be more widely accepted by members of society and thus acquire large amounts of social resources and developing further. Utilitarianism has thus made it possible for humankind to make immense progress in modern science while also shaping the nature of the modern culture of science.

4. The cultivation of the contemporary scientific culture

It is an inevitable trend in today's social development to cultivate a positive culture of science and promote its progress. To achieve this goal, it is necessary to understand the distinctive features of the scientific culture and to promote mutual exchange and benefit between the cultures of science and the humanities.

4.1 Combinations of methodologies of science and the humanities

The gap between scientific methodology and the methodology of the humanities can be bridged. In the 20th century, scholars in some areas of the humanities and social sciences used mathematical and experimental methods to ensure the popularity, accuracy and stability of knowledge. For example, the study of happiness is a typical study of ethics, but the mathematical method has been used in a popular research topic—happiness index. Figure 1 shows the 20 happiest countries based on the happiness index recorded in the *World Happiness Report 2019* published by the United Nations. The index was obtained by weighted calculation of the points of respondents' assessment of 33 indicators in nine aspects: education; health; environment; management; time; cultural diversity and inclusiveness; community dynamism; inner sense of happiness; and living standards. Notably, this quantified index reflects the differences among countries in terms of people's sense of happiness. However, it shows only the average situation rather than the situation of each person.

However, the experimental and mathematical methods used in scientific research are not always rational; and, in human cognitive activities, the scientific methodology has no priority. During the development of scientific philosophy in the 20th century, scientific philosophers sought rational scientific methodology.

Logical positivism, as represented by Moritz Schlick and Rudolf Carnap, favours the scientific methodology of positivism, which means that only results directly or indirectly proven through logical analysis and testing can be regarded as scientific and rational. It denies subjective thinking and speculation in conventional philosophy that has no experimental basis.

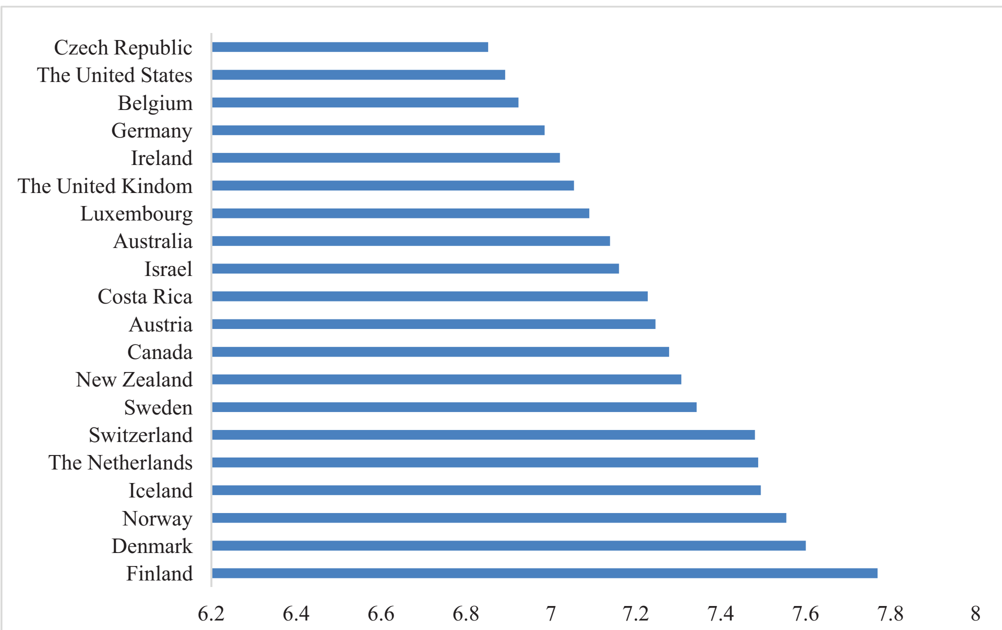

Figure 1: The 20 happiest countries in 2018, based on the happiness index
Source: Wang ST (2019)

Starting from the critical rationalism represented by Karl Popper, scientific methodology has transformed from the conventional empirical method into one that proves falsehood, uses guesses and refutation as means of argumentation, and is more practical.

In historicist philosophy of science, Thomas Kuhn developed the concepts of the scientific methodologies of historicism and relativism. According to him, in specific historical contexts, the scientific community adopts various paradigms of research, thus resorting to various kinds of scientific method. Imre Lakatos tried to avoid Kuhn's relativism, developing historicism into the methodology of scientific research programmes. He claimed that the research methodology should be changed according to the research programme. Paul Feyerabend claimed that science is an anarchistic undertaking and has no universal methodology.

The postmodernist philosophy of science represented by Larry Laudan and Richard Rorty seeks to surpass modernity by transforming scientific methodology from monism to pluralism, from rationality to irrationality, and from linguistic analysis to contextual analysis. To the scientific philosophers, scientific methodology transcends mathematical and experimental methodologies with the possibility of adopting any rational or irrational methodology. Thus, scientific research may also draw upon imaginal and intuitive thinking from the literary culture, for science not only concerns objectivity but also needs to rely on individual subjective factors and social factors to play its role.

4.2 A full understanding of utilitarian values of the scientific culture

It is important to understand the utilitarian values of the scientific culture to avoid the misuse of utilitarianism. In today's society, the utilitarian assessment of science has become a sort of institutional requirement, and is usually found in large-scale science. During World War II, the United States Government began nuclear technology research by launching the Manhattan Project. Since then, large-scale science has gradually emerged as the major mode of science development; notable examples have been the Apollo Program, the Human Genome Project and China's Chang'e Lunar Exploration Mission.

Sponsored by a nation, large-scale science involves enormous amounts of funds, giant devices and the concerted efforts of numerous personnel to conduct scientific research in the service of national missions and interests. This stands in sharp contrast with scientific research driven by the curiosity of scientists, which is small-scale science. However, the latter is often included in the former. The concept of large-scale science was first proposed by Alvin M Weinberg (1961). He found through comparisons that modern science was different from its predecessor in that it was large in scale and involved a large amount of money, so he called it large-scale science. Through scientific computation, Derek John de Solla Price subsequently discovered that some indices had shown exponential growth in publications in modern science, science journals, scientific discoveries, research funds and scientific researchers. This means modern science has gone beyond the conventions and entered a new era:

> Not only are the manifestations of modern scientific hardware so monumental that they have been usefully compared with the pyramids of Egypt and the great cathedrals of medieval Europe, but the national expenditures of manpower and money on it have suddenly made science a major segment of our national economy. (Price, 1965, pp. 2–3)

Modern scientific discoveries are being used in technical theories and products at an increasing rate. For example, optical imaging theory was proposed in 1727, but it took 112 years before the first camera was manufactured in 1839. By contrast, laser beams were discovered in 1960 and functional lasers were invented only a year later in 1961.

Today, one scientific finding is often applied in multiple areas, and each area may produce various new products and even bring about radical changes in technology or a technological revolution. In some areas, fundamental research and application development mostly go hand in hand. For example, genetic research and research on the structure of matter are application based and, when fundamental theories have been established, the development of related new technologies and new products begins immediately. Therefore, science has become a useful tool for driving national economic growth and social progress, and the utilitarian assessment has been accorded top priority as large-scale science becomes part of national programmes of scientific development.

Vannevar Bush (1945) noted in his famous report 'Science: The endless frontier' that 'Fundamental research is the foundation of research and development for the United States, driving economic growth and serving to improve life quality.' In 1994, this was clearly stated in a scientific policy white paper by the Clinton administration: 'The return from our public investments in fundamental science has been enormous . . . The principal sponsors and beneficiaries of our scientific enterprise are the American people' (Clinton and Gore, 1994). Moreover, fundamental research should reflect the requirements of national goals, for science serves national interests. In America, national core interests involve public health, social prosperity, economic growth, national security, environmental responsibilities, and improvement of the quality of life (Clinton and Gore, 1994). The development goal of science is like a road map that both matches the national goals of social prosperity and people's happiness and ensures support for and investment in fundamental scientific research.

The negative impact of utilitarianism is that people are concerned more about the application of scientific research, so many other factors are ignored during its development and application, including ethical restraints and the value of people and human society itself. This upsets harmonious relationships among people and between humans and nature and is contrary to humankind's pursuit of truth, kindness and beauty.

A case in point is the controversial birth of the world's first genetically edited babies in 2018. Chinese scientist He Jiankui claimed on 26 November 2018 that the world's first genetically edited human babies—twin girls given the pseudonyms Lulu and Nana—had been born in China. One gene of the twin babies was edited so that the babies would have natural immunity to acquired immune deficiency syndrome (AIDS) after birth. Yet reproduction in humans is a natural process, and the ethics of humankind do not allow artificially designed processes of reproduction. Although He's original purpose was to prevent diseases through medical solutions, the scientific community and many circles in society currently believe that his behaviour has seriously violated human ethics and scientific integrity. To eliminate the negative impact of utilitarianism in scientific research, peer reviews of science and technology and broad ethical, legal and social assessments should be conducted.

The report of the 18th National Congress of the Communist Party of China proposed an innovation-driven development strategy. The report of the 19th National Congress further stressed that innovation is the primary driving force of development and provides strategic support for building a modernized economic system. It is the historic mission of contemporary China to further socio-economic development via scientific and technological innovation. To develop a positive culture of science, we should advocate the spirit of science, spread scientific knowledge and methodology, and promote exchange and mutual benefit between the cultures of science and the humanities. This is the duty of contemporary scholars and has a bearing on the historic mission of creating a prosperous society in all aspects, the success of developing socialism with distinctive Chinese features in the new era, and the destiny and prospects of the Chinese nation as well as the rest of humankind.

