Citizen Science: Development and Challenges (Postprint)

Authors: Jin Ying, Zhang Xiaolin, Hu Zhihui

Date: 2023-07-26T00:00:00+00:00

Abstract

[目的/意义]Citizen science refers to a novel research paradigm in which non-traditional researchers and ordinary citizens participate in the scientific research process, representing a new model of open innovation. Analyzing the development trends and challenges of citizen science holds certain reference significance for its implementation in China.[方法/过程]Through methods including literature review, analysis of typical cases, and comparative analysis, this study examines the development of citizen science, typical citizen science projects, and existing challenges, and proposes policy recommendations for advancing citizen science.[结果/结论]Citizen science is a novel open innovation model that contributes to the advancement of open science, enhances citizens' scientific literacy, and facilitates public participation in governmental decision-making. The tremendous potential of citizen science should be fully recognized, and its progress should be promoted at the policy level.

Full Text

Preamble

Vol. 63 No. 13 July 2019 ChinaXiv Partner Journal

The Development and Challenges of Citizen Science

Jin Ying[1],[2], Zhang Xiaolin[1],[2], Hu Zhihui[1]
[1] National Science Library, Chinese Academy of Sciences, Beijing 100190
[2] Department of Library, Information and Archives Management, University of Chinese Academy of Sciences, Beijing 100190

Abstract

[**Purpose/Significance**] Citizen science refers to a new research paradigm in which non-traditional researchers and ordinary citizens participate in the scientific research process, representing a novel model of open innovation. Analyzing

the development trends and challenges of citizen science offers valuable insights for promoting citizen science initiatives in China. [**Method/Process**] Through literature review, case study analysis, and comparative analysis, this study examines the evolution of citizen science, typical citizen science projects, and the challenges they face, and proposes policy recommendations for advancing citizen science. [**Result/Conclusion**] Citizen science is a new form of open innovation that promotes the development of open science, enhances public scientific literacy, and facilitates public participation in government decision-making. We should fully recognize the enormous potential of citizen science and promote its advancement through policy-level support.

Keywords: Citizen Science; Public Participation in Scientific Research; Open Innovation
Classification Number: G304
DOI: 10.13266/j.issn.0252-3116.2019.13.003

Open research has become a crucial instrument for scientific and social innovation, enabling the aggregation of diverse collective intelligence, tapping into latent micro-wisdom, inspiring serendipitous discoveries, crowdfunding research resources, fostering broad and diverse collaboration, promoting public participation, and advancing knowledge and capacity building in our networked, digital, and virtualized environment. Open science makes research more effective, transparent, interdisciplinary, and innovative. While current discussions of open research primarily focus on the scientific research domain, citizen participation in scientific research should be included in the broader concept of open science—this participatory approach to research is called citizen science.

1. Citizen Science

1.1 The Meaning of Citizen Science

Citizen science, also known as crowd science, mass science, or volunteer monitoring, has been defined from multiple perspectives by different organizations and scholars. The European Commission states that when the public participates in scientific research activities through intellectual contributions, or through knowledge, tools, and resources related to intellectual work, it can be called citizen science [1]. The Oxford English Dictionary defines it as the process in which the public collaborates with professional researchers to collect and analyze data related to the natural world [2]. Citizenscience.org defines it as a research approach in which the public specifically participates in scientific research or global surveys [3]. The UK Biological Records Centre defines citizen science as volunteer participation in scientific research [4]. In essence, citizen science is a new research paradigm in which non-traditional researchers and ordinary citizens participate in the scientific research process, encompassing project design, data collection and analysis, scientific problem exploration, interest-driven research, decision support, and problem-solving [5].

1.2 The Development of Citizen Science

Research activities containing the essence of citizen science have early origins, such as Japan's cherry blossom blooming records, China's locust tracking [6], and later activities in the United States and Europe involving weather recording and natural object observation. These early activities focused on information recording, collection, and description of natural phenomena. The concept of "citizen science" was formally established in 1992 with Cornell University's "Public Participation in Ornithology" project, after which citizen science developed rapidly with increasing research and discussion. In 2016, the "Open Science Days" hosted by the Max Planck Society in Germany focused on the role of citizen science in open science, participation models, and achievements [7]. Due to the geographically diverse nature of citizen science project participants, citizen science research primarily concentrates on fields requiring broad geographic coverage and cross-regional studies, such as biodiversity, astronomy, ecological conservation, and environmental science [8].

