Postprint: Analysis of Collaborative Behavior in Open Scientific Data Sharing from a Citizen Science Perspective

Authors: Sheng Xiaoping, Qin Haoyang

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Abstract

[Purpose/Significance] By analyzing collaborative behaviors in scientific data open sharing from a citizen science perspective, this study provides references for enhancing the practical level of scientific data open sharing collaboration in China. [Method/Process] Using literature analysis method, this paper reviews the fundamental concepts of citizen science and its relationship with scientific data open sharing collaboration, constructs a collaborative model for scientific data open sharing from a citizen science perspective, and based on this model, analyzes how stakeholders coordinate and cooperate in scientific data open sharing. [Results/Conclusions] In a citizen science environment, stakeholders can achieve various forms of open sharing collaboration through establishing policies and agreements for scientific data open sharing, collaboratively funding open sharing activities, and conducting cooperation in scientific data open access, open publishing, open review, open linking, etc.

Full Text

Analysis of Cooperative Behaviors in Scientific Data Open Sharing from the Citizen Science Perspective

Sheng Xiaoping, Qin Haoyang
Department of Library, Information and Archives, Shanghai University, Shanghai 200444

Abstract

[Purpose/Significance] By analyzing cooperative behaviors in scientific data open sharing from the citizen science perspective, this paper provides references for improving the practical level of scientific data open sharing cooper-

ation in China. [**Method/Process**] Using literature analysis, this study examines the fundamental concepts of citizen science and its relationship with scientific data open sharing cooperation, constructs a cooperation model for scientific data open sharing from the citizen science perspective, and analyzes how various stakeholders collaborate in scientific data open sharing based on this model. [**Result/Conclusion**] In the citizen science environment, stakeholders can achieve various forms of open sharing cooperation by formulating policies and agreements for scientific data open sharing, collaboratively funding open sharing activities, and engaging in cooperative efforts such as open access, open publishing, open review, and open linking of scientific data.

Keywords: citizen science; scientific data; open sharing; cooperative behaviors
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Although the term "citizen science" has only recently emerged, public participation in scientific research has existed in various forms for a long time [1], with its history traceable to the 19th century. Examples include the "Cooperative Observer Program" launched by the U.S. National Weather Service in 1890 [2]. Today, increasing "public participation in scientific research" appears across diverse fields, from participatory action research in development studies and public health to citizen science projects with long histories in ornithology and astronomy, water quality monitoring, and community natural resource management. These initiatives have successfully addressed complex scientific and social problems [3]. In July 2015, China launched its first astronomical observation citizen science project—the Popular Supernova Project by Xingming Observatory [4]. Citizen science has gradually become a new method and form of scientific research [5]. Currently, citizen science provides a new pathway for scientific data open sharing. Researching scientific data open sharing cooperation from the citizen science perspective can help analyze the cooperative relationships and behaviors of stakeholders in this context, further promoting the development of scientific data open sharing practices in China.

1. Citizen Science Concepts and Models

1.1 Citizen Science Concept and Its Relationship with Open Science

Since the 1990s, citizen science has gained popularity in science, policy, education, and broader social domains, with growing recognition of its value [26]. Citizen science refers to public participation in scientific research activities, where individuals actively contribute to science through their intellectual work or local knowledge, tools, and resources [27], typically collaborating with or under the guidance of professional scientists and scientific institutions [28]. Citizen science represents a highly diverse practice encompassing scientific research exploration, technological development and innovation, emergency response to sudden incidents, environmental protection, and resource development and utilization [17]. To truly understand citizen science, one must comprehend its relationship with

open science, which includes two main aspects: First, citizen science is an integral component of open science. Citizen science constitutes part of open science [29], a prominent application field [30], and an important pillar of it [31]. It distinctly embodies the open and collaborative characteristics of Science 2.0, manifested as a comprehensive practice aimed at disseminating science, using collaborative cooperation as a means, and based on open data [32]. Second, open science promotes the further development of citizen science. Open science significantly enhances collaboration and connections among various social sectors and groups, transforming scientific research from a relatively closed, discipline-based system to an open, interdisciplinary one. In this context, the participants, organizational models, and research processes of scientific research have undergone systematic changes, with participants expanding from professional researchers to research enthusiasts and other non-professional researchers, and organizational models trending toward cross-regional, cross-disciplinary collaborative cooperation [33]. Therefore, open science can promote the development of citizen science, and the two have strong synergistic effects. Open science opens the doors of academia to the world, while citizen science invites the world to experience science.