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The development of a science popularization venue system and its impact on science culture dissemination

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Abstract

Science culture is an important part of the social culture system and has become a major force in shaping modern society. High-quality and sustainable innovation is not possible without a vibrant and engaging science culture. Science popularization (SP) venues serve as a bridge between scientists and the public and constitute an important platform for disseminating science culture. This study explores the organic connection between SP venues and science culture dissemination and the internal mechanisms of those venues by discussing practices of SP venues in China and elsewhere. It concludes that the SP venue system is becoming an important part of science culture dissemination. It offers specific suggestions on how to promote the development of the SP venue system to improve the quality, efficiency, effectiveness and scope of science culture dissemination.

Key words

Science culture, science popularization venue system, science culture dissemination

The concept of science being a kind of culture has been universally recognized. With advances in modern science, science culture has gradually become an important part of the social culture system and a major force in shaping modern society (Wang, 2015). In today's world, an excellent science culture is indispensable for a country or region to achieve high-quality and sustainable innovation (Wang et al., 2017). Many researchers think that science popularization (SP) in China today should be focused on exploring new approaches and new goals to popularize and disseminate science from the perspective of culture, and on systematically developing a science culture (Zheng and Wang, 2017). Sustainable scientific and technological innovation also calls for a robust science culture.

SP venues serve as a bridge that enables closer and smoother communication between scientists and the public. They provide places for SP work and platforms for science dissemination. The development of SP venues will greatly promote science culture dissemination and science education.

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1. Science culture, scientific spirit and SP venues

In the development of an excellent science culture, we need to have a full understanding of the relations between science culture, scientific spirit and SP venues.

1.1 Science culture and scientific spirit

What is science culture? Science culture is a new type of culture that has developed based on scientific practice (Li, 2019). It has been examined and expounded on by academics in different eras, from different points of view, and from both broad and narrow perspectives. Zheng Wei (2009) defines science culture narrowly as 'a set of ideas shared by the scientific community regarding how to engage in research activities', such as behavioural norms, values and ways of thinking. Han Qide (2012) considers science culture to be 'a set of values, modes of thinking, institutional regulations, codes of conduct and social norms developed in the scientific activities of the scientific community. It is the spiritual soil of science and technology and the source of innovative development.' The core of developing a science culture is to foster the scientific spirit.

With the development of science, science culture has permeated all sectors of society and developed a broad concept, which includes 'the public's understanding of and attitude towards science (and scientists); their judgment and pursuit of scientific values; their respect and support for and engagement with scientific activities; and young people's aspiration for scientific careers' (Zhou, 2019).

What is scientific spirit? The scientific spirit originated in ancient Greece and, following the historical periods of the Renaissance, the Enlightenment and the Industrial Revolution in Europe, gradually evolved into an ideological and cultural ethos. Aristotle gave the earliest description of the scientific spirit as 'philosophizing in order to escape from ignorance' and 'pursuing science in order to know, and not for any utilitarian end' (trans. 1993). Evidently, the earliest scientific spirit went beyond the utilitarian dimension of knowledge and was motivated by an interest in gaining knowledge and the desire to ascertain the absolute truth (Wu, 2011).

Merton thought that the values of modern science boil down to a set of four norms: universalism, communism, disinterestedness and organized scepticism (trans. 2003, pp. 363–364). With the development of modern science in China, Chinese academics have proposed different interpretations of the scientific spirit. Ren Hongjun (2002), the founder of the Science Society of China, defined the scientific spirit as 'the pursuit of truth'. Zhu Kezhen (1999) claimed that the scientific spirit is about the 'exploration of truth' and that the scientific attitude should be 'not blindly following, not going with the tide. . . concerning about what is right or wrong but not the gains or losses. . . being modest. . . [and] seeking truth from facts'.

Han Qide (2012) advocates scepticism and critical thinking in carrying forward the scientific spirit, stating that 'scepticism is the starting point of research, and critical thinking is the life of science.' The core value of the scientific spirit is the pursuit of truth, and its essence is rationality. Jiang Daoping made a comprehensive survey of Chinese and foreign academics' definitions and descriptions of the scientific spirit from various aspects, including epistemology, methodology, social norms, values and the humanities. He proposes that the scientific spirit comprises two dimensions:

> On the one hand, the scientific spirit is the sum total of faiths, values and behavioral norms formed in the process of humans' scientific inquiry; on the other hand, it is the ethos of the scientific community and what drives their pursuit of truth and innovation. (Jiang, 2017)

Scientists embody the scientific spirit and are direct practitioners of scientific methods and thoughts (Wang, 2015). As such, they play an irreplaceable role in carrying forward science culture. The spirit of the scientist epitomizes the scientific spirit and informs how the scientific spirit shapes the modern mind (Jiang, 2017). It is important to strengthen the role of scientists in developing science in the effort to promote science culture.

In contemporary China, the spirit of scientists encompasses not only free exploration, rational scepticism, truth-seeking and bold innovation but also patriotism, social responsibility and a sense of historical mission. The spirit is also shown in scientists' dedication to scientific research, as demonstrated by the Fudan University team, led by Professor Zhong Yang, that has spent more than 10 years on the Qinghai–Tibet Plateau researching biodiversity conservation. Also, data collected since 2018 shows that all research projects awarded the State Scientific and Technological Progress Award have had a research cycle of more than 10 years—demonstrating a true picture of the research world, in which long-term commitment and perseverance are required to achieve substantial research results.

1.2 Science culture and SP venues

SP venues play an important role in the dissemination of science culture. First, science culture is disseminated in the process of developing SP venues. Second, activities conducted by SP venues help to promote the integration of science culture with social culture and the globalization of science culture development.

1.2.1 Science culture dissemination in the development of SP venues

In the mid-18th century, when navigation technology made long sea voyages and explorations possible, explorers made expeditions to the far corners of the world and brought back all kinds of treasures to their home countries. Those private collections were often turned over to authorized third-party collections to be exhibited to the public. This was how the earliest museums emerged. The function of museums is to increase people's knowledge of nature. Museums serve to satisfy people's curiosity about nature by showcasing the results of previous scientific explorers and provide a platform for face-to-face communication among people.

At the beginning of the 19th century, as the number of scientific disciplines grew, there gradually came into being various types of specialized venues, including museums of science and industry. Those museums aimed to improve people's knowledge about industrial developments and scientific disciplines in different historical periods and about the connection between technological inventions and scientific discoveries, and to inspire the emergence of new knowledge. Specialized museums came into being in the mid-19th century with the development of scientific disciplines and various industrial sectors (Yin, 2015).

The earliest science centres appeared at the beginning of the 20th century. They promoted the development of science culture and science education through interaction with the public. This is a natural and rational process and is closely related to the advancement of scientific research and technological innovations. Science education is a strategic goal of governments and should be strengthened. Specifically, revealing scientific principles and promoting museum education through exhibits are crucial for shifting the focus of museums from exhibiting to educating (Schiele, trans. 2018).

China's current science and technology venue system includes science and technology museums; mobile science and technology stations; SP caravans; online science and technology museums; middle-school-based science and technology rooms in rural areas;

youth science workshops; community-based SP activity rooms; social organizations committed to SP work; and enterprises producing SP products. The venue system provides diversified platforms for effective communication among all stakeholders, including government agencies, scientists and the public. As one of those platforms, SP venues aim to maximize the value of scientific resources through interaction and sharing and to emphasize openness, innovation and the dissemination of the scientific spirit and science culture.

1.2.2 From a specific culture to a social culture: Science culture development as a global endeavour

At present, science culture remains somewhat confined to the scientific community. It needs to be better integrated with and grow in social culture. A survey of 10,403 scientists from the French National Centre for Scientific Research showed that, during the year when the survey was conducted, three-quarters of the scientists did not engage in any public activity, such as producing a popular science book, delivering a relevant lecture or making a relevant poster. About 70% of all public activities were participated in only by the most active 10% of scientists (Jensen, 2005).

Growing science culture from a community culture within the scientific community to a social culture that is constructed and shared by all people is a new approach and new requirement in efforts to involve the public in scientific and technological advancement and enable them to benefit from it (Zheng, 2019). The Science and Society Action Plan introduced by the European Commission in 2011 emphasizes that science culture development is part of the European Union's effort to improve its overall competitiveness and invest in the future. The United States has proposed an 'Innovation Strategy' to advance its national science culture system. Stanford University and the Johns Hopkins University offer elective courses in science communication for undergraduate and postgraduate students (Brownell et al., 2013). China sees scientific and technological innovation and SP as the two wings of its innovation-driven development strategy, thus placing both in equally important positions.

By organizing popular science events such as 'popular science lectures', 'face-to-face with scientists' and 'nights of science', SP venues provide opportunities for the public to communicate with scientists in person and experience the scientific spirit personally. Those venues encourage the participation of scientists in developing popular science courses, making exhibition plans and conducting venue–university and venue–enterprise cooperation, thus making their latest research results known to the public, helping to increase the scientific soundness and authority of science education programmes, accelerating science outreach and the integration of science culture with social culture, and improving the quality of science culture dissemination.

2. The SP venue system as an important part of science culture dissemination

The SP venue system functions as both a source and a vehicle of science culture dissemination.

2.1 SP venues are wellsprings of science culture dissemination

In achieving their missions and objectives, SP venues use permanent and special exhibitions. They are also becoming a vital complement to school education.

2.1.1 The missions and objectives of SP venues: Integration of science and culture

As the wellsprings of science culture dissemination, what can SP venues provide for the public? Many SP venues in China and in other countries have mission or objective statements that highlight efforts to 'discover, interpret, and disseminate—through scientific research and education—knowledge about human cultures', 'develop scientific attitude and temper, and create, inculcate and sustain a general awareness among the people', and 'advance knowledge for the benefit of society' (Table 1). These statements demonstrate the principle of integrating venue development and science culture dissemination.

The Shanghai Science and Technology Museum is a pioneer in thematic exhibitions that highlight exhibition themes and expansive thinking. Based on the science, technology and society (STS) model, with its focus on 'fostering a critical, sceptical and explorative scientific spirit', the museum is committed to 'increasing national scientific literacy and building an integrated platform of science and the humanities'. It does so by integrating three venues—the Shanghai Science and Technology Museum, the Shanghai Planetarium and the Shanghai Natural History Museum—that cluster together to span the past, present and future, and fuse science and technology with nature and astronomy (Wang and Song, 2015).