1.3 Public Participation Models in Citizen Science

The currently recognized model for citizen science research was proposed by J.L. Shirk et al. [10] based on frameworks published by the U.S. Center for Advancement of Informal Science Education [9]. The model includes five types: contractual, contributory, collaborative, co-created, and collegial. As public participation in research deepens and scientific capabilities improve, project types may evolve from contributory to collaborative or even co-created, with some citizen science projects incorporating multiple types simultaneously.

1.4 Libraries and Citizen Science

The development of citizen science impacts libraries in two main ways: first, libraries participating in citizen science, and second, libraries initiating citizen science projects. Libraries possess natural advantages in resources, personnel, platforms, and experience for participating in citizen science. Huang Mincong [11] suggests that libraries can engage with citizen science through data and platforms while conducting training, project organization and evaluation, and results dissemination and promotion. In recent years, libraries have increasingly initiated citizen science projects, such as the Australian National Library's digital newspaper project and the British Library's project inviting public transcription of its vast collection of Sheng Xuanhuai archives.

2. Typical Citizen Science Projects

Based on differing requirements for participant capabilities and involvement methods, citizen science projects can be divided into three types: mass participation, expert participation, and open innovation competition. Mass participation and open innovation competition types have lower requirements for participants' professional qualifications, while expert participation projects generally require

participants to have certain knowledge accumulation and professional skills in the relevant field. Different types of citizen science projects vary in task difficulty, professional knowledge requirements, project characteristics, skill support and training intensity, project operation management, incentive mechanisms, and derivative products. A comparative analysis of different project types is shown in Table 1 .

2.1 Mass Participation Type: The eBird Project [12]

eBird is a typical mass participation citizen science project and the world's largest biodiversity-related citizen science initiative. Managed by the Cornell Lab of Ornithology, eBird comprises hundreds of partner organizations, thousands of regional experts, and hundreds of thousands of users. It has revolutionized bird information collection and reporting. A key feature is the technical filtering of public submissions. Users can submit observation records and view regional statistics, hotspot data, and bird distribution maps. eBird data has provided a foundation for research papers, with over a hundred papers in Elsevier's ScienceDirect database citing eBird data. The project has also spawned derivative products such as Merlin Bird ID, a tool that helps users identify bird species.

2.2 Expert Participation Type: Foldit [13]

Foldit exemplifies expert participation citizen science projects. Besides requiring participants to have certain knowledge, the project tasks are designed as an experimental protein-folding video game, combining crowdsourcing with distributed computing. Research shows that gamified citizen science projects help stimulate public enthusiasm and inspiration [14], allowing users to gain multiple types of achievement and recognition during gameplay [15]. Players use provided tools to simulate protein three-dimensional structures online, feeding results back to the platform to compete with participants worldwide. Foldit provides users with a series of training tutorials to improve their skills and research literacy. A problem involving enzyme crystal structures in simian immunodeficiency virus that had remained unsolved for 15 years was solved by a group of users within just three weeks after being posted on Foldit. Citizen science aims to leverage large numbers of participants to solve problems that computers cannot.

2.3 Open Innovation Competition Type

Open innovation competitions strictly fall within the citizen science paradigm. Increasingly, organizations and institutions either open their data, integrate data and tools for public exploration, or pose problems for public solution proposals. Examples include China's "China Innovation Challenge" hosted by the Ministry of Science and Technology, and the "Open Information Innovation Application Competition for Research and Education" hosted by the University of

Chinese Academy of Sciences and the National Science Library. The U.S. federal government's Challenge.gov platform has achieved notable results. Challenge.gov is a problem-defined open innovation competition type that crowdsources complex public problems through challenges and prize competitions, fully utilizing public talent and collective intelligence to seek creative solutions and achieve government open innovation [16]. Since 2010, Challenge.gov has released over 1,000 challenges, with more than 250,000 participants and nearly $250 million in awards [17]. Leading agencies posting challenges include the U.S. Department of Health and Human Services, NASA, and the Department of Defense. The Challenge.gov citizen science project [18] has not only solved specific problems but also incubated enterprises. For example, the George Lee team participated in the USDA Innovation Challenge, won $29,500, and used the solution to create PastureMap, a technology company helping farmers and ranchers build healthier grasslands.

