Toppling the Ivory Tower: Increasing Public Participation in Research Through Open and Citizen Science

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Executive Summary: Prior to the emergence of professional researchers, amateurs without formal training primarily made contributions to science in what is known as 'citizen science.' Over time, science has become less accessible to the public, while at the same time public participation in research has decreased. However, recent progress in open and citizen science may be the key to strengthening the relationship between researchers and the public. Citizen science may also be key to collecting data that would otherwise be unobtainable through traditional sources, such as measuring progress on the United Nations Sustainable Development Goals (SDGs). However, despite myriad benefits, there has been limited legislative action taken to promote open and citizen science policies. The underlying issues are incentive systems which overemphasize publication in high impact, for-profit journals. The suggested policy solutions include: 1) creating an open database for citizen science projects, 2) restricting publishers from disadvantaging citizen science, and 3) incorporating open science in researcher evaluation.

I. History of citizen science

In the history of science, nonprofessional scientists were responsible for many discoveries. For example, after Lord Rayleigh published his experimental results on the thickness of oil films, perhaps the first measurements of molecular dimensions, he was contacted by amateur chemist Agnes Pockels, who had carried out similar experiments in her kitchen sink. Using a thin tray, a weighing scale, and buttons, she was able to produce monolayer films and measure their surface tension (Roberts 1985; Pockels 1892; Pockels and Rayleigh 1891). Since she was "not in a position to publish [her] observations in scientific periodicals," Rayleigh forwarded her letter to *Nature*, where it was eventually published (Pockels and Rayleigh 1891). This pioneering work would later inspire other discoveries, including the formation of the Langmuir-Blodgett trough, which won the Nobel Prize for Chemistry in 1932 (Langmuir 1916; Roberts 1985). As the 20th century progressed, formally trained researchers at universities and government laboratories began to dominate science. Some philosophers and scientists advocated for a return to this type of citizen science, where people who did not have the resources to obtain a degree could still participate in the scientific process (Feyerabend 1975; Chargaff 1978).

Since then, citizens have contributed to research in fields such as astronomy, ecology, zoology, and health––generally for studies which require high numbers of observations (Strasser et al. 2019). The term 'citizen science' was first used when the National Audubon Society established the Citizens' Acid Rain Monitoring Network to both collect data on the acidity of rainwater and raise public awareness about the hazards posed by acid rain (Bolze and Beyea 1989). Alongside improving public participation in research, citizen science provides an alternative to resource-intensive software solutions whereby researchers can use the human intelligence of willing citizens to collect data. The eBird project engaged a global network of amateur naturalists to report observations in a centralized database, while

Galaxy Zoo invited citizens to classify online images of galaxies from the comfort of their homes (Wood et al. 2011). Foldit, a multiplayer online game, engaged non-scientists in predicting protein structures (Cooper et al. 2010). Citizens can contribute by simply donating their resources as well––the SETI@Home initiative performed scientific calculations using the processing power of citizens' personal computers (Korpela et al. 2010). During the COVID-19 pandemic, researchers launched scientific crowdsourcing projects to simulate SARS-CoV-2 proteins and to collect data on symptoms (Zimmerman et al. 2020; Birkin, Vasileiou, and Stagg 2021). Citizen science has shown to be instrumental in accelerating research while providing unprecedented engagement between researchers and the public.

II. Current state of open and citizen science

Currently, there are other benefits to supporting citizen science in addition to solidifying the relationship between researchers and the public. Researchers can use citizen science to collect data that would otherwise be unobtainable through traditional sources. As an example, data used to track progress on the United Nations Sustainable Development Goals (SDGs) is typically sourced from government agencies and contain considerable gaps in social, economic, and environmental statistics, especially for developing countries. For areas where there is insufficient funding to collect complete statistics, citizen science and other non-traditional data sources may be the solution to fill in such gaps. Providing support to local level citizen science projects can improve SDG reporting while citizens actively participate in implementation of the SDGs as well as science in general (Fritz et al. 2019).

With anti-science and specifically anti-vaccine sentiment on the rise following the COVID-19 pandemic, public engagement, public trust, and science transparency are growing concerns for researchers (Hotez and Hotez 2021). Emerging interest in science transparency has also been attributed to the "reproducibility crisis" in the life and social sciences where few studies can be successfully replicated (Munafò et al. 2017). A shift to open science practices, which aim to make scientific research accessible to all levels of society, has been suggested to remedy such concerns. Such practices encompass the entire research process, and include sharing of data, better methodology documentation, as well as open access publishing (Munafò et al. 2017). Literature shows that open science improves not only reproducibility and the general conduct of science, but public trust as well (Munafò et al. 2017; Allen et al. 2019). The public has been shown to perceive open access research and researchers as both more trustworthy and credible compared with closed research (Song, Markowitz, and Taylor 2022; Rosman, Bosnjak, and Koßmann 2022).