2.1.2 Permanent exhibitions covering all related themes

Permanent exhibitions are the core of museums. They include a wide range of themes and diversified content that integrate science, culture and history. Permanent exhibitions are designated to express the fusion of science and art, and a transition from static description to dynamic display. They aim to strengthen people's understanding and appreciation of objects and phenomena in interactive

Table 1: Selected SP venues and their missions or objectives

Venue	Mission/ objective
French National Centre for Scientific Research	Mission: To advance knowledge for the benefit of society.
Deutsches Museum	Mission: We present science and technology as something to be seen and experienced and illustrate its cultural significance by exhibiting unique masterpieces. We inspire people to play an active role in shaping the future.
Science City of Kolkata	Objective: To develop scientific attitude and temper and to create, inculcate, and sustain a general awareness among the people.
Polytechnic Museum in Moscow	Mission: We create the territory of enlightenment, free thought and daring experiment.
H.R. MacMillan Space Centre in Vancouver	Mission: To educate, inspire, and evoke a sense of wonder about the universe, our planet and space exploration.
American Museum of Natural History	Mission: To discover, interpret, and disseminate—through scientific research and education—knowledge about human cultures, the natural world, and the universe.
Carnegie Museum of Natural History	Mission: To increase the scientific understanding and public knowledge of nature and human cultures.
Shanghai Science and Technology Museum	Mission: To increase national scientific literacy and build an integrated platform of science and the humanities.

Note: This information was obtained from the official websites of the institutions listed in this table.

experiential settings, which facilitates the development of scientific thinking and the scientific spirit and people's reflection on them.

The China Science and Technology Museum comprises five permanent exhibition halls: 'Science Paradise', 'Glory of China', 'Explorations and Discoveries', 'Science & Technology and Life' and 'Challenges and the Future'. The Shanghai Science and Technology Museum has permanent exhibitions including 'Cradle of Designers', 'Light of Wisdom', 'Home Planet', 'Information Age' and 'Academicians Wall'. The Guangdong Science Center's permanent exhibitions include 'Digital Park', 'Transportation World', 'Space Dreams' and 'Perception and Thinking'. The National Museum of Emerging Science and Innovation of Japan has permanent exhibitions including 'Environment and Cutting-Edge Science', 'Technological Innovation and Future', 'Information Technology and Society' and 'Life Sciences and Humans'. The California Science Center has permanent exhibitions including 'Science Plaza', 'World of Life', 'Creative World' and 'Ecosystems'. These permanent exhibitions demonstrate the historical process of scientific development, convey scientific methods and the scientific spirit developed in the process, and speak of the integration of the traditional and the modern and the fusion of science and the humanities.

2.1.3 Special exhibitions dedicated to frontier topics

In addition to permanent exhibitions, science museums also hold special exhibitions in the form of original exhibitions and introduced exhibitions. This juxtaposition of exhibits not only increases their appeal to and influence on the public but also improves their ability to disseminate science culture. Special exhibitions concern front-line scientific issues and the latest scientific achievements, as well as 'hot' topics related to people's lives, with a view to provoking public response and thought.

Table 2 lists the titles and themes of some special exhibitions hosted by selected Chinese and overseas science museums during the past five years. Some of the exhibition themes focus on scientific theories; some others display the development and application of science and technology, and the integration of different fields such as science, art and culture, allowing visitors to experience and understand science from different perspectives. For example, the Shanghai Science and Technology Museum's special exhibition 'How dinosaurs come alive' was staged at 15 places, including eight science museums and seven commercial plazas, in a nationwide tour across China within one and a half years. The exhibition extends its scope from the museum to society and covers many cities in east and west China, producing a widespread influence on the public and promoting the dissemination of science culture.

2.1.4 Museum education as an effective complement to school education

Museum education has become more diversified through the application of new media and new technologies. It plays an increasing role in informing the public of the latest scientific and technological advancements and in disseminating science culture. According to the 2017 national SP statistics of the Ministry of Science and Technology, SP activities were engaged in 771 million times by members of the public (that is, 771 million person-times); 880,100 popular science lectures were accessed 146 million person-times by members of the public; 48,900 science competitions were organized; and 2,713 international exchanges were accessed 702,100 person-times by members of the public (Wang, 2018a). Museum education is a form of open, informal education that is different from regular school education, and the two can be organically combined to create a public science education system.

Table 2: Special exhibitions of selected venues, 2015 to 2019

Venue	Exhibition name and theme
American Museum of Natural History	Nature's fury: The science of natural disasters Life at the limits: Mythic creatures Countdown to zero: Defeating disease Unseen oceans
Palace of Discovery	100 years of the theory of general relativity Beautiful and fragile planets From the past to the present When mathematics meets the game The infinite future
Natural History Museum, London	Tiny space explorers: A sensory experience; 500 years of robots Top secrets: From passwords to cyber security Light of India Autonomous driving
National Museum of Emerging Science and Innovation	The art of Disney: The magic of animation Move into the wildlife Design Ah! Exhibition in Tokyo 'Under construction'—Is it safe to enter!? Heavy machinery in use!
National Museum of Nature and Science, Tokyo	Leaps in evolution—Tracing the path of vertebrate evolution Ancient civilization of the Andes Wine the exhibition Bless the future of the Earth World Heritage Lascaux—Cave paintings left by the Cro-Magnon Landscape science exhibition
Natural History Museum, Rotterdam	101 poppies a day Plastic bodies: Evolution caused by waste Stories of animals and death Swan songs X-ray art Plants, animals, and waste on sidewalk tiles Rotterdam countryside Barnacles and cute dirt
Polytechnic Museum	Journey of impressions Maximum approximation High-tech: Shukhov and mesh structures Noise reconstruction Gifts to sheiks Alice in the land of science The Aegean Sea: The genesis of an archipelago Inventing the bicycle
Shanghai Science and Technology Museum	Da Vinci machines exhibition The cave paintings of Lascaux The fusion of science and art Blue and white: The glory of the Silk Road Starry sky illumination Genesis eco photography exhibition Year of the Tiger exhibition Year of the Snake exhibition How dinosaurs come alive

Note: Information on special exhibitions was obtained from the official websites of the museums listed in this table.

By organizing activities such as popular science lectures and thematic exhibitions that debunk pseudoscience and falsehoods, SP venues can help the public increase its scientific literacy.

‘Popular Science Forum’ is a signature popular science programme of the Shanghai Science and Technology Museum. The forum focuses its content on frontier technologies, scientific events and hot topics related to people’s lives and emphasizes the integration of science and the humanities and the arrangement of interactive online and offline activities. Since its launch in 2009, the forum has held more than 130 events to which more than 230 experts, including Nobel laureates and academicians, have been invited. These events have benefited an online and offline audience of more than 10 million person-times.

‘Meet@the scientist’ is another signature programme of the museum launched in 2019. Each month, the museum will select a renowned scientist born in that month as the star scientist and organize activities to showcase the scientist’s scientific spirit and achievements. The programme aims to foster a social atmosphere that embraces science and honours scientists. It provides the public with opportunities to get familiar with scientists and is an effective way to disseminate science.

2.2 SP venues are an important vehicle of science culture dissemination

SP venues are places where science culture is disseminated, and they are applying new technologies and new formats to achieve their objectives and are making extensive use of the internet.

2.2.1 SP venues provide spaces for science culture dissemination

SP venues provide spaces for activities of varying sizes and disciplines and for the public to communicate and learn. Of the 20 most popular museums in the world in 2018, as published by the Themed Entertainment Association and AECOM, five were natural science museums, which received visits of 25.63 million person-times (Rubin, 2018). Large comprehensive SP venues in China—the China Science and Technology Museum, the Shanghai Science and Technology Museum and the Guangdong Science Center—have average visits of more than 3 million person-times annually. Visitors are from all age groups and backgrounds, indicating that SP venues are appreciated by the general public and have become the main places of science culture dissemination.

According to the 2018 Chinese national scientific literacy survey, the most visited SP venues in China were zoos, aquariums and botanical gardens (58.1%); science and technology museums and science centres (31.9%); and natural history museums (29.5%) (He et al., 2018). All percentages were higher than the 2015 percentages for those venues, which indicates growth in the use of SP venues, public engagement in SP activities, possibilities of acquiring scientific knowledge and information and science culture dissemination.

Besides venue-based exhibitions and education activities, SP venues have also developed some special forms to reach wider audiences in remote areas, such as SP caravans on exhibition tours, mobile museums, and science and technology rooms in rural middle schools. These flexible forms effectively expand the scope of science culture dissemination and benefit wider audiences.

From 2000 to 2018, the China Association for Science and Technology dispatched 1,538 SP caravans that travelled a total of 37,103,000 kilometres nationwide and offered 217,000 activities that reached 230 million person-times (CSTM, 2019). In the same period, the China Mobile Science and Technology Museum Programme dispatched approximately 420 sets of exhibits for 3,260 exhibitions that reached approximately 117 million person-times (Qiu, 2019). In the period from 2012 to 2018, 708 science and technology rooms were established in rural middle schools and directly reached and benefited more than 3.02 million person-times (Mao, 2019). These figures speak volumes about the fact that SP venues have become a main vehicle of science culture dissemination.

2.2.2 The application of new technologies in SP venues helps to expand the scope of science culture dissemination

In the process of constructing intelligent SP venues, many museums use new technologies, including remote video, virtual tour guidance, holography, virtual reality and augmented reality to develop more engaging visual products that appeal to the public and bring science to wider audiences, thus narrowing the gap between different regions and achieving balanced deployment of scientific resources and widespread dissemination of science culture.