3. Contributions of Citizen Science

3.1 Citizen Science as a New Open Innovation Model

The environment for knowledge creation, dissemination, and utilization is transitioning from the information age to the data age [19]. Big data is the main characteristic of this era, and helping researchers collect data is a common form of public participation in citizen science. This participation model first enriches datasets. Second, with the development of the open access movement, countries and organizations worldwide have actively introduced policies to promote open access to research results, open use of government public data, open-source access to tools for knowledge discovery and intelligent computing, and open courses for lifelong learning, providing unprecedented conditions and possibilities for public participation in scientific research. Third, citizen science is crowd intelligence science, where the public plays an important role in solving scientific problems and formulating national policies, leveraging the advantages of collective intelligence pools under open innovation models to create tremendous social and economic value. Therefore, the value of citizen science should not be considered solely from individual projects but from its contribution to the entire innovation chain.

3.2 Citizen Science Benefits Public Literacy

Citizen science helps improve public scientific literacy. On one hand, participants can master relevant disciplinary knowledge and understand the latest developments during project participation, which enhances citizen scientific literacy. On the other hand, improved citizen scientific literacy will in turn promote the entire scientific research process and quality. Therefore, enhancing public participation is crucial. A considerable proportion of citizen science projects provide training services for participants, which plays a role in promoting citizen scientific literacy.

3.3 Citizen Science Facilitates Public Participation in Government Decision-Making [20]

Citizen science has increased public participation in government decision-making processes, such as blocking projects with potential negative environmental impacts, shaping major national strategies, and even influencing international relations. Through citizen science, citizens can directly participate in decisions and policy-making closely related to public interests, such as determining railway station locations.

3.4 Citizen Science's Contributions to Ecology and Conservation

As previously mentioned, citizen science currently focuses on biodiversity, astronomy, ecological conservation, and environmental science. Its contributions to ecology and conservation are evident, including evaluating coastal ecological conditions [21], proposing integrated monitoring systems combining citizen science with traditional reporting methods for small-scale pollution events [22], classifying species distribution and population data, species characteristics (birds, moths, plants), whale sounds [23], and simulating bird migration routes to assess global biodiversity status and trends [24].

4. Challenges Facing Citizen Science

Despite efforts to promote citizen science through policies and actions in various countries and certain achievements made, citizen science still faces numerous challenges.

4.1 Data Quality

Data quality is the most significant challenge for citizen science, which largely relies on public data collection. The public lacks systematic scientific training, leading to errors in data collection, management, and upload, and in some cases, data fabrication or tampering. Research shows that public expertise, practical experience, training, and equipment all affect data quality [25-27]. According to surveys [28-29], data quality or completeness issues may undermine project effectiveness and have become an obstacle to publishing research. In a North American bird citizen science project, FeederWatch [30], when volunteers were asked to provide supporting documentation for potentially problematic records (with a 77% response rate), 15% required data correction and 30% could not be verified due to insufficient evidence. Beyond collection issues, scholars have also identified challenges in information integration [31], calling for new and more sophisticated big data analysis methods.

4.2 Intellectual Property Protection

In data-intensive research models, the importance of data is increasing. Throughout the entire citizen science process—from project design to data

collection, upload, storage, management, cleaning, analysis, and application, to research conclusions, publication, and sharing—data remains the core element. Compared to traditional paper-based outputs, data-based knowledge products often lack proper regulation and protection. In an open research environment, data ownership and usage rights should be standardized. Scientists collaborating with the public should clarify data ownership and other IP issues when launching projects, acknowledging contributions from all stakeholders, and inform the public about rules and procedures for data sharing, including what data can be shared, when, and how.

4.3 Ethical Protection and Balance

The final obstacle for citizen science is trust. As part of open research and open innovation, citizen science's most notable characteristic is openness, which to some extent means individuals and groups have considerable freedom in data use, potential fabrication, and rights protection. Beyond legal and policy regulations, some aspects require moral constraints and balance, such as privacy protection, research integrity, and conflict resolution. Citizen science's extensive application in ecology-related fields should also consider human impact on ecosystems.