Multiple initiatives and recommendations have been made in support of open science, and specifically open access publishing. In 2018, a coalition of state-funded research organizations from 12 countries across Europe launched Plan S. The essence of the plan demands that researchers funded by national research agencies must publish all works in open access journals or repositories by 2021. Additional stipulations include the standardization of publication fees, rejection of hybrid open-access journals as a valid solution, and support for pre-print repositories such as arXiv (cOAlition S 2018; Mirowski 2018). Though Plan S has been supported by research institutes, the European Commission, and the World Health Organization, there was strong opposition from multiple publishers (McNutt 2019). Conversely, Representative Darrell Issa introduced the Research Works Act, a bill to prohibit federal agencies from requiring open access policies when issuing grants, to the United States Congress in 2011. It was ultimately not passed after publisher *Elsevier* withdrew support for the Act, following a boycott by researchers in response to the bill (The Lancet 2012). It is possible that publishers fear the potential decrease in revenue caused by adopting open science policies. However, the potential decrease in income is insignificant compared to the threat to public trust caused by inaccessible science (Bedessem, Gawrońska-Novak, and Lis 2021).

III. Barriers to public participation in open science

Though citizen science projects have gained momentum internationally in terms of both scale and quantity, limited publications use crowdsourced data in peer-reviewed scientific journals. The lack of publications denies citizen scientists the fruits of their participation while also widening the divide between the public and research (Trojan et al. 2019). Multiple factors can cause this phenomenon, including bias against data collected by citizen scientists (Gadermaier et al. 2018). While it may be possible to generate reliably high-quality data through citizen science, best practices to ensure the integrity of individual datasets are relatively unclear, especially in the absence of relevant publication guidelines (Guerrini et al. 2018).

Some researchers have raised concerns regarding the quality of data obtained by citizen scientists (Kosmala et al. 2016). It has been found that though individual data collection accuracy can vary, statistical tools can decrease the types of bias found in citizen science datasets. Furthermore, as long as the testing and analysis methodologies are sound, citizen scientists are capable of providing reliably high quality data sets, comparable to those collected by professional researchers (Kosmala et al. 2016). Pre-testing volunteer skill levels or providing volunteers with intensive training programs can improve data quality. Depending on the project complexity, volunteers can complete this training over hours or even days. Without such training, not only can data quality be lower, but volunteers may also be at risk for injury (Kosmala et al. 2016).

High quality data may also require cost-prohibitive training and volunteer screening (Kosmala et al. 2016). The cost of publication in open access journals is another barrier to citizen science publications that prevents the scientific community from investigating the data (Burgess et al. 2017). Furthermore, the general lack of open access publications may prevent citizens from properly conducting or analyzing their own research (Hecker et al. 2018). Encouraging open science practices is therefore vital to strengthen citizen science initiatives.

Despite the numerous benefits of open science as well as the growing demand for it, publishers themselves are still hesitant to adopt more progressive measures. Publishers prefer to operate on hybrid open access models where writers often pay an exorbitant fee to make their articles available. This is especially limiting for underrepresented and early career researchers (Björk 2012). On the Scopus database, a modest increase in open access publications from 31% of total publications in 2009 to 36% in 2018 was observed (Hessels, Koens, and Diederen 2021). Web of Science presented a more optimistic outlook, showing a plateau prior to 1995 at 25% open access publications, which increased to 47% by 2015 (Akterian 2017). Regardless, possible barriers to further progress on open access publishing are the high costs associated with transitioning to an open access format, the confusing diversity of publication routes as well as open access policies, and the potential disruption of scholarly communication (Hessels, Koens, and Diederen 2021; McNutt 2019). However, these separate issues do not exist in a vacuum. A unifying factor amongst these concerns is that current rewards systems in research, and research in general, are reliant on traditional publishing in high impact, for-profit journals (Hessels, Koens, and Diederen 2021).

In essence, progress in both open science and citizen science requires a systemic change in the institution of academic research. Current research evaluation depends heavily on quantitative measures such as impact factor and publication number. This inevitably encourages competitive rather than collaborative behavior and pushes researchers to favor quantity over quality (Working Group on Rewards under Open Science 2017). Moreover, impact factor, the main indicator of research quality, has continued to lose meaning as high impact factors can be misattributed to few very highly cited papers. These few highly cited articles help those who publish in high impact factor journals, but the concept of impact factor can do more harm than good by conflating research quality with prestige (Nature 2016; Working Group on Rewards under Open Science 2017). Furthermore, like all prestige-based systems, researcher and manuscript evaluation can be strongly influenced by indirect factors such as connections rather than real values such as research quality (Working Group on Rewards under Open Science 2017). We must rethink how institutions disseminate knowledge to ensure the equity of academic success, to further the potential of citizen science, and to increase public participation in science.