1.2 Citizen Science Models

Today, various citizen science models have emerged, which can be summarized into three main types: the science shop model, participatory action research model, and adaptive citizen science research model [34]. A comparison of these three models is shown in Table 1 .

Table 1. Comparison of Three Citizen Science Models

Citizen Science Model	Implementation Scope and Characteristics	Public Participation Type
Science Shop Model (Scientific Consultation Research Model)	Problems are raised by amateur groups; universities and scientific institutions are responsible for data collection, analysis, and verification. Projects are typically limited to small geographical areas to solve local community problems, such as conducting public science education.	Public participation in “contractual projects” research

Citizen Science Model	Implementation Scope and Characteristics	Public Participation Type
Participatory Action Research Model	Amateur volunteers and professionals participate together in all scientific research processes. Research topics are highly relevant to local community issues and needs, can promote cooperation between scientists and local communities, and enhance local community science education awareness.	Public participation in "contributory projects" and "collaborative projects" research
Adaptive Citizen Science Research Model	This model involves cooperation with local public and is suitable for conservation projects in residential landscapes.	Public participation in "co-created projects" and "collegial projects" research

Citizen science projects under different models show significant differences in scope, field, methods, and requirements. Based on varying levels of participation, citizen science projects currently include five types: contractual projects, contributory projects, collaborative projects, co-created projects, and collegial projects [17]. From contractual and contributory projects to collaborative projects, and then to co-created and collegial projects, the degree of public participation gradually increases, and correspondingly, the scientific literacy and research capabilities required of the public also gradually increase [20]. Summarizing citizen science models and project types helps better understand the ways and characteristics of stakeholder participation in scientific data open sharing cooperation.

2. Significance and Value of Citizen Science for Scientific Data Open Sharing Cooperation

2.1 Promoting the Concept of Scientific Data Open Sharing Throughout Society

The global goal of citizen science is to enable active public participation in scientific processes, emphasizing the importance of openness and inclusiveness, and stimulating public creativity and motivation for learning and innovation [37]. Citizen science can promote scientific data open sharing and public participation in scientific research, breaking traditional constraints on scientific research in terms of participant numbers, regions, and industries. It allows as many departments, public entities, and other participants as possible to voluntarily engage in scientific processes across larger regions and longer timeframes, bridging the gap between science and society [26], and collaboratively conducting various

scientific investigations and research, including formulating research questions, designing and improving projects, conducting scientific experiments, collecting and analyzing data, interpreting results, developing technologies and applications, and solving complex problems [38]. It reduces research costs, increases public scientific literacy, and provides the public with deeper understanding of scientific research processes [4]. Citizen science provides necessary tools and methods to engage the public, which in turn benefits from their unique insights and creativity, thereby more efficiently achieving citizen science goals. For example, when community advocates, patients, and caregivers have direct contact with researchers, new models of sharing and cooperation flourish [39]. Therefore, citizen science helps foster a fully open philosophy and atmosphere throughout society, further promoting the development of open science and open sharing cooperation.

2.2 Providing Platform and Resource Support for Scientific Data Open Sharing Cooperation

Scientific data open sharing cooperation requires infrastructure and resource support. Citizen science platforms are new types of scientific infrastructure that can display citizen science data and information, projects and practical examples, and provide guidelines and tools needed for citizen science projects and activities. Currently, Europe has developed many citizen science platforms (see Table 2).