5. Policy Recommendations for Developing Citizen Science

Citizen science represents a future innovation model that helps harness collective intelligence to advance science and society. It is necessary to actively develop and promote citizen science.

5.1 Recognize the Enormous Potential of Citizen Science

The role of citizen science should not be limited to traditional concepts such as data collection. We should consider citizen science from a higher strategic perspective, focusing on overall social benefit calculations. The success probability of open research models with public participation far exceeds that of traditional models. From the perspective of building a science and technology powerhouse, the degree of public participation in research and depth of involvement in government decision-making are manifestations of such strength. Achieving this requires urgently improving citizens' research literacy, which will yield enormous benefits. Government recognition of citizen science's value [32] and its inclusion in policy agendas are two means to achieve transformation [33]. The education field has also begun exploring citizen science's educational significance for society and individuals [34]. Research shows [35] that citizen science generally improves volunteers' scientific literacy, disseminates scientific concepts, and turns volunteers into mediums for spreading research results, expanding citizen science's influence while participants acquire scientific skills such as data collection, analysis, logical reasoning, visualization, smart device operation, and internet knowledge.

5.2 Actively Promote Citizen Science Policies

Recognizing citizen science's enormous benefits, countries and institutions have introduced policies to promote its development, improve IP systems, strengthen publicity, and increase support. Public participation is highlighted in the U.S. "Memorandum on Transparency and Open Government" [36]. The second and third phases of the "U.S. Open Government National Action Plan" include citizen science as an independent component. Challenge.gov and citizen science are considered important measures in building U.S. scientific and innovation capacity during the Obama administration. The U.S. National Science Foundation annually supports numerous citizen science projects. The EU's Seventh Framework Program [37] supports "Science in Society" projects involving many citizen science initiatives. The European Citizen Science Association has released a white paper on citizen science to promote its development. Additionally, Germany released "Germany Citizen Science Strategy 2020," France released "France Citizen Science," Singapore released "Singapore Citizen Science Initiative," the UK released "UK Open Government National Action Plan 2016-2018," and the Netherlands formulated the "National Open Science Plan," either specifically targeting citizen science or including it in open science plans.

Although China has made efforts to promote open access, such as the "Scientific Data Management Measures," "Opinions of the State Council on Opening National Major Research Infrastructure and Large-Scale Research Instruments to Society" (State Council Document [2014] No. 70), and the "Policy Statement of the National Natural Science Foundation of China on Open Access to Research Papers from Funded Projects," we should fully recognize citizen science's transformative impact on research models, paradigms, outputs, and socioeconomic benefits, and actively introduce policies to promote citizen science, establish relevant projects, and even appropriately favor citizen science projects during project approval.

5.3 Focus on Citizen Science Infrastructure Construction

An article in *Science* on citizen science [38] identified two key factors for future potential: collaborative mechanisms and strategic investment. Infrastructure construction can give citizen science wings, enabling faster and more stable development. Driven by the White House Office of Science and Technology Policy, the "Federal Crowdsourcing and Citizen Science Toolkit" platform was established to provide open tools for citizen science. The third phase of the "Horizon 2020" program (2018-2020) reserved €600 million for the European Open Science Cloud project and planned to establish "technology bounty prizes" to solicit solutions from society, with individuals or institutions developing the best solutions receiving substantial awards [39]. National-level investment in infrastructure such as data clouds should be increased to accelerate the construction of open knowledge organization systems, open information environments, shareable analytical and computational tools, and open science public service platforms, while promoting integrated utilization of open research resources to reduce costs.

5.4 Anticipate Potential Challenges in Citizen Science

Citizen science will encounter challenges and issues during its development. Possible challenges should be anticipated and studied in advance to provide actionable implementation recommendations. To better guide and promote citizen science, the European Citizen Science Association released the "Ten Principles of Citizen Science" to guide implementation. The Chinese Academy of Sciences Bureau of International Cooperation established the "Open Science Policy Measures and Implementation Mechanism" project to study themes in open science, including citizen science. Issues such as citizen science data traceability, verifiability, protection, contribution recognition, training and education mechanisms, management, funding support, and social benefits warrant continued research.