IV. Policy options

Citizen science and open science can accelerate research. Through encouraging open collaboration, everyday citizens as well as experts in various fields can quickly and easily contribute to relevant projects. Research is then able to proceed faster than if only a limited professional circle participated (Woelfle, Olliaro, and Todd 2011). By supporting open science and public participation, it may also be possible to accelerate progress on the SDGs while improving the public's relationship to research (Bedessem, Gawrońska-Novak, and Lis 2021). Open science practices also offer a plethora of potential benefits for researchers. Despite the common belief that open practices may threaten academic career progression, open access publications have been shown to receive both more citations and more media coverage compared to closed access publications (McKiernan et al. 2016; Hajjem, Harnad, and Gingras 2006; Adie 2014). The following policy options aim to support citizen science and open science, improving public engagement in research as well as the conduct of science itself.

i. Option 1: Create a platform for citizen science projects

One option to promote the integrity of citizen science would be the creation of a publicly available repository which collects all data and methodology for citizen scientists. According to a survey on barriers to citizen science, this database should include information on training and verification methods as well as sampling protocols, and could follow guidelines developed by DataONE (Wiggins et al. 2013). Additionally, this platform should be able to coordinate general data analysis and scientific conduct training, as well as project-specific training. Ideally, experts in citizen science as well as research infrastructure would design this system and federal research agencies would provide funding.

Advantages: A single, publicly available database and training platform would greatly facilitate scientific engagement with citizen scientists, allowing researchers to better identify relevant, high-quality citizen science data (Burgess et al. 2017). Moreover, the data could be more easily investigated to ensure its reliability.

Disadvantages: Such a system would largely be regulated by the honor system, especially for citizen science projects that are not federally funded or conducted with governmental employees. It may be possible for citizen science journals to recommend or require contribution to the database. However, projects without interest in traditional publication may be hesitant to share their data (Guerrini et al. 2018). Furthermore, such a system would require continuous funding and though publicly available data is beneficial, it would be difficult to interpret without associated publications.

ii. Option 2: Restrict publisher policies that disadvantage citizen science

Another policy option to support citizen science is to require publishers to cease charging fees for open access publications and to encourage the use of pre-print repositories, as described by the principles of Plan S.

Advantages: By abolishing fees and acknowledging pre-prints, researchers can more easily make scientific contributions. The cost of open access publishing prohibits many citizen scientists as well as underrepresented and early career researchers from easily participating (Björk 2012). This would also allow the public to access more scientific publications and learn about opportunities to engage with research.

Disadvantages: Backlash from publishers in response to such policy is inevitable. Elimination of open access fees would result in a loss of revenue for publishers, and it is likely that long legal battles may result from attempted implementation of the policy. A transitionary policy option could be standardized and capped open access fees, as suggested by Plan S, that would eventually lead to abolished open access fees. However, another disadvantage would be that this policy option does not address the root of the problem, which is that research institutions overvalue high impact journals. Furthermore, while pre-print repositories moderate submissions for relevance and quality, submissions do not tend to undergo the review process.

iii. Option 3: Re-align values in academic research

A third proposed policy involves redesigning academic systems such that institutions prioritize open science and collaboration over publications in high impact journals. This would include implementation of an open science-centric researcher evaluation scheme. The Open Science Career Evaluation Matrix (OS-CAM) developed by the European Commission aims to provide a more comprehensive approach towards evaluating research (Hessels, Koens, and Diederen 2021). It incorporates broader aspects of research, valuing service, teaching, and leadership in the context of open science, as well as stakeholder engagement and citizen science. It is a qualitative framework which institutions can use to better evaluate a more diverse range of researchers, providing incentives to engage with open science (Hessels, Koens, and Diederen 2021). Federal research agencies can introduce the OS-CAM to the wider research community by requiring its documented use for funding eligibility.

Advantages: The main benefit of this policy option is that it changes incentive systems within academia in a way that encourages collaborative, reproducible, and accessible science. The use of a system such as the OS-CAM can inspire both more productive research and more public trust in science. As a result of its use, researchers could be compelled to develop open science skills and communicate more effectively with the public. Moreover, it is an option which is unlikely to face opposition from for-profit publishers as it does not directly impact their profits.

Disadvantages: This system would be difficult to implement simultaneously and universally, which may disadvantage researchers transitioning between institutes which do and don't use the OS-CAM. Some researchers may simply not want to participate in such a system given how deeply entrenched the concept of impact factor is in our current academic culture. More experienced researchers may be hesitant to relinquish a system which is so advantageous to them. Some may not see the legitimacy of a system that does not value publication in high impact journals. While federal funding agencies can make the OS-CAM a requirement for funding, they cannot assure implementation in all other circumstances.

V. Recommendations

The policy options described differ considerably both in impact and probability of implementation. While Option 2 would immediately remove the open access publication barrier for citizen scientists, the probability of support from publishers is very low. Similarly, though Option 3 could have the most significant impact, it would also take the longest to implement. Policy alone likely cannot change the way institutions conduct research evaluation. Therefore, Option 1 is recommended: Creating a database and training platform for citizen science projects. The creation of this platform would facilitate both the collection of high-quality citizen science data and its validation by other scientists. Furthermore, the use of this platform should be encouraged in academic institutions which make use of citizen science, starting with those supported by government funding agencies. The proposed policy will enable underrepresented and early career researchers to easily support citizen science, while also allowing citizen scientists gain valuable training. Researchers will be able to disseminate knowledge more successfully to the public and the public will be able to better engage with research. By bringing citizens closer to science, we may be able to accelerate discoveries and encourage public participation in science.

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