Postprint: The Realistic Context and Future Direction of National Science Popularization Capacity Building in the New Era

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Date: 2018-07-26T00:00:00+00:00

Abstract

General Secretary Xi Jinping' s statement that "scientific and technological innovation and science popularization are the two wings of achieving innovative development, and that science popularization should be placed on an equal footing with scientific and technological innovation" points the way forward for science popularization work in the new era and clarifies its important status. Strengthening national science popularization capacity building must be oriented toward the people' s aspirations for a better life and the needs of national innovative development, aim at constructing a "four-dimensional integrated" science culture, advance market-oriented reforms of the science popularization supply system, and utilize new media and digital technologies to promote the informatization of science popularization.

Full Text

Context and Future Trend of National Science Popularization Capacity Improvement in New Era

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Abstract: Chairman Xi Jinping pointed out that science and technology innovation and science popularization are the two key elements for national innovation, and we should equally set importance to science popularization and science and technology innovation. This viewpoint has set a new direction for the national science popularization in the new era. To strengthen national science popularization capacity should meet the need of the country' s innovative development and the need of people for a better life. With the goal of science culture construction contained by four-dimensions, we need to carry out the market-oriented institutional reform of supply for science popularization, and

to use new media and digital technologies to promote the construction of science popularization informatization.

Keywords: science popularization capability, science culture, institutional reform of supply, science popularization informatization

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The New Era Context for National Science Popularization Capacity Building

The Urgent Need for Science Popularization Capacity to Support National Innovation-Driven Development Strategy

A review of countries that have experienced major scientific and technological revolutions, as well as current technologically advanced nations, reveals that major scientific discoveries and technological innovations are closely related to national science popularization capacity building. As Italian science communication scholar Giovanni Carrada stated, scientific research has become more than ever a driver of economy, society, and culture, and the quality of science communication has become an important factor for democracy and progress [1]. Science popularization not only effectively promotes exchange and learning within the scientific community, overcomes barriers between different disciplines and professional fields, and fosters a favorable ecosystem for collaborative innovation, but also facilitates interaction between science and society, seeking the broadest social consensus for national innovation initiatives. The example of genetically modified organisms has fully demonstrated that mutual isolation or even disconnect between science and society can trigger serious social questioning and resentment, making the promotion of science and technology extremely difficult.

For a long time, due to various subjective and objective reasons, neither the scientific community itself nor other social sectors have given sufficient attention to science popularization work. There exist problems of insufficient and unbalanced supply content and methods relative to the actual needs of the people, resulting in weak public sense of gain and affecting their enthusiasm for active participation in science popularization. Entering the new era, science popularization must not only become one of the "two wings" of national innovation but also focus on meeting people' s needs for a better life. This constitutes an important contextual factor for strengthening national science popularization capacity building at present.

Science Popularization Services as an Important Demand for People' s Better Life

Currently, major scientific research institutions in developed countries, including the American Association for the Advancement of Science (AAAS), the Royal Society, and the French Academy of Sciences, require their members to discuss

ethical norms and latest achievements with the public, regarding such popularization behavior as a responsibility and obligation of scientists. In reality, the value of science popularization in livelihood areas such as health, environmental protection, and safety has become increasingly prominent. In the new era, China' s government has formulated and introduced important plans and strategies in health, environmental protection, and emergency response. As an important wing of innovative development, science popularization has also adopted a series of measures to meet people' s diversified needs and address the supply-side reform of insufficient and unbalanced development, focusing on building national science popularization capacity that meets people' s needs and can effectively improve citizens' scientific literacy. In fields such as health science popularization, emergency science popularization, and environmental science popularization, overall planning and focused investment have been carried out. Science popularization has become an important means to transform public concepts, prompting the public to form a scientific spirit of rational questioning and evaluative thinking, and has become an effective method for the public to learn, understand, and apply science. Science popularization is also playing an increasingly significant role in serving national development strategies, with science popularization for poverty alleviation and intelligence improvement not only providing important support for mass innovation activities but also improving people' s survival capabilities and quality of life.