Table 2. Five Types of European Citizen Science Platforms [40]

Platform Type	Target Users	Main Functions
Commercial Platform for Citizen Science Projects	Individuals or institutions wanting to conduct citizen science programs	Data collection tools, data processing and storage infrastructure, data security and protection, community and user incentive toolkits
Specialized Citizen Science Platform	Citizen scientists, policymakers and decision-makers	Information on the topic, data collection toolbox, option to upload data
Platform for Specific Scientific Themes	Citizen scientists, policymakers and decision-makers	Information on the topic, data visualization, links to related initiatives, data collection instructions, option to upload data

Platform Type	Target Users	Main Functions
National Citizen Science Platform	National citizen science networks	Related citizen science information, national citizen science activity information, cooperation opportunities for specific citizen science themes
EU Citizen Science Platform	EU citizen science network	Activity information of the organization, resources on citizen science including tools and guidelines, best practices and training modules, data interaction such as mapping and sharing air quality observations, biodiversity data

These platforms can be open to a range of stakeholders including the public, scientific institutions, administrative departments, policymakers, and media. They can serve as technical frameworks for one or more applications to run and store data and information, or be designed as functions enabling participant-project data interaction, such as mapping and sharing air quality observations and biodiversity data. They can also serve as spaces for mutual learning, providing useful resources about citizen science [40]. Particularly in scientific data open sharing cooperation, citizen science platforms like Zooniverse can provide infrastructure and resource support for stakeholder participation in open scientific communication, sharing, and cooperation [20].

2.3 Providing New Methods for Scientific Data Open Sharing

Citizen science can encourage innovation in scientific data open sharing methods, providing entirely new ways for public participation in scientific data open sharing. For example, driven by the open science and citizen science movements, some institutions and platforms have launched various open data competitions [41]. These open data competitions are important approaches and models for fully stimulating the potential of open data, releasing its application value, promoting open data innovation, and empowering digital transformation across industries [42]. They benefit both open data providers seeking solutions to problems and participants who use open data to develop new prototypes, promoting scientific data open sharing and efficient utilization in an innovative way to achieve greater open innovation. For instance, under the impetus of open science and citizen science, the “OpenStreetMap” (OSM) project crowdsources data globally, with the public collecting and contributing data. Based

on the open access philosophy, the project's data is freely available to everyone. Therefore, OSM is widely recognized as an open access data platform created through public participation, containing data contributed, edited, downloaded, and evaluated by up to 5 million users [59]. This model of research institutions, researchers, and the public jointly participating in scientific data open access cooperation promotes scientific research progress and enhances public scientific literacy and research participation in a bidirectional manner.

3. Construction and Behavioral Analysis of a Scientific Data Open Sharing Cooperation Model from the Citizen Science Perspective

On one hand, the citizen science actor network in the citizen science perspective includes individuals such as public participants, professional researchers, project organizers, task designers, data managers, and platform developers, as well as organizations including research institutions/teams and third-party management agencies. The citizen science project implementation process is not only about public participants assisting professional researchers in collecting data and information for scientific research activities, but also a collaborative process among research institutions/teams and third-party management agencies [43]. On the other hand, scientific data open sharing is not an isolated activity but a value creation activity directly associated with scientific data production, organization, publication, dissemination, and utilization. It involves scientific data producers, funders, organizers, publishers, disseminators, managers, and users. In the process of scientific data open sharing cooperation, governments, research institutions, researchers, research funding agencies, library and information institutions, data centers, industry associations, publishers, and the public are all stakeholders [44]. Therefore, based on the relationship between citizen science and scientific data open sharing, we can construct a cooperation model for scientific data open sharing from the citizen science perspective, as shown in Figure 1 [Figure 1: see original paper].

