Open science: The science paradigm of the new era

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1. Background of the open science movement

Science is characterized by the demand for open communication within a community. In the early days, members of the scientific community exchanged their academic results through correspondence, and they later established academic organizations to organize academic conferences, and to publish academic journals to strengthen communication. It is shown that there is an inherent need of scientific community to seek improvement through exchanges. At present, academic journals have become an important channel for the academic community to conduct academic exchanges internally and externally, and communication and mutual learning are intrinsic needs.

The informatization of global society that started in the 1990s has unlocked the demand for scientific development and created unprecedented conditions for the open exchange of scientific research. Science and technology, as the primary productive force, has penetrated into our lives and production, resulting in an unprecedented public interest in the outcomes and applications of scientific and technological innovation. In the past few decades, such public interest has gained much traction. For example, the discussion of issues such as genetic modification, climate change and ‘carbon peaking and neutralization’ target is no longer confined to the scientific community and a small circle of scientific sponsors but has become a topic of extensive public interest. Against such a background, a new concept — ‘post-normal science’ — appeared in the 1990s.

Normal science refers to science in which scientific issues are discussed by scientists within the scientific community. Post-normal science gives the concept a wider scope. After entering the public domain, scientific issues have become public science or open science, and the earlier concept of the ‘science of science’ has also evolved into the concept of public science policy. As part of public policies, public science policy represents the aspirations of the general public. The most distinctive feature of the ongoing open science movement is open data, because, with the development of the internet and the creation of big data, people have increasingly realized that data plays a very important role in our lives and production, and is in a sense a new economic factor. Based on that fact, open data has served as the starting point of the current round of open science promotion.

Internationally, developed countries, especially European countries, have acknowledged the trend of open science since the beginning of this century. They have attached great importance to its development model and the composition of a country’s discourse in this development process. Governments have taken the lead in promoting its development and played a dominant role in this round of open science promotion.

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data and the open science movement. Table 1 shows some of the documents issued by different countries or regions to promote open science since the beginning of the 21st century, dealing with not only the promotion of open data, but also rule-making and governance in the opening process. Unfortunately, China has not yet published a dedicated document on this subject.

2. UNESCO’s effort to promote open science

UNESCO has gone through the following stages in promoting open science. In November 2019, a proposal was made at the 40th session of UNESCO’s General Conference to draft a UNESCO recommendation on open science, which was adopted by the conference. After the adoption of the proposal, UNESCO launched an online campaign to call for proposals on open science from all member states and collected the policies of international governmental and non-governmental organizations. The wide-ranging consultation gathered more than 3000 proposals from 133 member states. After the completion of the first draft in March 2020, UNESCO organized a series of committees of technical experts, legal experts and policy experts, with the participation of both governmental and non-governmental organizations such as the World Federation of Engineering Organizations and the International Science Council. From March 2020, UNESCO started an extensive consultation process and produced a new draft, which was sent to 139 member states for comments. At the end of 2020, on the basis of the consultation, UNESCO held a series of meetings in the world’s six regions, including the Asia-Pacific, the Arab states, America and Western Europe, to discuss the draft. On the basis of the discussion, the draft was put to rounds of consultation and revision. It was finally adopted by the 41st session of UNESCO’s General Conference. The whole process reflected the principle of open science, as this document on open science was formulated in a thoroughly open way. Inclusiveness, consultation, responsibility and transparency are the most prominent features of the policy-making process.

The recommendation consists of six main parts: Preamble, Aim and objectives of the recommendation, Definition of open science, Open science core values and guiding principles, Areas of action, and Monitoring.

Preamble

There are several important points in the preamble of the recommendation that deserve particular attention. First, it argues that open science is an urgent policy to address the complex global problems facing humanity. Second, science, technology and innovation (STI) have contributed to human progress, and the imperative now is to close the STI gap between countries. Third, access to and enjoyment of the fruits of science is a universal human right, and open science plays a crucial role in realizing that human right. Fourth, open science has the potential to promote the democratization of knowledge and reduce the imbalance in STI development within and between countries. Finally, we need to respect cultural diversity and the plurality of knowledge holders and sources, which in this case includes indigenous knowledge and citizen science. Open science respects the cultures and legal policies of all countries and makes policy recommendations within the international framework.