References

[1] SERRANO F, SANZ F, HOLOTSCHE-ERTL T, et al. White paper on citizen science [EB/OL]. [2018-08-14]. http://www.societize.eu/sites/default/files/white_{paper}0.pdf.
[2] Oxford living dictionaries. Citizen Science [EB/OL]. [2018-08-14]. https://en.oxforddictionaries.com/definition/citizen_{science}.
[3] CITIZEN SCIENCE.ORG. The power of citizen science [EB/OL]. [2018-08-14]. http://citizenscience.org/.
[4] Biological Records Centre. Citizen Science [EB/OL]. [2018-08-14]. https://www.brc.ac.uk/theme/citizen-science.
[5] MILLER-RUSHING A, PRIMACK R, BONNEY R. The history of public participation in ecological research [J]. Frontiers in ecology & the environment, 2012, 10(6): 285-290.
[6] Zhang Jian, Chen Shengbin, Chen Bin, et al. Citizen science: integrating scientific research, ecological conservation, and public participation [J]. Biodiversity Science, 2013, 21(6): 738-749.
[7] Open Science Day. Open Science Days 2016 [EB/OL]. [2018-08-14]. http://osd.mpdl.mpg.de/?page_{id}=468.
[8] Zhang Xuanhui, Zhao Yuxiang. Analysis of the evolution path and research hotspots in international citizen science [J]. New Technology of Library and Information Service, 2017, 1(7): 22-34.
[9] SHIRK J L, BALLARD H L, WILDERMAN C C, et al. Public participation in scientific research: a framework for deliberate design [R/OL]. [2018-08-14]. http://informalscience.org/images/research/PublicParticipationinScientificResearch.pdf.
[10] Public participation in scientific research: Defining the field and assessing its potential for informal science education [EB/OL]. [2018-08-14]. https://eric.ed.gov/?id=ED519688.
[11] Huang Mincong. The rise of citizen science and the role of libraries [J]. Library and Information Service, 2014, 58(14): 59-62.
[12] eBird. About eBird [EB/OL]. [2018-08-14]. http://ebird.org/content/ebird/about/.
[13] CURTIS V. Motivation to participate in an online citizen science game: A study of Foldit [J]. Science communication, 2015, 23(6): 967-974.
[14] KOIVISTO J, HAMARI J. Demographic differences in perceived benefits

from gamification [J]. Computers in human behavior, 2014, 35: 179-188.
[15] DETERDING S. The lens of intrinsic skill atoms: A method for gameful design [J]. Human-computer Interaction, 2015, 30(3-4): 294-335.
[16] Qi Ning, Li Zhaoyou. Application and implications of crowdsourcing in U.S. government management [J]. Leadership Science, 2016(4Z): 43-45.
[17] Challenge.gov. About [EB/OL]. [2018-08-14]. https://www.challenge.gov/about/.
[18] SUCCESS STORIES: GEORGE LEE, USDA innovation challenge [EB/OL]. [2018-08-14]. https://www.challenge.gov/prize-wire/2017/09/12/success-stories-george-lee-usda-innovation-challenge/.
[19] Zhang Xiaolin. Disruptive changes and the post-library era: Promoting knowledge service supply-side structural reform [J]. Journal of Library Science in China, 2018, 44(1): 4-16.
[20] Li Ji. Citizen science: A new paradigm for ecological field research [J]. Science and Society, 2016, 6(4): 37-55.
[21] HESLEY D, BURDENO D, DRURY C, et al. Citizen science benefits coral restoration activities [J]. Journal for nature conservation, 2017, 40: 94-99.
[22] HYDER K, WRIGHT S, KIRBY M, et al. The role of citizen science in monitoring small-scale pollution events [J]. Marine pollution bulletin, 2017, 120(1/2): 51-57.
[23] Citizen Science Alliance. Citizen science alliance projects (2014) [EB/OL]. [2018-08-14]. http://www.citizensciencealliance.org/projects.html.
[24] CHANDLER M, SEE L, COPAS K, et al. Contribution of citizen science to international biodiversity monitoring [J]. Biological conservation, 2017, 213(SI): 280-294.
[25] DICKINSON J L, ZUCKERBERG B, BONTER D N. Citizen science as an ecological research tool: challenges and benefits [J]. Annual review of ecology & systematics, 2010, 41(41): 149-172.
[26] CHEN G, KERY M, PLATTNER M, et al. Imperfect detection is the rule rather than the exception in plant distribution studies [J]. Journal of ecology, 2013, 101(1): 183-191.
[27] LEIBOVICI D G, EVANS B, HODGES C, et al. On data quality assurance and conflation entanglement in crowdsourcing for environmental studies [J]. ISPRS annals of photogrammetry remote sensing & spatial informa, 2017, II-3/W5(3): 195-202.
[28] RIESCH H, POTTER C. Citizen science as seen by scientists: methodological, epistemological and ethical dimensions [J]. Public understanding of science, 2014, 23(1): 107-120.
[29] BURGESS H K, DEBEY L B, FROEHLICH H E, et al. The science of citizen science: exploring barriers to use as a primary research tool [J]. Biological conservation, 2016, 208(SI): 113-120.
[30] DICKINSON J L, ZUCKERBERG B, BONTER D N. Citizen science as an ecological research tool: challenges and benefits [J]. Annual review of ecology & systematics, 2010, 41(41): 149-172.
[31] ROTMAN D, PROCITA K, HANSEN D, et al. Supporting content curation communities: the case of the encyclopedia of life [J]. Journal of the American Society for Information Science & Technology, 2012, 63(6):