Figure 1. Scientific Data Open Sharing Cooperation Model from the Citizen Science Perspective

Note: A: Government; B: Research Institution; C: Researcher; D: Research Funding Agency; E: Library and Information Institution; F: Data Center; G: Industry Association; H: Publisher; I: Public

In Figure 1, the outermost layer represents the citizen science environment, which can provide stakeholders with an atmosphere and mechanism for scientific data open sharing cooperation, while also providing a background for public participation in scientific research, promoting and ensuring public engagement in scientific data open sharing practices. The second layer from the outside comprises the main stakeholders in scientific data open sharing (represented by capital letters in the figure), who are various entities practicing scientific data open sharing and cooperation. Through sharing and cooperation among themselves

in the citizen science environment, they can generate an aggregated, amplified synergistic effect. The third layer from the outside represents the specific content of scientific data open sharing cooperation, mainly including six aspects: formulating scientific data open sharing policies and agreements (abbreviated as "policy formulation" in the figure); collaboratively funding open sharing activities (abbreviated as "collaborative funding"); conducting scientific data open access cooperation (abbreviated as "open access"); conducting scientific data open publishing cooperation (abbreviated as "open publishing"); conducting scientific data open review cooperation (abbreviated as "open review"); and conducting scientific data open linking cooperation (abbreviated as "open linking"). These activities involve somewhat different main stakeholders, forming a scientific data open sharing value chain among different stakeholders. "Cooperation" becomes the "core" of this value chain—in other words, "cooperation" runs through every link of the value chain, placing it at the center of the scientific data open sharing cooperation model from the citizen science perspective. All stakeholders implement scientific data open sharing through "cooperation." The following sections further analyze these cooperative behaviors.

3.1 Collaborative Formulation of Scientific Data Open Sharing Policies and Agreements

Governments, research funding agencies, research institutions, and industry associations can collaboratively formulate scientific data open sharing policies to provide guidance for related sharing activities. In this process, governments can play a leading role in policy formulation, such as the G8's "G8 Open Data Charter." Research funding agencies can negotiate with other stakeholders to develop scientific data open sharing policies (particularly funding policies for open sharing), promoting extensive cooperation among researchers, research institutions, data managers, and publishers in scientific data open access. Industry associations can provide advice or recommendations to governments on scientific data open sharing policy formulation. For example, the American Psychological Association requires government agencies to carefully balance rights, responsibilities, benefits, and burdens among stakeholders when developing data sharing policies, define specific levels and permissions from fully open access to restricted access, and clarify time requirements for data sharing and applicable regulations and prior agreements [45]. Additionally, industry associations can set requirements for open sharing activities of research institutions and researchers, or establish open sharing standards to jointly promote scientific data open access. For instance, the American Heart Association's (AHA) "Open Science Policy Statements for AHA-Funded Research" requires not only that journal articles resulting from AHA funding be made open access through PubMed Central within 12 months of publication, but also that factual data supporting research conclusions be openly shared within 12 months after funding ends, unless such data involve personal privacy, legal restrictions, intellectual property, or cause excessive financial burden [46].

Although the public are not direct parties in formulating scientific data open sharing policies and agreements, they can provide suggestions and feedback for policy formulation. Some Western countries emphasize the role of the public in policy development. For example, the Danish Board of Technology collects public opinions through online citizen summits, voting meetings, coffee discussions, and parliamentary hearings, while the Netherlands adopts "constructive technology assessment" to incorporate public user opinions into the technology development phase [47]. In fact, the public can participate in scientific data open sharing policy formulation through various means such as citizen surveys, online participation, citizen assemblies, hearings, citizen forums, and citizen volunteers [48], to understand and master relevant policy information. This is not only an important channel for safeguarding public right to know and express their interests, but also a crucial prerequisite for ensuring policy quality and effectiveness [49].