The Severe Challenge of Pseudoscience Dissemination to National Science Popularization Work

With the development of the Internet and various social media, numerous "pseudoscience" claims are being disseminated online under the guise of "science." In reality, various specious so-called "health and wellness" knowledge and deliberately abstruse "latest technological inventions" are widely circulated online, confusing the public. Particularly in remote and rural areas, content promoting feng shui, fortune-telling, and similar topics are brazenly presented online, and even some metaphysical and superstitious ideas are spread through new media as so-called "scientific frontiers and latest developments." Due to the concealment of self-media, the harm caused by these issues is difficult to detect and expose, yet they may bring great troubles to the public' s production and life. In hot public opinion events involving science, various rumors always follow and sound alarming, and information that is difficult to distinguish between true and false can easily induce irrational "anti-science" trends and even mass incidents, bringing instability to society.

The dissemination of various pseudosciences not only misleads public cognition and behavior but also poses severe challenges to national science popularization work. While the Internet has created convenience for the flow, dissemination, and acquisition of knowledge and information, it has also caused the dilemma of fragmented knowledge and difficulty in distinguishing true from false information. To properly address such problems, we must recognize the new situation, strengthen the construction of science popularization content in mainstream so-

cial organizations and formal communication channels, such as further building the "Science Popularization China" brand, implementing the "Hundred Cities, Thousand Schools, Ten Thousand Villages Action" (referred to as the "Hundred-Thousand-Ten Thousand Action"), and building a science popularization supply network for the "first mile" and "last mile" to provide authoritative, scientific, and credible knowledge, information, and news to the public, using scientific thinking to enhance public identification capabilities and prevent them from being deceived.

Emerging Communication Technologies Are Reshaping Traditional Science Popularization Models

In the mobile Internet era, information and communication technologies characterized by intelligence and digitalization, artificial intelligence technology, and virtual reality technology are converging into an important transformative force that is reshaping traditional science communication models. For example, information and communication technologies have created necessary conditions for various online science popularization services; artificial intelligence technology can be used to develop "intelligent science popularization robot" products to better meet the public's ubiquitous science popularization needs; and virtual reality technology provides immersive science popularization experience environments for the public to understand profound scientific principles and phenomena.

According to the latest "41st Statistical Report on China's Internet Development" released by the China Internet Network Information Center (CNNIC), by the end of 2017, China's Internet user population had reached 772 million, with 40.74 million new users; the Internet penetration rate had reached 55.8%; and the mobile Internet user population had reached 753 million, with the proportion of Internet users accessing the Internet via mobile phones increasing from 95.1% in 2016 to 97.5% [2]. With the substantial improvement of China's Internet penetration rate and the rapid expansion of the Internet user population, especially the mobile Internet user population, the ways in which the public receives science popularization are also undergoing important changes. Research by Professor Kuang Wenbo of Renmin University of China points out that new media plays an important role among media that the public can more easily and willingly accept scientific knowledge from.

Ubiquitous network connections provide an important platform for the public to obtain scientific knowledge online and for science popularization workers to disseminate science online. Artificial intelligence and virtual reality technologies create more fun and experiential sense for the public to observe scientific phenomena and comprehend scientific principles. More importantly, the development of emerging communication technologies is changing the status between science communicators and science popularization audiences, making both sides move toward openness, transparency, and networking in interactive communication, and in some occasions, even turning the public into ubiquitous self-media "experts" who are both disseminators and recipients. Under such circumstances, traditional science popularization models should also change accordingly, ac-

tively promoting the informatization development of science popularization, including digitalization of science popularization content, platformization of science popularization dissemination, terminalization of science popularization presentation, and sustainability of science popularization effects. This is an objective situation that must be focused on in current national science popularization capacity building.

Current Situation and Goals of National Science Popularization Capacity Building

The Current Situation of National Science Popularization Capacity Building

In 2018, the China Research Institute for Science Popularization released the "National Science Popularization Capacity Development Report (2017-2018)," continuing dynamic evaluation of changes in national science popularization capacity [3]. According to this report, China' s national science popularization capacity development index reached 2.10 in 2016, representing a 2.44% increase compared with 2015. Overall, from 2006 to 2016, China' s science popularization capacity development index showed a year-by-year increasing trend, with significant effects in comprehensive science popularization capacity building.