Aim and objectives

The purpose and goal of the recommendation is to provide an international framework for the policy and practice of open science. First, to recognize disciplinary and regional differences in perceptions of open science; second, to consider the factors of academic freedom, the specific ways to promote reform in gender equality, and the practical challenges faced by scientists and other open science actors in different countries, especially developing countries; and finally, open science can bridge the digital, technological and knowledge divides that exist between and within countries.

Definition of open science

Open science is defined as an inclusive construct that combines various movements and practices aiming to:
1. make scientific knowledge openly available, accessible and reusable for everyone
2. increase scientific collaborations and sharing of information for the benefits of science and society
3. open the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community (UNESCO, 2021).

It is important to emphasize here that access to scientific knowledge should be as open as possible and that any restrictions on access should be proportionate and reasonable. By reasonable, restrictions should be imposed only for reasons of protecting human rights, national security, confidentiality, privacy and respect for the people who are the subject of the research, legal process and public order, protection of intellectual property and personal information, protection of sacred and secret indigenous knowledge, and protection of rare, threatened or endangered species.

The concept of open science has evolved during the course of drafting the recommendation. It was suggested to consist of nine aspects: open access,
Figure 1. Open science taxonomy (revised based on Bezjak et al., 2018).
open data, open reproducible research, open science definition, open science evaluation, open science guidelines, open science policies, open science projects and open science tools (Figure 1).

Finally, it is agreed to comprise five elements of open science: first, open scientific knowledge, including open scientific publications, open research data, open educational resources, open source software and source code, and open hardware; second, open scientific infrastructure; third, open participation of social actors; fourth, open research programmes in which the public sector plays a leading role and the private sector provides funding; and fifth, open dialogue with other knowledge systems.

**Core values and guiding principles**

The core values of open science include quality and integrity, equity and fairness, collective benefit, and diversity and inclusiveness. The guiding principles are: 1) transparency, scrutiny, critique and reproducibility; 2) equality of opportunities; 3) responsibility, respect and accountability; 4) collaboration, participation and inclusion; 5) flexibility; 6) sustainability (UNESCO, 2021). These principles serve as important guidelines for the further promotion of open science in the future, such as the establishment of international rules and standards for open source.

**Areas of action**

The recommendation proposes seven specific areas of action:

1. Promoting a common understanding of open science, associated benefits and challenges, as well as diverse paths to open science
2. Developing an enabling policy environment for open science
3. Investing in open science infrastructures and services
4. Investing in human resources, education, digital literacy and capacity building for open science
5. Fostering a culture of open science and aligning incentives for open science
6. Promoting innovative approaches for open science at different stages of the scientific process
7. Promoting international and multi-stakeholder cooperation in the context of open science and with a view to reducing digital, technological and knowledge gaps (UNESCO, 2021).

**Monitoring**

The recommendation proposes deploying appropriate monitoring and evaluation mechanisms to measure the effectiveness and efficiency of open science policies and incentives against defined objectives; collecting and disseminating progress, good practice, innovation and research reports on open science and its implications with a multi-stakeholder approach; and developing a monitoring framework with qualitative and quantitative indicators, within national strategic plans and shared at the international level, with objectives and actions in the short, medium and long term for the implementation of the recommendation. In the meantime, the recommendation calls for the adoption of strategies to monitor the effectiveness and long-term efficiency of open science, which include a multi-stakeholder participatory approach. Such strategies could focus on strengthening the connections between science, policy and society and increasing transparency and accountability for research (UNESCO, 2021).

**3. Observations and suggestions**

Some people trace the spirit of open science back to the Renaissance in the 17th century, when science gradually spread from aristocratic circles into the people and knowledge became a public good through open science. At present, open science is the call of the times and an inevitable policy choice. My understanding of the motivation of open science includes the following four points.