3.2 Collaborative Funding of Open Sharing Activities

Governments, research funding agencies, research institutions, and the public can collaboratively fund scientific data open sharing activities. Among them, governments are often the largest funders. In recent years, the Chinese government has increased financial investment, focusing on funding 20 national scientific data centers and 30 national biological germplasm and experimental material resource banks to accelerate the pace of open sharing of scientific data generated from public funding. The U.S. Environmental Protection Agency spends nearly $400 million annually to promote the open sharing of U.S. environmental data (including drinking water, atmosphere, waste, toxic substances, etc.) to strongly support environmental protection [50]. Research funding agencies can effectively guide and support research institutions and researchers to conduct scientific data open access by providing funding, stimulating more public participation in scientific research and promoting sharing cooperation among scientific data stakeholders [16]. For example, the UK Medical Research Council (MRC) not only funds various clinical trials and other medical research, but also includes clinical trials and clinical intervention research data, public health intervention research data, and observational research data from its funded research in the scope of open sharing. Researchers and the public in relevant and interdisciplinary fields can openly use these research data. In this process, the MRC requires researchers to follow the "Good Practice Principles for Sharing Individual Participant Data from Publicly Funded Clinical Trials" guidelines, making research protocols, analysis plans, and all relevant statistical analysis and research data openly shared and utilized [51]. With funding from the European Commission, as of June 12, 2021, the OpenAIRE project has achieved open cooperation among 23 funding agencies and 7,951 content providers, offering open sharing of 14,225,469 datasets, 11,982,806 publications, 22,780 software items, and 8,671,412 other research products [52].

In addition to governments and research funding agencies, the public can also

play an important role in funding scientific data open sharing activities. "Crowdfunding" is a new internet-based financing method. Research crowdfunding refers to researchers publishing project crowdfunding applications via the internet, directly raising research funds from the public, and publicly sharing research results [53]. It reflects important demands of public participation in science: publicity, openness, and democracy [54]. Over the past decade, research crowdfunding, as a new model of open scientific research, has gradually demonstrated its importance. Numerous research crowdfunding platforms such as Experiment, Futsci, and CrowdScience have been successfully operated [55], raising substantial and rapidly growing amounts of funds. For example, the public platform Kickstarter (www.kickstarter.com) raised $99 million through crowdfunding in 2011. Cancer Research UK regularly raises hundreds of thousands of dollars through crowdfunding to support basic biomedical research [56]. Therefore, the public can use professional crowdfunding websites to collaboratively fund scientific research.

3.3 Conducting Scientific Data Open Access Cooperation

Open access (OA) is a typical open sharing behavior. Scientific data open access involves extensive cooperation among stakeholders including research institutions, researchers, and the public. On one hand, research institutions provide research platforms and data resources for researchers and the public. For example, the National Sleep Research Resource platform (NSRR), supported by the U.S. National Heart, Lung, and Blood Institute, can provide researchers and the public with a large amount of free research data, with 12,545 files and over 4TB of data, including de-identified physiological data and clinical data collected from research cohorts and clinical trials [57]. The Population Research Data Sharing Platform (DSDR), supported by the U.S. National Institute of Child Health and Human Development, can archive, preserve, and disseminate data related to population research, providing community data services including fertility, health and mortality, marriage, family, immigration, population distribution, population growth and decline, elderly health, and child and adolescent obesity [58]. The data provided by these institutions can be openly accessed, offering rich data resources for researchers and public participation in scientific research.

On the other hand, researchers and the public jointly participate in scientific data collection while being able to freely obtain, utilize, and share data. For example, NSRR encourages interested researchers, educators, and trained public members to join its community, collaboratively participate in research activities, share their collected data and research tools, exchange knowledge on sleep improvement and physiological data analysis methods, and provide ideas and suggestions on how to make NSRR and other resources better serve the scientific community. Additionally, under the background of open science and citizen science, the public can widely participate in open scientific research projects. For instance, in the "OpenStreetMap" (OSM) project, data is crowdsourced glob-

ally, with the public collecting and contributing data. Based on the open access concept, the project's data is freely available to everyone. Therefore, OSM is widely recognized as an open access data platform created through public participation, containing data contributed, edited, downloaded, and evaluated by up to 5 million users [59]. This model of research institutions, researchers, and the public jointly participating in scientific data open access cooperation promotes scientific research progress and enhances public scientific literacy and research participation in a bidirectional manner.