According to the analysis in the "National Science Popularization Capacity Development Report (2017-2018)," the main reasons for these changes in China' s national science popularization capacity development index lie in the obvious rise of three development indices: national science popularization funding, science popularization infrastructure, and science education environment, especially the science education environment. With the increasing popularity of the Internet, various online resources have exerted greater influence on the education environment, and its development index rose significantly by 27.19% year-on-year. In addition, improvements in the science education environment and science popularization infrastructure are also two important factors driving the enhancement of national science popularization capacity.

However, the problem that cannot be ignored is that although national science popularization capacity has been growing since 2006, the growth rate has been relatively moderate, basically maintaining a small increase of 0.1-0.2 each year, and the science popularization capacity index in 2016 was only 2.10, indicating relatively low overall capacity. Returning to reality, the factors constraining science popularization capacity building are multifaceted: (1) there remains a shortage of domestic original science popularization resources; (2) professional science popularization personnel mainly originate from the China Association for Science and Technology system, while other social science popularization entities remain weak; (3) scientific and technological workers lack strong awareness and motivation to actively carry out science popularization, with the proportion of personnel engaged in science popularization work among scientific and technological workers still being relatively small; (4) science popularization

activity forms are relatively monotonous, with limited influence; and (5) the social atmosphere for science popularization is insufficient, especially the public' s awareness of actively accepting science popularization is not strong, and science popularization needs have not been truly stimulated.

Goals of National Science Popularization Capacity Building

Over the past decades, the relationship between science and society has been quietly changing. On this issue, John Ziman summarized it as the transition from "academic" science to "post-academic" science [4]. Along with this transition, science communication is not a simple process of knowledge diffusion; those elements inherent in scientific culture—so-called scientific spirit, scientific thought, and scientific methods, as well as the relationship between science and society—should be more known to the public [5]. Therefore, it is advocated that science communication should shift from the "deficit model" of "public understanding of science" to the "democratic model" of "public participation in science."

The realistic problem is that if society lacks a cultural atmosphere that advocates science, if the public lacks conscious identification with science, or if they do not possess basic scientific literacy themselves, everything becomes a nihilistic discussion. Therefore, to promote the transformation from "public understanding of science" to "public participation in science," the long-term goal of China' s science popularization capacity building should be to establish public scientific culture within society.

In fact, since Joseph Schumpeter proposed the innovation economy, culture as a core factor promoting innovation has become a consensus in Western academic circles. American economist S. Shane [6] pointed out as early as the early 1990s that culture is the key factor affecting a country's innovation capability. Chinese sociologist of science Li Kete [7] also explicitly stated that the development of science itself is a process of cultural formation. The reason why national science popularization capacity building in the new era should aim to cultivate citizen scientific culture is that citizens' scientific literacy reaching more than 10% is one of the basic conditions for a country to enter the ranks of innovative countries and is also one of the signs of an innovative country. This requires us, while vigorously improving citizens' scientific literacy in the context of the new era, to more vigorously build citizen scientific culture, especially integrating scientific cultural elements into "grassroots culture" to make it more vibrant and provide a solid foundation for innovation and entrepreneurship [8].

Indeed, for any cultural form, whether it is the culture of a nation or an organization, different scholars' deconstruction of culture is multi-dimensional, but in summary, it does not exceed four dimensions: material culture, institutional culture, behavioral culture, and spiritual culture. To strengthen national science popularization capacity building in the new era, we need to aim at the "four-dimensional integration" framework of scientific culture and systematically promote it through phased task planning. The goal is to allow scientific culture

to emerge from within the scientific community and become a new institutional culture jointly built and shared by all people.

Future Trends of National Science Popularization Capacity Building

Market-Based Science Popularization Capacity Building Through Science Popularization Industry Development

Science popularization services are comprehensive activities that require investment of various resources such as manpower and material resources. Traditional public welfare science popularization services face dilemmas of single entities, shortage of operating funds, and supply-demand imbalance. In contrast, with the advent of the knowledge consumption era, the public has very strong demand for science popularization service products, so developing science popularization with industrial thinking is more conducive to improving the efficiency of science popularization resources. Both the 2016 "13th Five-Year National Science and Technology Innovation Plan" and the 2017 "13th Five-Year National Science Popularization and Innovation Culture Construction Plan" issued by the Ministry of Science and Technology and the Publicity Department of the Communist Party of China Central Committee mentioned the development of the science popularization industry.