For instance, the Shanghai Science and Technology Museum has introduced a remote video system that delivers real-time images of wild elephants in Yunnan to museum visitors in Shanghai. The new Shanghai Natural History Museum (a branch of the Shanghai Science and Technology Museum) uses augmented reality technology to animate a dinosaur skeleton in its collection, return it to the museum's original premises, and then place the animated skeleton on a time travel platform to its habitat 66 million years ago. This use of technology best expresses the inheritance of science culture and the vision of a return to nature.

New technologies such as information and communications technology and artificial intelligence facilitate the creation and dissemination of scientific knowledge and make it possible for people to experience and understand science and acquire knowledge at any time and from anywhere. By enabling everyone to create and share information, these technologies have been able to effectively promote science culture dissemination.

2.2.3 New formats of the popular science industry keep emerging to meet diversified needs

SP venues have been trying to explore ways to integrate science culture and creative industries and gradually introduce new formats of the popular science industry. Videos are a popular medium with the public, and many institutions around the world are making efforts to produce popular science videos.

The Shanghai Science and Technology Museum began developing popular science videos in 2009 and has carved out a new path for science communication. So far, the museum has produced 11 films and 17 documentaries on a diverse collection of popular science topics, including palaeontology; living animals; land and sea creatures; rare and endangered species; and biodiversity conservation. The series of documentaries on rare species highlights the role of science in documentary production by presenting high-quality scenes, conveying the concept of ecological civilization, displaying the achievements and ideas of Chinese scientists, and promoting nature conservation. The series of 4D films on the major achievements of China's basic research in palaeontology present the survival and evolution of animals and plants in the Palaeozoic, Mesozoic and Cenozoic eras. The focus of these films is on scientific themes, including the life cycles, environmental adaptations and coexistence of different species. The appearance of popular science films on cinema screens has promoted the development of such films and expanded the boundaries of the popular science industry.

2.2.4 The internet promotes the integration of the SP cause with the popular science industry and the dissemination of science culture

The internet has become a new platform for science culture dissemination: on the internet, everyone is a communicator and messenger of science. In 2018, the number of internet users in China reached 829 million, and fixed and mobile internet connections were the primary channels to access scientific and technological information for 76.3% of citizens (He et al., 2018). SP venues are not yet able to meet the strong public demand for scientific resources; this shortfall calls for mobilizing all social forces to develop the popular science industry and create opportunities and exchange platforms for science culture, on the basis of which an integration of the SP cause and the popular science industry would be achieved (Ren et al., 2018).

The development of internet technologies has advanced the cultural industry and helped to integrate the scientific spirit and scientific methods with cultural industry content (Zeng and Gu, 2010). China's national policy has explicitly advocated the development of the cultural and creative industry in SP venues with a view to developing science culture as both an industry and a public good. With regard to the development of venues, the cultural and creative industry can help to increase their social influence and competitiveness, enrich the cultural meanings of their collections, improve people's understanding of science culture, make art and science part of everyday life and make cultural innovation an intangible property. With regard to the external environment, driven by the 'internet plus', in-depth integration is a trend in future development; and, with increased domestic cultural consumption, enthusiasm for cultural development has reached a peak, boosting the cultural and creative industry and promoting social development (Wang, 2018b).

3. Conclusions and suggestions

Here we offer some suggestions for promoting science culture dissemination through the development of SP venues.

3.1 Build an SP venue system committed to open access to scientific resources to improve science culture services

As a first step, the development of an SP venue system should be included in the national cultural system to promote science culture dissemination. This step was taken at the First International Symposium on the Development of Natural Science Museums under the Belt and Road Initiative hosted by the Chinese Association of Natural Science Museums. At the symposium, the *Beijing Declaration* was adopted to promote long-term cooperation between SP venues in different countries and to develop exchange platforms for popular science exhibitions, education programmes and human resources among venues in 'Belt and Road' countries.

Second, diversified sharing platforms should be created to improve resource development and access and to maximize the efficiency of science culture dissemination. Cooperation between the Shanghai Science and Technology Museum and the Dunhuang Research Academy is a good example in this regard. The museum introduced popular science lectures and performances that integrate science, the humanities and the arts into the academy. In addition, the two organizations have also made extensive arrangements for personnel exchanges, academic exchanges and popular science education in order to attract more young people to the academy and to promote further development of the splendid cultural heritage of Dunhuang. Moreover, the museum took its original popular science films and exhibits to remote regions, including Xinjiang, Tibet and Inner Mongolia, and provided training for local SP workers in conducting science education activities. These representative and inclusive endeavours are geared to promoting science culture in a sustainable way and to maximizing the efficiency of science communication.

Third, all social forces should be directed to further increase the openness of the SP venue system. Enterprises, foundations, non-government organizations and other social forces have been increasingly involved in developing SP venues. For example, the Shanghai Science Education Development Foundation has provided comprehensive support to the Shanghai Science and Technology Museum since its inception, contributing to exhibits collection, education programme development, large-scale event planning and mobile museum development. In recent years, an increasing number of Chinese and foreign companies have provided support, including funds and exhibits, for special exhibitions and education programmes in SP venues. As part of this trend, a growing number of commercial plazas have established cooperation with SP venues and become new spaces for science communication. They provide places or funds for popular science exhibitions and education activities that are open to the public, allowing people to experience an atmosphere of science culture in their leisure time.

3.2 Strengthen museum education and special exhibitions to increase the efficiency and timeliness of science dissemination

Research on exhibits and specimen collections provides a strong foundation for museum exhibitions. Efforts can be made in the following two directions.

First, tap into the stories behind classic and precious exhibits and transform them into educational resources. In July 2018, the Shanghai Science and Technology Museum, Shanghai Museum and Shanghai History Museum launched the 'Centurial collections—the history of museums in Shanghai' special exhibition. The exhibition presented a choice collection of 83 animal specimens, seven categories of anthropological specimens and 17 books, displaying the integration of science, culture, art and history and representing an exploration of the history of Chinese museums and a compelling expression of Shanghai's deep cultural heritage.

Second, try to present the latest scientific achievements in exhibitions and other activities. For example, only hours after the paper 'A feathered dinosaur tail with primitive plumage trapped in mid-Cretaceous amber' was published online in *Current Biology* on 9 December 2016, its two authors appeared on the New Questions Salon programme at the Shanghai Natural History Museum to introduce the study to the audience and discuss such topics as the methodology and the scientific spirit included in their research. The speed at which this communication took place is a testament to the timeliness of science culture dissemination. Five months later, the Shanghai Science and Technology Museum launched the special exhibition 'How dinosaurs come alive' based on the study's findings, demonstrating how efficiently scientific findings can be transformed into scientific resources.

3.3 Put in place a sound administrative system of SP venues to expand science culture dissemination

In the process of globalization, SP venues face the challenge of steadily improving their administrative mechanisms and promoting science culture dissemination.

The Association of Science Popularization Venues of the Yangtze River Delta Region was initiated by eight organizations, including the Shanghai Science and Technology Museum. The association includes 78 SP venues and 80 organizations, including universities, enterprises and public institutions. It is united by the values of mutual consultation, sharing and win–win, and is committed to conducting in-depth exchanges in popular science education, exhibition, collection and research; forming an industry–education–research–application and exhibition chain; promoting coordinated development among museums, between museums and enterprises, between museums and research institutes, and between museums and universities; and achieving the integrated development of the Yangtze River Delta Region as a world-class megalopolis.

On National Popular Science Day in 2018, the association launched a special exhibition titled ‘Into the blue oceans: Marine popular science exhibition’ that staged simultaneously in eight museums. The exhibition presented a visual feast of knowledge on the marine world that reached wide audiences and successfully demonstrated how well science culture can be disseminated in the region.

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The influence of the traditional Chinese technological ideal on the development of modern technology

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Abstract

The traditional Chinese technological ideal focuses on harmonious relationships among humans; between humans and nature, society and tools; and between the body and the mind in technological activities. These basic characteristics contributed to technological innovations and progress in the era of the natural economy, but, to some extent, they hindered the transformation of technology from the traditional to the modern mode and the progress of modern technology in China. It is necessary to understand the essence of the traditional Chinese technological ideal to reflect on and eliminate its historical limitations, and to better coordinate the relationship between technological development and social life to benefit human survival and prosperity.

Key words

Traditional Chinese technological ideal, modern technology, harmony, dominating technique by the Tao

The traditional Chinese technological ideal, rooted in traditional Chinese culture, features the aspects of basic categories, ideological systems and research methods. This means that it emphasizes the relationship between related elements, such as a harmonious relationship between the operator and the tool, and the demands and feelings of the subject in technological activities. From this perspective, the traditional Chinese technological ideal can be understood as a harmonious technological ideal that has exerted a profound influence on the progress of traditional technology and has inspired the development of modern technology.

1. Basic characteristics of the traditional Chinese technological ideal

The traditional Chinese technological ideal features harmonious relationships among humans; between humans and nature, society and tools; and between the body and the mind in technological activities.

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1.1 Harmony between humans and nature—'conforming to nature'

The traditional Chinese technological ideal takes the natural features of things as the highest order, and adaptation to the laws of natural changes as a priority in technological activities. 'Nature' in this concept is the natural state towards which technological activities tend, rather than the state caused by human behaviour.

Laozi said: 'Man models himself after the Earth, the Earth models itself after Heaven, Heaven models itself after the Tao, and the Tao models itself after Nature' (Chen, 2006, p. 169). 'Man models himself after the Earth' means that human practice should adapt to the laws of natural changes on the Earth. 'The Earth models itself after Heaven' means that everything on the Earth should adapt to the changes in the weather, which is most apparent in farming. 'Heaven models itself after the Tao' means that changes in the universe follow the intrinsic Tao; that is, the reasonable and optimal way to create and nurture. 'The Tao models itself after Nature' means that the reasonable and optimal way of the Tao must be in accordance with the inherent nature of things (Wang, 2005).