3.4 Conducting Scientific Data Open Publishing Cooperation

Strictly speaking, open publishing refers to open access publishing. Generally, scientific data open publishing is conducted through OA repositories or OA journals. Citizen science provides new opportunities for stakeholders including the public to participate in scientific data open publishing cooperation, mainly reflected in two aspects.

3.4.1 Cooperation Among Research Funding Agencies, Research Institutions, Researchers, and Publishers Specifically, research funding agencies set funding application conditions, and research institutions and researchers, according to the requirements of funding agencies, publish research results through publishers or institutional repositories and deposit raw research data in OA repositories. For example, Plan S requires that research results and related data from publicly funded research projects in the EU or its member states must be published in open access journals and stored in designated OA repositories [60]. Similarly, European and U.S. public funding agencies often require applicants in their funding programs to strictly implement open publishing requirements. If publications from funded projects cannot achieve open publishing, the U.S. National Institutes of Health and the UK's Wellcome Trust can take extreme measures such as freezing funds to supervise implementation [61].

3.4.2 Publishers Providing Open Publishing Services to Research Institutions, Researchers, Library and Information Institutions, and the Public First, publishers can support users or collaborators in accessing data for free and provide free OA paper publishing services. For example, Elsevier has merged its database access rights and free OA paper publishing agreements into a "Read and Publish" agreement, which allows cooperative alliances and their affiliated institutions to use its database and submit and publish OA papers for free [62]. Second, publishers provide comprehensive open publishing services for research institutions and library and information institutions. For example, SCOAP3, an alliance comprising over 3,000 libraries, research institutions, and funding agencies from 44 countries, has reached agreements with 7 publishers of high-energy physics journals to convert their 12 journals to open publishing models [63]. Publishers need to provide SCOAP3 with comprehensive open

publishing services including but not limited to peer review and publishing, format editing, open access, reference and link verification, linking with data, and inclusion in abstracting and indexing services [64]. Finally, publishers provide convenient open publication reading services for the public. For instance, Taylor & Francis cooperates with Researcher App, allowing the public (readers) to use Researcher App on mobile devices to track the latest research from Taylor & Francis anytime. These apps can be downloaded from Apple App Store, Google Play, or AppGallery [65]. Through this approach, the public can access Taylor & Francis open publishing results and data on mobile devices anytime. This is a brand-new open publishing practice of great significance for expanding the influence of open publishing and promoting public participation.

3.5 Conducting Scientific Data Open Review Cooperation

In the network environment, researchers and industry experts can conduct online comments and recommendations, such as the Faculty of 1000 academic recommendation system, where selected review experts in specific subject areas regularly screen highly valuable papers from the PubMed database and recommend them to the F1000 database. Although the F1000 database fully discloses reviewers' names and identities, review reports, and comprehensive scores, this form cannot achieve open peer review among authors, reviewers, and the public (readers) [66]. However, in the citizen science environment, open peer review has new changes—both researchers and the public can participate in the open review process. Since paper reading volume, citation status, and public evaluation are important factors in examining paper quality, using public evaluation allows papers to receive supervision from outside the scientific community, helping to improve the quality of open publishing papers and screen out high-quality academic papers. This open review cooperation is of great significance. For example, the PLoS One online platform focuses on post-publication attention and citation status, providing registered users with discussion, annotation, and rating functions after paper publication. Readers, whether researchers or the public, can comment on and rate each paper online, and editors identify and recommend important papers based on this feedback. The open access journal eLife also implements open review through cooperation with researchers and the public. In July 2020, the journal's publisher announced that it would only review manuscripts already published as preprints, replacing the "review first, publish later" model with a "publish first, review later" model, shifting the editorial process focus from deciding which papers to publish to open review of preprints. If editors believe a paper is unsuitable for eLife, they allow the paper to be formally published in other journals before making review content public, to avoid negative review content affecting publication in other journals [67]. In this open peer review model, researchers and the public can be either field experts or professionally trained ordinary people, who cooperate in participation. Their cooperation with publishers in open review activities helps improve social awareness of open review and the quality of open publishing.