Based on the fundamental regulatory role of market mechanisms, we should develop the science popularization industry and provide science popularization services. On the one hand, we need to actively promote the integration of science popularization services with traditional commercial activities, creating various new business forms of "Science Popularization +" such as "Science Popularization + Tourism," "Science Popularization + Games," and "Science Popularization + Movies." For example, the online protein folding game Foldit not only uses gaming methods for public science popularization of protein structures but also verifies theories related to RNA molecule folding based on game data. Of course, developing the science popularization industry requires following the development laws of the science popularization industry, promoting supply-side reform and innovation, and creating and driving demand through supply. Only when the science popularization industry develops can we achieve the simultaneous development of science popularization industry and science popularization undertakings, making the wing of science popularization stronger and enabling it to compete with scientific and technological innovation.

We advocate viewing science popularization services as a kind of cultural service, promoting the reform of the science popularization service supply system, and implementing the parallel development of public welfare science popularization and market-based science popularization to form a dual service supply system [9]. National science popularization departments at all levels should focus on providing science popularization services for scientific production, disaster prevention and mitigation, health care, and safety protection based on basic public services and public production and life needs, integrating national science and

technology venues into important components of the national modern public cultural service system. At the same time, various market entities and innovation entities should be encouraged to provide commercial science popularization services based on their own advantages in science popularization resources, technology, and platforms. The two types of services have different orientations and complement each other.

Precision Science Popularization Based on People' s Life Needs

Entering the new era, China' s science popularization undertakings shoulder a sacred mission to meet the people' s aspirations for a better life, practice the people-centered development concept, and build new advantages for future development through the continuous improvement of 全民科学素质, thereby thickening the scientific and human resource foundation for national innovative development. We must arm science popularization work with new concepts [10]. With the transformation of China' s main social contradictions in the new era, science popularization must also serve to resolve these main contradictions, not only becoming an important wing of innovative development but also serving the people to meet diversified needs and addressing insufficient and unbalanced development. To this end, future science popularization work, especially government-led public welfare science popularization services, should focus on basic public service needs, strengthen effective connection between supply and demand, and enhance the ability to provide precision science popularization services.

(1) We need to establish a multi-entity science popularization service coordination mechanism to form a strong science popularization synergy. First, governments at all levels need to do a good job in top-level design, establish science popularization resource information databases at all levels, record science popularization service projects and content information of science popularization organizations at all levels, and create supply-side platforms for science popularization services to create conditions for the government to allocate effective science popularization resources according to public science popularization needs. Second, we should establish an online expression mechanism for public science popularization needs and create demand-side platforms for science popularization services. For example, a certain urban community can apply online for corresponding science popularization service methods and content based on the actual needs of its residents, and the government can coordinate the supply of science popularization services according to public needs, building a multi-entity collaborative participation mechanism for science popularization service supply. Finally, we should explore the establishment of an evaluation system for science popularization service effectiveness, enabling science popularization audiences to provide feedback evaluations of science popularization work effectiveness through various media to identify existing problems and make corresponding improvements, further enhancing the precision of science popularization.

(2) We need to collect, analyze, and study the common needs and science

popularization service preferences of key social groups to provide targeted science popularization services. For example, for rural residents, we can focus science popularization on areas closely related to their daily lives such as energy conservation, environmental protection, ecological protection, scientific farming, emergency 避险, and healthy living, transforming science popularization into capabilities to improve villagers' lives and production and enhancing the public' s sense of gain from participating in science popularization.

Information-Based Science Popularization Based on Emerging Communication Technologies

Promoting the informatization construction of science popularization is an important direction for national science popularization capacity building. The purpose of science popularization informatization construction is to build an online and offline integrated national science popularization system. We must do a good job in both the "serving end" and "first mile" of content construction and dissemination channel construction, as well as the final terminal presentation and effect evaluation work, forming a high-efficiency operation model for the entire science popularization chain.