'Conforming to nature' means that, while engaging in technological activities, humans must follow the Tao's guidance and change the natural world in accordance with the nature of things rather than passively waiting and obeying whatever comes. Thus, dynamic stability between humans and nature can be established, and the sustainable development of human beings can be guaranteed. According to the optimal requirements of the Tao, conforming to nature means making full use of the power of nature to achieve the expectations of human beings, with minimal human input and maximum profit. If technological activities are guided by the Tao to obtain an integrated and long-term benefit relating to the survival and development of human beings, any change and remaking of nature is justified and reasonable.

Ancient Chinese engineering technology conformed to nature by making the maximum use of natural elements in operations and making full use of renewable resources in nature. For example, ventilation, drainage, support, backfilling and even the recycling of biological vulcanized iron were considered during coalmining to avoid significant environmental pollution (Liu and Zeng, 1991, pp. 31–33). Meanwhile, the conflicting relationship between the early development of modern Western technology and the ecology is widely known. Due to overconsumption of nonrenewable resources, and the replacement of natural elements by artificial elements, environmental pollution became a serious problem.

1.2 Harmony between humans and society—'statecraft ideology for practical utility'

'Statecraft ideology for practical utility' is a guiding principle for the choice of traditional Chinese technology and the criterion for the social assessment of technology. 'Statecraft ideology' means that technological development prioritizes the design of the political system, and 'practical utility' assumes a secondary role and must be subject to the requirements of statecraft ideology. The standard of practical utility is not based simply on economic interests, but on the unity of economic and social benefits. Economic demands should be strictly confined when they tend to threaten the stability of social structures, even if certain technological activities have practical value and can yield considerable economic benefit. Such a principle is not likely to be accepted in Western society, which emphasizes industrial and commercial gains. This regulation, however, has a specific significance in traditional Chinese culture and is important for the construction of a harmonious relationship between humans and society in technological activities.

If emphasis is placed on material wealth in the manufacture and circulation of luxury goods for the lavish pleasure of a few, it will result in significant social polarization and instability in the natural economy. Therefore, to achieve the goal of statecraft ideology for practical utility, the idea of restraining extravagance must be considered an essential measure to ensure a harmonious relationship between the development of technology and society. The fight against diabolic tricks, wicked practices, extravagance and waste has been a major theme since before the Qin Dynasty in tackling problems and conflicts in the development of technology and society. For practical purposes, ancient Chinese technological products were designed in line with consumers' convenience, with the aim of preventing accidents. This emphasis on practical objectives served to save manpower and material resources and to rectify the general social mood in the natural economy. On the contrary, in the early stage of the market economy, modern Western technology considered economic interest the primary objective and neglected the convenience of the operators and consumers, the conservation of resources, and the social benefits of technological products to a certain extent.

1.3 Harmony among humans—'dominating technique by the Tao'

Traditional Chinese technology emphasizes moral constraints on the application of technology. The idea of 'dominating technique by the Tao' is a principal requirement that considers the Tao as the highest morality, and technique as technological activities to achieve economic interests. This pre-Qin Confucian concept stresses the macrosocial effects of engineering technology and strives to constrain and eliminate the negative impacts of inappropriate applications of technology and to achieve a harmonious relationship among humans in their technological activities.

Confucius argued in *The Analects* that one should 'set your heart on the Tao, base yourself on virtue, lean upon benevolence and seek relaxation and enjoyment in the arts' (as cited in Yang, 1980, p. 67). Morality is here taken as the ideological basis of all social activities, including activities concerning technology. The Mohist argument of 'dominating technology by morality' focuses on moral constraints on the individual craftsman in technological activities. Yu the Great, who conquered the great flood in Chinese legend, is the personification of wisdom, perseverance and selfless devotion: a highly glorified example for the Mohist disciples (Mei and Li, 1992, pp. 88–89, 285). Zhuangzi said in *Zhuangzi* that 'most Mohist disciples should take coarse clothes and straw sandals, working endlessly day and night to bring vexation on themselves' and that 'those who cannot follow this way of life should not call themselves Mohists' (as cited in Guo, 2005, p. 196).

Since the Qin Dynasty, a generally stable moral code has been established with the development of technology, which requires benefiting the country and the people as the ideal in the application of technology. It also requires that technical staff in all trades work hard and with care, respect their superiors and abide by the rules in all professional activities. Most people of later generations who learned skills in the teacher–apprentice system followed this tradition. Only those who met these requirements in technological activities were called 'people with the Tao'. Many well-known ancient Chinese craftsmen were known to have high moral character. In addition, skills and moral education were considered to have equal importance in the process of apprenticeship. The ancient Chinese technological morality, which values loyalty above material gains, forms an obvious contrast to the modern Western utilitarian ethical ideal.

1.4 Harmony between humans and tools—'inventing implements by imitating images'

Technological inventors in ancient China followed the principle of 'inventing implements by imitating images', which emphasizes that the duty of Heaven is implemented by humans. This principle derives from an idea in *Zhouyi-Xici*: '*Zhouyi* contains the following four aspects of the Tao of sages: speaking by imitating principles, acting by imitating changes, inventing implements by imitating images, and telling the future by imitating divination' (Guo, 2005, p. 47). As an ideological principle, 'inventing implements by imitating images' aims to encourage the craftsman to learn from nature and abstract the essential image from the natural world, in order to acquire an inner vision of inventions. The operator's physical strength and convenience are considered when deciding the size of facilities to achieve the optimal effect. Such ideological characteristics can be seen in many inventions throughout Chinese history. A typical example is the 2nd-century invention of the crank handle—a tool adopted in the West more than a thousand years later. The crank handle was used in rotary winnowers and other machines. With the crank vertical to the wheel, the rotation of the wheel could save much energy (Temple, trans. 1995, p. 82).

The traditional Chinese technique also attends to the operator's physiological characteristics in the design and method of operation. For example, it is recorded in *Kaogong Ji* (*The Artificers' Record*) that in the design of carts, the diameter of the wheel catered to human height and convenience in getting on and off. Based on this design, the best ratio of the round track wheel and other parts of the carts was worked out (Liu, 1990, pp. 551–552). Shen Kuo's *Mengxi Bitan* (*Dream Pool Essays*) also states that palace steps should be designed in accordance with the scale of the royal sedan chair. To ensure convenient operation of the vehicle, the steps were categorized into those for steep roads, slow roads and flat roads (Shen, trans. 1995, p. 127).

1.5 Harmony between the body and the mind—'integrating art and technique'

A fable in *Zhuangzi* titled 'The dexterous butcher' tells the story of an ideally harmonious relationship between the body and the mind in technological activities. In the fable, when Paoding began his career as a butcher, he saw an ox as an undivided whole, but three years later he could see the bones, flesh, tendons and gaps between the joints. By carving into the gaps when slaughtering an ox, his knife remained sharp for years. 'Dancing' the knife in accordance with a rhythm, he could carve up an entire ox in an instant and appreciate his work in a calm and natural mood, like an artist.

Paoding's skill depended on a tacit agreement between the mind and the hand and high integration of deep inner experience with skilled handicraft. Many outstanding craftsmen throughout Chinese history possessed such skills. Idiomatic Chinese expressions such as 'craft', 'skills' and 'consummate skill' all reflect the ideal of integrating technique and art. Craftsmen would regard technological activities as the art of mental and physical pleasure, and thus could endure hard work that needs labour-saving, high-efficiency and graceful movements, and finally produce marvellous products. By contrast, the inventors of machines in the West did not fully consider the psychological needs of the workers in the early stages of the Industrial Revolution, leading to individual skills submerging in technical regulations and reflecting neither the intrinsic value of technique nor mental or physical pleasure.

The traditional Chinese technological ideal helps to eliminate or mitigate unnecessary conflicts among elements in technological activities. The harmonious technological ideal explains why traditional Chinese technology was able to reach an advanced standard in many fields from the 1st to the 14th century.

Similarly, the ideal of a harmonious relationship among Heaven, Earth and humans has contributed significantly to the sustainable and stable development of farming over thousands of years in the history of China. In particular, the concept of land conservation makes long-term farming possible while maintaining a rich diversity of species and a fertile supply of land resources.

Moreover, the harmonious technological ideal also helped to achieve a number of technological innovations, such as the collar harness for horses, the oar, the watertight bulkheads of ships, and the bed censer, all of which prove the harmonious relationship between humans and facilities. Hydraulic engineering achievements, such as the Dujiangyan irrigation system and the Lingqu canal, which made full use of local natural resources and minimized environmental changes, also embody the harmonious relationship between humans and society and between humans and nature.

2. The limitations of the traditional Chinese technological ideal

The traditional Chinese technological ideal has contributed a lot to technological inventions and progress in the natural economy. However, it also constrains the transformation from traditional to modern technology. Compared to modern technology, traditional Chinese technology has the following limitations.

2.1 Poor at transforming nature at large scale and weak in competition

The ideal of 'conforming to nature' is significant in eliminating and avoiding the undesirable side-effects of technological activities. However, it can find only a narrow application and can be realized only within the framework of the natural economy. Thus, it cannot meet the demands of continuous development of human society.

With limited resources in the natural economy, the traditional ideal could ensure healthy and orderly progress in technological activities with a slow pace, stronger cyclic utilization and a poor sense of competition. These defects would lead to the failure of local and traditional Chinese technology when confronted with challenges from modern Western technology. The ideal of 'conforming to nature' prevents humans' process of transforming nature and is weak in competition, leading to difficulties in its progress.

Traditional Chinese technology's inefficiency in transforming nature at large scale is manifested in its emphasis on human power while ignoring the use of natural power through technological innovation. For example, China started to smelt iron using coal in the Han Dynasty and with coke in the Ming Dynasty (a century earlier than Europe), and oil and gas were first discovered during the Han Dynasty. However, the potential of all those resources was largely ignored and they were used only at a small scale (Temple, trans. 1995, pp. 30–33). In another example, mills to manufacture gunpowder were established in the Northern Song Dynasty. Despite the fact that firearms have tremendous power, the use of gunpowder was restricted, and edged and pointed arms remained the major weapons on the battlefield at that time.