3.6 Conducting Scientific Data Open Linking Cooperation

Open linking is a new method for virtual resource construction and utilization. It is both an important link in digital resource integration and a technical standard for solving interoperability among different digital resource systems [68], enabling seamless linking of different types and formats of distributed digital resources [69]. In the citizen science environment, library and information institutions, data centers, research institutions, researchers, publishers, and the public can conduct scientific data open linking cooperation in three ways.

3.6.1 Cooperation Between Library and Information Institutions and Data Centers to Provide Open Linking Library and information institutions and data centers establish virtual collection resources and virtual data platforms to provide users with virtual resource links. This open, extensible, context-related open linking can provide users with as many extended links as possible related to the topic for the literature they obtain, thereby fully excavating and improving the utilization efficiency of collection resources and digital resources stored in data centers. For example, some university libraries in China actively cooperate with database vendors to add personalized identification links of collection resources to databases, helping users obtain links to electronic resources purchased by their institutional libraries or resources collected elsewhere when retrieving information resources, thereby expanding the scope of digital resources users can access [70].

3.6.2 Cooperation Between Library and Information Institutions and Publishers to Provide Open Linking Services Library and information institutions and publishers can provide open linking services for scientific data to research institutions, researchers, and the public. For example, publishers can achieve linking services from citations to full text through Digital Object Unique Identifiers (DOI). Libraries import DOI locally and combine it with OpenURL to provide users with opportunities to access literature not collected by the library or scientific data, thereby improving the utilization effect of open digital information resources and scientific data through open linking services.

3.6.3 Cooperation Between Library and Information Institutions and the Public to Improve Open Linking Services Library and information institutions often have large amounts of openly accessible digital resources, while the public has various needs for open digital resources but faces multiple obstacles in using them. When library and information institutions cooperate with the public, they can improve open linking services by fully adopting reasonable suggestions from the public on open sharing of digital resources based on understanding public needs. For example, Texas A&M University Library involved 21 public volunteers in developing its SFX OpenURL link resolver to push bibliographic information to users, including researching the usability of its menu revisions, testing newly added bXTM recommendation services and related plugin programs. Additionally, the public evaluated the quality and usability of

bXTM recommendation services and discussed their preferences for help options and full-text format settings. This cooperative research inspired the library to redesign the OpenURL menu and improve user experience, providing open linking services that better meet user needs [71].

In summary, citizen science, based on internet and new media technologies, overcomes barriers between organizations and between organizations and the public. It mobilizes collective wisdom through large-scale cooperation in the form of mass collaboration, can promote the development of large-scale scientific research, and represents an emerging research model. This paper has sorted out the basic concepts of citizen science, arguing that citizen science can promote the concept of open sharing throughout society and create an atmosphere of open cooperation. It can also provide platform and resource support for scientific data open sharing cooperation. Scientific data open sharing cooperation from the citizen science perspective involves numerous stakeholders, mainly including governments, research institutions, researchers, research funding agencies, library and information institutions, data centers, industry associations, publishers, and the public. These stakeholders can achieve various forms of open sharing cooperation by formulating scientific data open sharing policies and agreements, collaboratively funding open sharing activities, and conducting cooperative efforts in scientific data open access, open publishing, open review, and open linking. These stakeholders play different roles in the above scientific data open sharing activities, such as producers, providers, organizers, storage managers, users, evaluators, and policy agreement formulators of scientific data. However, although this paper has constructed a scientific data open sharing cooperation model from the citizen science perspective and analyzed related cooperative behaviors, the current research remains at the theoretical analysis stage and needs further verification and improvement in practice to better promote the development of scientific data open sharing and citizen science in China.

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Author Contributions:
Sheng Xiaoping: Framework design, writing, and revision;
Qin Haoyang: Participation in initial draft writing.

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