(1) Promote the online supply of traditional science popularization services. Encourage various scientific research institutions, social entities, or individuals to participate in the construction of online science popularization resources, develop new science popularization media, and jointly push offline science popularization resources to online platforms to create online science popularization brands and high-quality columns. At the same time, strengthen the organization, mining, and creation of traditional science popularization resources, and develop various social market-based online science popularization media and self-media science popularization according to online dissemination characteristics, strengthening online science popularization services.

(2) Use new media technology to promote innovation in science communication methods. Change traditional print media communication with text and images as expression elements, and develop audio-visual communication dominated by sound and images. Through forms such as animation, documentaries, science fiction movies, scientific interview TV and radio programs, and online video live streaming, traditional science popularization content can be made more visualized, mobile, and transformed, promoting the transformation of science communication methods from traditional media to integrated media.

(3) Use emerging digital technologies to develop new forms of science popularization. Using digital technology, rely on new technologies such as artificial intelligence and virtual reality to build online science popularization laboratories, online science popularization interactive communities, and online knowledge sharing platforms. Encourage various market entities

to integrate science popularization into online education, life and health online services, and online entertainment and leisure activities, developing interactive and participatory science popularization products such as online science popularization games and online health science popularization based on social sharing and location services, promoting the diversification of science popularization service types.

Crowdsourced Science Popularization Based on Public Participation in Science

With the development of the Internet, the crowdsourcing model that utilizes public wisdom to jointly participate in enterprise production and service activities is emerging. Not only have globally renowned companies such as Procter & Gamble, Starbucks, and Nike developed crowdsourcing platforms, but crowdsourcing communities such as InnoCentive and Mechanical Turk have also been born [11]. Currently, the crowdsourcing model has not only attracted widespread attention from academia, but its application scope is also expanding from the commercial field to broader social fields, including science-related crowdsourcing activities. Especially with the development of research crowdsourcing, many scientific research institutions in Western countries have begun to recruit and absorb the public into science popularization activities such as astronomical monitoring and natural species tracking and protection. For example, the "Galaxy Zoo" activity organized by the University of Oxford for public participation in online galaxy classification, and the "Free Rice" crowdsourced science popularization game developed by the United Nations World Food Programme [12,13]. Such phenomena indicate that crowdsourced science popularization has a broad social foundation and the potential for science popularization industrialization, providing a new path for improving national science popularization capacity building based on the development of the science popularization industry.

Against this background, future science popularization should actively shift to a new paradigm of "public participation in science," encouraging various science popularization entities, organizations, and individuals to develop public welfare or commercial crowdsourced science popularization projects that combine online and offline approaches. The public should be invited to jointly participate in science popularization content creation, science popularization facility design and production, science popularization project planning and operation, and other activities, exploring crowdsourced science popularization service models with distinctive features.

With the proposal of the "two wings of innovation theory" and the growing public demand for science popularization, strengthening science popularization capacity building in the new era and improving citizens' scientific literacy have received high attention from governments at all levels. Examining the new situation facing science popularization work in the new era, future national science popularization capacity building should seek new breakthroughs in four directions: marketization, informatization, precision, and socialization. At the same time, we need to further improve the evaluation dimensions and indicator

systems for national science popularization capacity under the new era context of networking, informatization, and intelligence, conduct dynamic monitoring of science popularization capacity building for the nation and various regional provinces through evaluation, and implement targeted improvement plans for fields and regions with insufficient capacity.

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[Figure 1: see original paper] *Trend of National and Regional Science Popularization Capacity Development Index in China, 2006-2016*

Note: The calculation of the science popularization capacity development index does not include Hong Kong, Macao, and Taiwan regions of China. Eastern, central, and western regions are divided according to the "China Science Popularization Statistics." The eastern region includes 11 provinces (municipalities/autonomous regions): Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The central region includes 8 provinces: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region includes 12 provinces (municipalities/autonomous regions): Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. The science popularization capacity development index is obtained through comprehensive evaluation based on the standard ratio method using six dimensional indicators: science popularization personnel, science popularization funding, science popularization infrastructure, science education environment, science popularization works dissemination, and science popularization activities.

Note: Figure translations are in progress. See original paper for figures.