Manual labour was dominant in various technological activities. The motivation for this was based on Chinese economic and cultural beliefs. First, manual labour itself was not a commodity in the natural economy, and thus the development of natural forces that occurred in the commercial economy was restricted in ancient China. Second, orthodox Confucianism seriously separated the craftsman tradition from the scholar tradition. Most illiterate craftsmen found it difficult to grasp systematic and theoretical knowledge for technological advancement and for economic and political gains. With low social status and poor economic conditions, the craftsmen had no power to engage in the invention of large-scale machinery. In addition, manual labour was regarded as fundamental to life and as a means of spiritual purification. Winning through the development and use of natural forces was regarded as ‘opportunism’ and was severely restricted.

2.2 Conservative and empirical in terms of practical objectives

The practical concept of traditional Chinese technology is conservative. Once the concept has been set, people are usually required to adapt to it and pass it on for generations. An emerging technology can be excluded for being ‘impractical’ when users are unfamiliar with the devices that use the technology. Skills and products relating to new technology can be upgraded quickly in the Western market economy, but that could take a long time in ancient China. The promotion and use of a new technology relies heavily on certain social and political factors. Such practical objectives may pose barriers to technological innovation.

With intense relativity and particularity, the practical objectives depend mainly on people’s intuitive grasp and assessment. Thus, the standardization of the products using new technology is rare, making them difficult to circulate and transform into mass production. Without standardization, the craftsman needs to make more effort to trim and polish the parts of a machine in order to make them match with each other. With an increasing particularity in this process, some parts will be difficult to replace after damage, and thus the profit from maintaining the machine will be unimaginably low. Moreover, the use of traditional technology is often empirical, and considers the absence of accidents as the major target. This has had negative effects on the development of modern Chinese technology.

Concerns about waste prevention in the process of production occurred due to ignorance of modern technology. For example, in the early stages of the introduction and development of modern technology, the parts of certain machines were polished to cope with the problem of assembly precision. Some machines were overused without due maintenance. Some mechanical components therefore failed to maintain the required standard due to wear and tear. The majority of administrators were reluctant to renew technological standards even though there was a desperate demand in the market.

The traditional Chinese concept of technology is superior to the Western concept in its coordination of technological and social relations and its avoidance of excessive exploitation of resources. However, it is inferior in its failure to adequately utilize natural resources. Based solely on experience, it is challenging to avoid arbitrary interpretation and self-interest. In addition, the traditional Chinese concept of technology becomes an obstacle to the dissemination of the scientific spirit, which is regarded as the ideological basis for modern technology.

2.3 Neglect of equipment renewal

In ancient China, the first people who invented tools were regarded as saints. They included Shen Nong, the inventor of the plough; Chui, the inventor of the rule and yardstick; Gong Gu and Dai Di, the inventors of the boat; and Ji Guang, the inventor of the wooden vehicle (Liu, 1988, pp. 10–14). However, no major improvement was made to those inventions for a long time. People of later generations just passed them down without making any changes. This is what one Chinese saying signifies: ‘The wise men create tools. The skilled workmen take them as inheritance, and pass down their essentials to the following generations. This is known as craftsmanship.’ (Wen, 1993, p. 117).

Moreover, scrupulously following ancestral doctrine was a basic requirement within the teacher–apprentice system in ancient Chinese craftsmanship. Neither technology nor tools were allowed to be changed or replaced, and those that were privately improved would be categorized as ‘foxy contrivances’. The craftsmen therefore developed a tradition of maintaining the start-up system and following its rules and regulations. For example, the wooden plough and the spinning wheel were invented in the Han Dynasty and did not change much for a thousand years. This implies that those artefacts had been invented in the light of the convenience of the operator, but were not developed further.

Lack of renewal of equipment led craftsmen to make more effort to improve their personal skills, which were difficult to popularize because they were owned by individuals. Therefore, once those skills were lost in time, craftsmen of the future were unable to replicate previous designs. In addition, the handling of tools was often a matter of individual skills. All professionals in ancient China had their own dedicated tools and equipment. This helped the development of individual skills but greatly restricted improvements in those tools. The vast majority of tools and machinery were locally manufactured based on demand, and multiple-skilled craftsmen could make various mechanical tools themselves. Moreover, there was no professional standard for the manufacture of tools and machines, making it hard to make any improvement in precision and efficiency. Thus, the road to transformation from the handicraft industry to modern industry was blocked.

3. The contemporary value of the traditional Chinese technological ideal

Most concepts of traditional Chinese technology that were rooted in the natural economy could not keep step with developments in modern technology. However, certain aspects of those concepts are valuable in contemporary social life.

3.1 ‘Conforming to nature’ and reforming nature in the modern sense

It would be helpful to reform nature effectively by following both the traditional ideal of conforming to nature and the idea of modern industrial civilization. The concept of conforming to nature stresses the idea of changing the natural world in technological activities in accordance with the nature of things. This idea provides a strong guarantee of dynamic stability between humans and nature. It changes people’s mode of thinking and welcomes and encourages the transformation of technological activities that, in the past, have destroyed the stability between humans and nature into activities conforming to nature. The realization of the ideal of conforming to nature must be accompanied by effective systemic support and protection, which includes ethical, legal and governmental constraints.

The mood of ‘reverence for nature’ comes from the observation of facts related to the ‘revenges’ of nature after human-made reformation. Thus, people sometimes regard the idea of conforming to nature as minimizing changes to the primitive ecosystem. Such an attitude is unnecessary. It might be rational to think highly of the value of the primitive ecosystem in biology and medicine, which are closely related to biological activities. However, in fields concerning energy, materials, transportation and information, maintaining the primitive ecosystem is not possible.

The development of modern civilization is increasingly reliant on the active reformation of nature. Reforming nature and conforming to nature are not opposite poles, but a highly organic unity.

‘Conforming to nature’ refers to respect for the laws of nature, rather than succumbing to unfavourable natural conditions. Nature will not automatically provide a comfortable environment for the survival and development of human beings. Human society could not have developed into its present stage if humans had not had the courage to reform nature. However, the reformation of nature should consider environmental issues and the idea of sustainable development, instead of pure passion and utilitarian purposes. The technological concept of conforming to nature can provide a broader vision to make natural reformation more effective.

3.2 ‘Statecraft ideology for practical utility’ and macroeconomic control in the modern sense

The traditional Chinese concept of ‘statecraft ideology for practical utility’ is not out of place in the market economy, but requires a fresh interpretation from the perspectives of technological and social modernization to conform to new developments.

In the market economy, technological activities by enterprises are independent of each other. Those activities affect the immediate social environment and eventually the living environment of humankind as a whole. In other words, technological activities in the market economy are highly independent and discrete, while their social consequences can be comprehensive. Furthermore, the independence and discreteness of those activities can bring about a series of social problems that should be taken seriously.

One problem is that the market economy can adjust the optimal allocation of local technological activities but will not take lead in optimizing the influence of those activities on the ecological environment and social life. The Industrial Revolution has been inspired by many technological inventions and local technological progress. It has also generated a series of ecological, environmental and resource-related problems. The concept of ‘statecraft ideology for practical utility’ can contribute to detecting and controlling conflicts between technological progress and society. It can thus establish a harmonious relationship between the development of technology and the development of society in the market economy.

There persists a lack of coordination in developments in technology, the market and society. The improvement in China’s market economy is a long process, and technology, as a relatively independent element, can be developed in the current economic system with macroeconomic control. Under such circumstances, a displacement among technology, the market and society can be avoided.

Certain technology might be able to yield great benefit for a particular region at a particular time, but it might become obsolete in the near future or even pose pollution-related problems in the context of globalization from a developmental point of view. The blind introduction of such technologies will cause enormous waste as well as serious social problems. Advanced technology requires high-quality staff for its operation, advanced management systems to maintain efficiency, and a strong culture of enterprises to fulfil its role. The major problem is that the corporate culture suited to modern technology lags behind, so it is necessary to adopt the strategy of ‘statecraft ideology for practical utility’. The aims are to establish a harmonious culture of technology, combine the rational component in traditional Chinese culture with modern technological management and develop a corporate culture with Chinese features. This can guarantee the ideal development of technology.

3.3 Preventing improper application of technology by 'dominating technology by morality'

'Dominating technology by morality' means making the ethical evaluation of social consequences a major concern while engaging in technological activities. The traditional claims against 'foxy contrivances' and for restraining extravagance are still significant in preventing the improper application of technology, even though they were developed in the natural economy in China. What is technologically reasonable is not necessarily ethically right. Without moral restraints, technological advances will only be means for utilitarian purposes.

Traditional Western ethics are concerned more about moral virtue and social order and less about the ethical relationship between humans and nature. Not until recently has that relationship emerged as an important issue. By contrast, as early as before the Qin Dynasty, the Chinese senses of Tao and virtue were involved in the understanding of the ethical ideal: 'being kind to all people and loving live beings', and 'loving the people and creating advantageous conditions for things', which enabled positive and effective measures for the maintenance of the ecological environment, and the harmonious relationship between body and mind and between the operator and his or her tools in technological activities. An ethical concept that pays too much attention to utilitarian purposes leads to the excessive exploitation of nature. Therefore, the idea of 'dominating technology by morality' is particularly important when considering the ecological crisis and improper application of technology brought about by the excessive exploitation of nature in industrial society.

It is generally accepted that tools should be produced and methods for their operation should be designed in accordance with the physiological characteristics of human beings. However, driven by economic interests, the design of tools now rarely considers this, sometimes resulting in disharmony between humans and their tools. The renovation of tools would become a weapon for strife when it is solely for economic profit. Thus, justice cannot be maintained if the power of tools is concentrated in the hands of a few. New technological goals proposed in the application of those tools thus might not be reasonable or optimal. And the design of some technological products might exceed the needs of users, resulting in functional redundancy. But developers still profit from this. Furthermore, some technological products might not be controllable. In conclusion, the concept of 'dominating technology by morality' must be adhered to in the modern sense to avoid harms to humans.