First, inevitability. Open science is an intrinsic need of science, not imposed from the outside. Second, relevance to the present times. Open science is the need of the society. While science needs to enter society, the public also needs to understand science. Third, morality. Open science is a basic human need and a basic human right. From the perspective of international human rights as well as values and beliefs, access to scientific
research and its applications is a basic human right, and openness is a fundamental value of the scientific and technological community. The ‘Joint appeal for open science’ issued by UNESCO, the World Health Organization and the United Nations Human Rights Council calls on ‘every Member State to ensure the fundamental right to access scientific research and its applications, with a view to creating a global knowledge commons and closing existing gaps in science, technology and innovation, especially in developing countries and with respect to women’ (UNESCO, 2020). Fourth, urgency. Open science is needed for promoting sustainable development and addressing pressing issues. Viewed in the context of global sustainable development, open science can help unite the world’s efforts to tackle global challenges, such as climate change, public health, the environment restoration and water resources, through international, interdisciplin ary and cross-sector cooperation.

As an important actor, China needs to be more proactive. The best way to avoid following in others’ footsteps is to keep the initiative in hand. The founding mission of the Communist Party of China was to secure human rights and democracy for its people. Human rights today are no longer just about having enough food, clothing and shelter. As the primary productive force, science and technology has propelled human society to a point where universal human rights have evolved to include the ability to understand knowledge and use technologies. In becoming an innovation power, China must be able to develop a stronger awareness about this.

Having learned about the motivation of open science, the second question we must think about is how to understand the open science movement. In my view, open science can be understood as a new paradigm for scientific innovation. From the perspective of the academic community, it is a paradigm shift from normal science to post-normal science. Whereas in the past we emphasized that issues must be discussed within their discipline, now we not only have to cross disciplinary boundaries, but even go beyond the conventional scope of the academic community and communicate with the public as equals. In the past, the work of science popularization was to tell the public and let people accept the results of science. Now the public wants to participate in the verification of scientific results, which raises the requirement for scientific literacy and rational scepticism on the part of the public. For the government, it used to deal mainly with the scientific community and scientific research institutions in conducting science and technology management. However, in the context of open science, the government needs to face all stakeholders involved in the scientific process.

Based on such changes, the Chinese Government has proposed to deepen the reform of the scientific research system. Open science provides a very important opportunity for China to integrate into the global scientific and technological innovation system from a new starting point. Then, in addition to deepening the reform of the scientific research system, what else can we do to strengthen and improve open science? First, foster a culture of honesty and rigour, freedom and relaxation, openness and cooperation, self-discipline and responsibility; second, build an incentive mechanism that respects pioneering and bold experimentation; third, deepen reforms and establish a reasonable evaluation system and trust mechanism; fourth, make use of diversified and well-designed standards and tools; fifth, encourage the media and science and technology workers to participate in science popularization, focusing on areas of public interest; and finally, take an active part in the international open science process to increase China’s influence through greater participation.

First, China should take pragmatic initiatives to promote open science. In this endeavour, non-governmental organizations such as the China Association for Science and Technology can play an active role. To achieve this goal, we should adopt a problem-oriented approach. We need to know the things we lack in terms of scientific atmosphere and culture, evaluation of and public trust in science, scientific standards and tools, science popularization in the media, and participation and influence in the international community. Based on that knowledge, we must do something to improve the situation. We need to put the open science concept into action, with specific initiatives on the ground.

Second, in the international arena, China needs to look at the big picture but start with small things. Looking at the big picture means always bearing in
mind the sustainable development goals, and properly managing international conflicts in the current geopolitical context. Starting with small things means to begin our work with open data. On open data, people always say that a big pool of data is China’s strength, but to use it well is easier said than done. To put big data resources to good use and break the barriers is not an easy task. Considering China’s plan and ambition for science, we must be determined to do our work well.

I suggest an idea called ‘FAIR + PS’. FAIR is the open data principle championed by the International Council for Science. F stands for findable, A for available, I for interoperable and R for reasonable. Together, they make the word FAIR, and that is why the council is promoting this principle. And then two more letters, P and S, are suggested to add. P stands for privacy, and S for security. I think the Chinese scientific community could start working on scientific data and make it an important tool for promoting sustainable development in the country’s rapid progress.

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