1092-1107.
[32] UNITED STATES GOVERNMENT GENERAL SERVICES ADMINISTRATION. Citizen science [EB/OL]. [2018-12-08]. http://www.citizenscience.gov/about/.
[33] OFFICE OF ENVIRONMENT AND HERITAGE. OEH citizen science strategy 2016-18 [EB/OL]. [2018-08-14]. https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Research/Citizen-science/oeh-citizen-science-strategy-2016-2018-150859.pdf.
[34] BERRY D M. Introduction: understanding the digital humanities [M]. London: Understanding digital humanities. palgrave macmillan, 2012.
[35] BONNEY R, BALLARD H, JORDAN R, et al. Public participation in scientific research: defining the field and assessing its potential for informal science education. a case inquiry group report [EB/OL]. [2018-08-14]. https://eric.ed.gov/?id=ED519688.
[36] White House. Memorandum on transparency and open government [EB/OL]. [2018-08-14]. http://edocket.access.gpo.gov/2009/pdf/E9-1777.pdf.
[37] EUROPEAN COMMISSION. Research and Innovation funding 2014-2020 [EB/OL]. [2018-08-14]. http://ec.europa.eu/research/fp7/index_{en}.cfm.
[38] BONNEY R, SHIRK J L, PHILLIPS T B, et al. Next steps for citizen science [J]. Science, 2014, 343(6178): 1436-1437.
[39] Ministry of Science and Technology of the People's Republic of China. EU releases third phase of "Horizon 2020 Plan" (2018-2020) [EB/OL]. [2018-08-14]. http://www.most.gov.cn/gnwkjdt/201712/t20171213_{136775}.htm.

Author Contributions:
Jin Ying: Developed research ideas, collected materials, and wrote the paper;
Zhang Xiaolin: Designed the topic and conceptualized the paper framework;
Hu Zhihui: Provided logical guidance and writing supervision.

Upcoming Topics:

On the status challenges and value reaffirmation of contemporary libraries—using the rise and limitations of "knowledge payment" as a reference (Zhang Qilin, Ye Jiyuan)

Research on a multi-source data-based hotspot detection model for professional fields (Wang Xiaoguang, Wang Hongyu)

Construction and application of tactile interactive services for blind reading (Qi Binbin, Hu Yuning, Zhu Xuefang, et al.)

Research on methods for extracting thematic knowledge elements from professional social media (Lin Jie, Miao Runsheng, Zhang Zhenyu)

Analysis of influencing factors for user engagement in university library WeChat services (Tong Wanju, Shen Junwei)

Investigation and inspiration of MOOC copyright services in foreign university libraries (Hao Qun, Zhang Libin, Zhou Xiaokang)

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