Disharmony in technological activities continues to increase. For instance, greenhouse gas emissions have intensified the disharmony between humans and nature, and military competition threatens harmonious social existence. A variety of technological devices have been invented simply to meet sensory demands and even overstimulate people. Those activities have harmful effects on physical and mental health.

Under these circumstances, the traditional Chinese technological ideal assumes new significance and value. The pursuit of a harmonious relationship among the elements involved in technological activities is a process approaching the unity of truth, the good and the beautiful. To better coordinate technological developments and the social lives of people, it is necessary to grasp the essential concept of the traditional Chinese technological ideal and to reflect on and eliminate its historical limitations.

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Some reflections on science popularization and science culture in China*

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Abstract

China's social development strategy has evidently shifted from a focus on economic growth and material sustenance to balanced development and the enrichment of cultural and spiritual resources. In other words, Chinese society has transformed from a phase seeking rapid development to one seeking steady and all-round development. China's science popularization since the founding of the People's Republic of China has been focusing on the immediacy and timeliness of science communication but, in its current efforts to build a new science culture, it is more concerned with the cultivation of scientific values and the quality of persistence. In this era that upholds science culture, the mission of both science popularization and science culture is to make science go beyond the scientific community and to develop values and practice paths that support the public's pursuit of a better life. For that purpose, this paper proposes five projects based on the action network of science culture construction: fostering scientific spirit; disseminating science culture; institutionalizing science culture; science culture infrastructure for public benefits; and public engagement with science.

Key words

Science popularization, science culture, a better life, strategic transition, five projects

1. From science popularization to science culture construction

In contemporary China, the transition from the phase of science popularization to the development of a science culture is in line with the general background of China's transformation in social and economic development patterns. The report of the 19th National Congress of the Communist Party of China convened in October 2017 stated clearly that the principal contradiction facing Chinese society has shifted from that existing between the ever-growing material and cultural needs of the people and the backwardness of social production to one that exists between unbalanced and inadequate development and the people's ever-growing needs for a better life. This declaration is indicative of a strategic shift within Chinese society from the prioritization

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of economic growth and material sustenance to an emphasis on balanced development and the enrichment of cultural and spiritual resources.

Science popularization is a kind of verbal and interactive communication that emphasizes immediacy and timeliness, while cultural development stresses persistence in a long-term process.

There are several understandings about China's science culture construction. First, big data is making the world more open and energetic. It is a requirement for China's traditional industries to embrace the 'Internet plus' initiative for better development. Second, China's recent policy initiatives relating to crowdfunding, crowd innovation, crowdsourcing and crowd support have provided new options for establishing open, multidisciplinary and cross-sectoral collaborations. They have, together with Web 2.0 and above technologies and advances in artificial intelligence, created new insights and action options for the endeavours of public understanding of science and science communication. The application of new cross-sectoral technologies and platforms in manufacturing, services and even people's daily lives marks the beginning of a new era of human civilization.

Over the past several years, the Chinese Government has introduced a series of new guidelines and models. Compared to previous ones, they place greater emphasis on long-term persistence, balance and diversity. These changes relate not only to existing issues in China, such as overcapacity and excessive infrastructure accumulated over the years, but also to ecological constraints, the complexity of cultural values and widening gaps in wealth. A historical survey of developed societies over almost a century shows that they have all experienced a pattern of social, scientific, technological and economic development, from rapid development focusing on the achievement of specific short-term goals to slowerpaced development focusing on the achievement of medium- and long-term goals. This pattern has been observed in the United States, Japan and European countries.

A question that arises is: in which areas will efforts be focused during the phase of slowerpaced development in China? Whereas the faster phase has been geared towards the production and utilization of hardware such as products, equipment and infrastructure, and the development of land and natural resources, the emphasis during the slower phase will be on software, such as structures, mechanisms, culture and spiritual life. During the faster phase, the gap between software and hardware tends to widen because resources and efforts are focused on hardware development, while projects focusing on software are relegated to secondary roles of coordination and support. There are positive and negative examples of countries that have made both successful and less successful efforts to advance their status from developing to developed countries.

It is important for a country to slow down its pace after undergoing a phase of rapid development and to foster a quality of persistence. Persistence is a requirement in the construction of foundational projects that need continuous long-term efforts. At a prominent national science and technology conference in May 2016, when speaking of China's innovation-driven development strategy in science popularization, Xi Jinping emphasized that 'technological innovation and science popularization are the two wings of innovation-driven development, and it is important to put science popularization in the same important position as technological innovation.' This comment shows that science popularization, which is the soft side in scientific research, is becoming increasingly important in China's development and that China has high expectations for the development of the soft side.

In recent years, many science popularization researchers and practitioners have found that the concept of science popularization and related practices are too narrowly defined. Some people have begun to advocate science dissemination and divide it into several developmental stages, with reference to the Western model; some others believe that science dissemination alone is not sufficient and that it is necessary to develop a science culture.

There are three concepts involved here: science popularization, science dissemination and science culture. Some researchers and practitioners have proposed replacing science popularization with science dissemination or science culture. Although that proposal is not necessarily a practical option at present, it reflects an expectation for a transformation from science popularization to science culture construction.

The traditional framework of science popularization, which entails a non-interactive process in which science is disseminated by active communicators to passive audiences, is incompatible with the spirit of open innovation that currently prevails. In the contemporary world, in which the engagement of various participants is emphasized, the traditional framework can no longer meet people's needs to learn, use, enjoy and engage in science. New service platforms should inspire people's love for science and encourage their use of science instead of regarding them as passive audiences for scientific knowledge, methods and spirit.

Facing new conditions, in China's efforts to reconstruct the pathways of science popularization, dissemination and science culture, it is important to adapt to the new mainstream value of open innovation. A question that merits a response is whether the initiatives centring on 'crowdfunding, crowd innovation, crowdsourcing, and crowd support' as well as 'mass innovation and entrepreneurship' imply the mainstream values of science. The answer to that question is clearly affirmative. The 'Internet plus' initiative is also aligned with those mainstream values. Therefore, to integrate those values with science culture is a key role for the culture to play. Culture is about concepts and ideas, so the establishment of scientific values is more important in science culture construction than in science popularization and dissemination.

Traditional science popularization focuses on the supply of scientific knowledge by the scientific community to the general public through a one-way process that is based on the assumption that scientists and engineers represent the authority of science and technology, and that the general public is not sufficiently well versed in those aspects to interact with them. This arrogant assumption has become increasingly tenuous, as science is no longer considered an exclusive endeavour of the scientific community. Therefore, it is a requirement of the new era that science culture construction should not be confined to the small scientific community. Advances in science and technology need the efforts of all people and should benefit all people.

The new science culture is different from the traditional one, which mostly involves the institutional culture, norms and values of the scientific community. It can be understood in three dimensions. First, it represents the spirit and philosophy of the scientific community. This is the traditional understanding of a science culture that has been propounded in the earliest Western theories. Second, it is a cultural form that extends beyond the sphere of science and technology. Third, it provides the institutional environment and social atmosphere that support and regulate scientific activities.

2. Proposals for science culture construction

This study reaches the conclusion that science culture is a by-product of the production of scientific knowledge and methods. The key task in developing a science culture is to build a network of actors, because science culture concerns not only the scientific community but also the political, economic, social and educational communities, as well as other actors and stakeholders.

Figure 1 depicts the action network for science culture construction. The block on the left side shows the different actors; the central block shows the supporting system, which includes values, institutional regulations, material elements and activities; and the block on the right side shows the action proposals involving five projects: fostering scientific spirit; disseminating science culture; institutionalizing science culture; science culture infrastructure for public benefits; and public engagement with science.

2.1 Fostering scientific spirit

Amid growing interest in indigenous innovations and concerns about academic malpractice, the Chinese public has expressed increasingly strong dissatisfaction with the country's scientific community.

Specifically, the public is dissatisfied with the insignificant presence of indigenous innovations. Some people have even expressed their doubts about the innovative ability of academic institutions. Another issue that has raised public anxiety and indignation is the increasing incidence of malpractice within the academic community. The public's increasing dissatisfaction is starting to have a negative effect on the image of the traditional scientific community and on its work.

To accomplish the task of developing a science culture in contemporary China in the face of increasing doubts concerning the academic community and the challenges facing it, I think we should first extract the cultural gene from the traditional culture that can be used to explain the connotations of contemporary science culture. The cultural gene implied in China's current innovation-driven development strategy and its drive to build a modern nation is significantly different from China's traditional culture. To promote the scientific spirit of the Chinese nation, instead of merely that of its scientists and engineers, it is very important to extract some excellent core values from traditional Chinese culture and integrate them with the mainstream scientific values of contemporary society. There is still a long way to go in this regard.

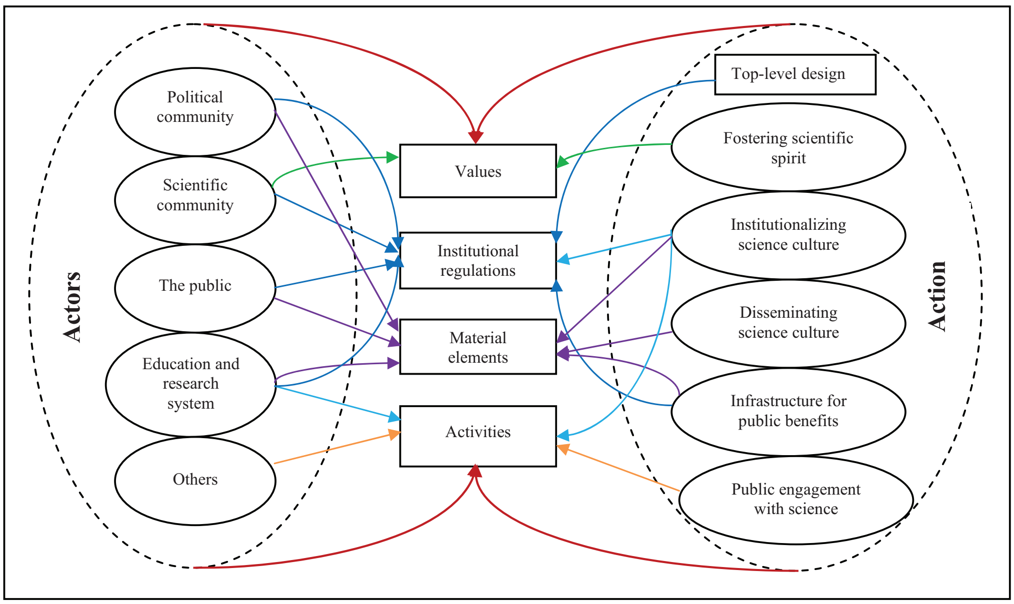

Figure 1: The action network for science culture construction

2.2 Disseminating science culture

We should make efforts in three dimensions of science culture dissemination. First, improve the policy system relating to dissemination. Second, adopt a new approach that encourages diversification of the actors involved in culture dissemination. Third, accelerate and prioritize the development of visual products that appeal to the general public.

2.2.1 Improve the policy system relating to science culture dissemination

The policy system concerning the dissemination of science culture includes related laws and regulations. One example is China's Science Popularization Law of 2002, which made China the first country to enact a law dedicated to science popularization. However, almost two decades after its enactment, the law remains unaccompanied by detailed implementation rules, despite futile attempts and proposals to draft and adopt such rules as national laws. Consequently, in the absence of detailed implementation rules, the Science Popularization Law with its general principles and guidelines cannot be actualized by actors engaged in science popularization at the grassroots level.

It is important to ensure that an accountability mechanism is introduced in alignment with efforts to promote science culture, because disjunctures existing between the scientific community and the media (especially the new media) seem to have caused scientists' worries about inaccuracies and serious mistakes in communication. The findings of a national survey of the Chinese scientific community indicated that widespread hesitation prevails among research institutions regarding the sharing of their latest discoveries with the media because of the fear that inaccurate reporting could lead to misunderstandings and other undesirable consequences. This often leads to a significant time lag in the broadcasting of science-related news. However, it is also important to take punitive measures against those who fabricate or distort scientific information and to strengthen the development of a review system of scientific information dissemination.

2.2.2 Diversify the actors involved in disseminating science culture

Disseminating science culture entails broad-based participation of actors to include not only relevant government agencies and research institutions but also actors from the wider society. There are three ways to accomplish this goal.

First, establish an official dissemination system that serves as the guiding force and authority, and encourage other organizations' engagement with science culture dissemination in an attempt to form a diversified and coordinated system. For example, Guokr is a non-governmental popular science organization that has millions of fans in China. There is a proposal that 100 organizations like Guokr would significantly advance China's science popularization. Guokr exemplifies the important role that non-governmental organizations can play in the dissemination of scientific knowledge and the promotion of science culture.

Second, continue to support the development of traditional popular science media such as newspapers, magazines, books, radio and TV programmes, and encourage new media operators to develop and promote popular science products based on new media. The traditional media are inclusive and rich in resources that have been accumulated over a long period. Policymakers should introduce supportive policies rather than relegating traditional media to the sidelines because of the emergence of new technologies.

Third, encourage the effective use of new media by all of the actors concerned, including the government, the scientific community and non-governmental organizations, so as to create an interactive mechanism to increase the public's engagement with science and its ability to communicate through digital media. Science should go beyond the scientific community and step into a new open era. In other words, science should not be confined to research institutions, universities and industries. Scientific results should be widely spread and benefit the general public, rather than being selectively promoted by researchers. This view has gained momentum, reflecting a widespread demand for changes in science culture.

2.2.3 Strengthen the development of visual products

We can take the following measures to strengthen the development of visual products.

First, support science popularization initiated by businesses aiming to promote new products, encourage the development of online science popularization and online science centres, and establish new media brands with Chinese characteristics.

Second, carry out regular popular science activities related to people's daily lives and life in the future, and thus narrow the gap between science and everyday life and improve public scientific literacy.

Newly developed visual products should make science easier for the general public to understand. Chinese society is still significantly stratified in terms of scientific literacy. It is therefore important to provide popular science products that appeal to the varied preferences and levels of knowledge of different groups. For example, the traditional appearance of highbrow popular science works is ill-suited to the general public, especially young people below the age of 15 or even 25 years who have grown up in a visual media environment. Thus, the challenge of creating popular science products that cater to and meet the needs of the young generation merits consideration.

Visualization is not just about making content more vivid. It reflects an entirely different means of consumption by the current generation, which has developed in a completely visualized environment (including augmented reality and virtual reality), and of future generations. A supply-side reform is needed because the current pattern of visualized consumption will last for decades or even longer before a new mainstream consumption pattern takes shape. The development of visual products does not mean an expedient strategy of simply adding decorative visual elements to traditional popular science works.

2.3 Institutionalizing science culture

There are three tasks in the institutionalization of science culture. First, improve the regulatory framework of the scientific community. Second, construct comprehensive scientific procedures and rules. Third, optimize the administrative mechanism for scientific research. This project encompasses academic disciplines, universities, research institutes and enterprises. We can promote the project through efforts in the following dimensions.

First, try to meet the needs of companies to engage in science popularization through the promotion of new products. Companies have an increasingly stronger need for product-based science popularization. While the inclusion of science-focused marketing activity within the scope of science popularization remains controversial, companies are strongly motivated to spread scientific knowledge related to their products. Consequently, this mode of disseminating scientific knowledge can potentially become a driving force for science popularization.

Second, make full use of the advantages of science and technology associations in uniting research personnel and promoting research ethics and academic integrity. Academic integrity cannot be achieved merely by the efforts of research institutions and science popularization departments. It is part of China's larger social credit system, which is much more complicated and not easy to implement. Efforts to promote academic integrity should be implemented at approximately the same pace as the development of the social credit system.

Third, promote the China Association for Science and Technology's project for collecting data on scientists' academic growth. The project is an important academic event and has a strategic meaning. If it could cover a long period and be institutionalized and implemented on a large scale, it would be a very significant database on Chinese science culture.

2.4 Science culture infrastructure for public benefits

Science culture infrastructure for public benefits extends beyond science popularization *per se*. I think there are two core aspects in science popularization: knowledge popularization and public benefits. During the first phase of China's science popularization, which extended from the time of the founding of the People's Republic of China (PRC) to the end of the 20th century, the overall emphasis was on the popularization of scientific knowledge, which was in line with the social background and needs of that specific historical period. However, in the current new era in which science and technology deeply integrate with people's everyday life, making science benefit all people may be more important than knowledge popularization.

Over the decades since the founding of the PRC, we have undertaken extensive efforts in science popularization, although there is still a long way to go for us to catch up with the developed countries in terms of scientific literacy and the application of science and technology. How, then, can we assess the achievements of China in its efforts to make science culture infrastructure inclusive? Against the backdrop of China's ongoing efforts to drive development through investments in infrastructure, the introduction of a system to assess the performance of the country's science popularization work has assumed particular importance.

Here, I identify three key measures to substantiate science popularization achievements:

- Encourage the engagement of the private sector in science popularization and the development of science culture infrastructure.
- Effectively use the existing infrastructure, such as the now widespread hackerspaces, to arrange scientific resources.
- Expand global collaboration to build open science popularization platforms and strengthen the use value and efficient use of them.

The development of science culture infrastructure that benefits all people can focus on the following aspects:

- Use the existing infrastructure to protect the heritage of science culture.
- Accelerate the construction of national demonstration bases and thematic venues for science culture.
- Develop video platforms dedicated to science culture dissemination, including explorative social media platforms.

In addition, the Chinese Government attaches great importance to the supply of resources in rural and other underdeveloped areas and to balanced urban–rural development, which is evidenced by China's commitment to its 'poverty alleviation' strategy. Specifically, in promoting science culture, efforts should be made to balance resource deployment between rural and urban areas while preserving the cultural identities (such as ethnic cultures and religious cultures) of those areas, and thus to accelerate the development of science culture in rural and rural-urban areas and promote the establishment of a mechanism whereby advanced areas in eastern China assist remote areas in western China.

2.5 Public engagement with science

Public engagement with science involves two main tasks: establish a science culture education system that includes all people; and launch activities to increase public engagement with science culture.

2.5.1 Construction of a system involving all people

It is important to involve all social forces in the construction of a comprehensive science culture system. The resources provided by the government, such as funds and personnel, are limited. Moreover, a significant increase in expenditure within the national budget incurred in the promotion of public engagement with science is not feasible in the short term. Therefore, all related initiatives at the national and local levels should encourage the involvement of diverse social forces.

There is also a need to establish a system of science culture norms promoted by all people. This work should focus on making science culture education a continuous long-term effort, keeping educational content up-to-date, combining science culture education with academic integrity education, improving the researchers' training system by highlighting training in research ethics, and establishing a diversified and flexible cultivation system by using the internet.

2.5.2 Launching of scientific activities

The goal of increasing public engagement with science by launching scientific activities can be achieved through the following two measures.

First, encourage scientists to popularize science within society and evaluate their effectiveness in doing so as part of their overall performance evaluations. The challenge is how to include science popularization in the performance evaluation system of researchers, given that the work is often done by retired scientists who have much spare time, and that it would be difficult for young scientists to do it. If this evaluation method is not feasible, young scientists might not see it as their responsibility to popularize science among the public. In this way, the action network for science culture construction would end up being fragmented.

Second, develop science activity brands and launch demonstration projects to engage the public in science culture. In particular, mobile social media can be used for science popularization, such as by establishing virtual science museums, social websites or apps focusing on popular science, and science dissemination platforms using artificial or virtual intelligence.

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Author biography

Shukun Tang is a professor and the director of the Centre for Science Communication Research and Development at the University of Science and Technology of China. He also serves as the vice chairman of the 7th governing board of the China Science Writers Association (CSWA) and as the director of CSWA's Professional Committee on Popular Science Education.

Aims and Scope

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

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

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

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