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Perspective

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Open Science: The citizen's role and contribution to research

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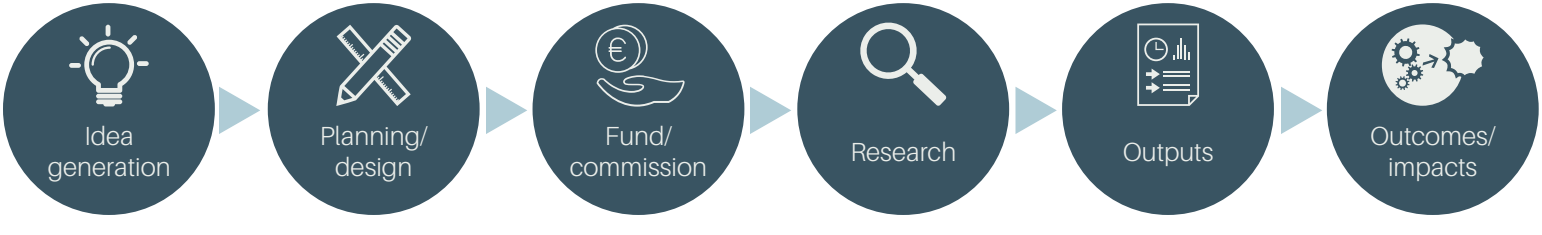
Open science can be thought of as a movement or an evolution in the research process. It relates to how scientists interact with one another and how the public engages with and is engaged in science. It also relates to societal expectations about the imperative to share results – particularly those obtained through publicly funded research. In practical terms, open science can be seen as a systemic change in the way research is conducted, affecting steps throughout the research process, from idea generation, planning and design, through to the outputs and impacts of research further along in the process.

Linking these changes towards openness is a shift in our understanding of the role of science in society that, some have argued, is bringing back values that have been overshadowed in modern science, such as a spirit of exploration (Lichten et al. 2014) and an appreciation for sharing knowledge (Könneker & Lugger 2013). Digital technology has enabled radical changes in how we

Figure 1: Steps in the research process



communicate, travel, consume and create (Schindler et al. 2013), and the related implications for science are significant and important to understand. Potential benefits include science becoming more inclusive, democratic and relevant to society (Kroes 2014). At its best, open science could help break down barriers between disciplines and between science and society, as well as speed up the scientific process by tapping in to the critical mass necessary to generate ideas and facilitate falsification of theories (Popper 1963).

What is citizen science?

An important feature of open science relates to the public taking a more active role in science, which involves a set of activities that is often referred to as 'citizen science'. Citizen science is both an aim and enabler of open science. It can refer to citizens 'doing science'– contributing at various points in the research life cycle (Figure 1), including gathering of resources, defining research questions, collecting data, analysing data, disseminating results and even evaluating a project's success (Newman et al. 2012). Citizen science can also mean greater understanding of science on the part of the public, made possible through developments in digital technology that allow greater access to information about the research process, such as the ability to use open research data or download open access journal articles. Citizen science can also refer to the ability of the public to understand science and engage with scientists, through more open communication in the form of blogs and social media. And citizen science can also refer to the public being engaged in policymaking through, for example, agenda setting for research systems.

Citizen science is by no means a new phenomenon. Two hundred years ago, almost all scientists earned a living through another profession (Silvertown 2009), and many of these amateur scientists were recognised experts in their field, conducting distinguished research (Miller-Rushing et al. 2012). For instance, Charles Darwin embarked on *The Beagle* as an unpaid companion to its captain, and not as a professional naturalist, and Benjamin Franklin was a scientist and inventor, as well as a statesman, printer and political theorist (Silvertown 2009). As science became more professionalised, amateur scientists became increasingly sidelined, but citizen science never disappeared (Miller-Rushing et al. 2012). In recent decades, citizen science has gained renewed prominence, boosted by technological advances and digital tools, such as mobile applications, cloud computing, wireless and sensor technology, and developments in simulation and gaming, which enable new modes of engagement in research (Bonney et al. 2016).

Citizen science is both an aim and enabler of open science

This new wave of citizen scientists has begun to fill two key niches: research projects that investigate questions of scale beyond a professional scientist's resource capacity and those that answer questions that professional scientists may not undertake on their own due to challenges related to the site of the study or because the question may only be of interest to a narrow audience (Miller-Rushing et al. 2012).

A recent survey of 173 citizen science projects in Europe, conducted by the Helmholtz Centre for Environmental Research UFZ/ German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, found that citizen science activities span a wide range of disciplines (Hecker et al. 2017), although the majority are in the life sciences (Figure 2a). Approximately half of the projects

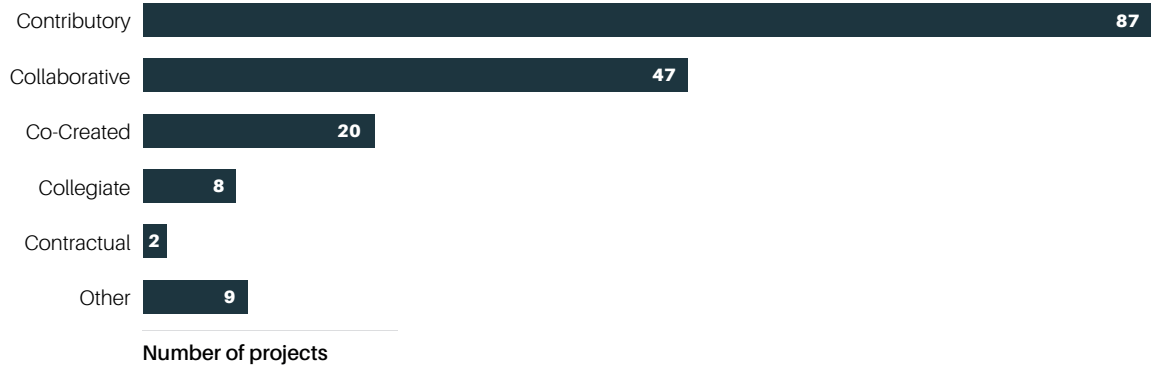
Figure 2: Survey results of European citizen science projects[1]

A

What is the primary subject area of the citizen science project?

B

What is the primary level of engagement of citizen scientists in the project?



Legend

Contributory projects are designed by professional researchers, with members of the public primarily contributing data.

Collaborative projects are designed by professional researchers, with members of the public contributing data as well as helping to refine project design, analyse data and/or disseminate findings.

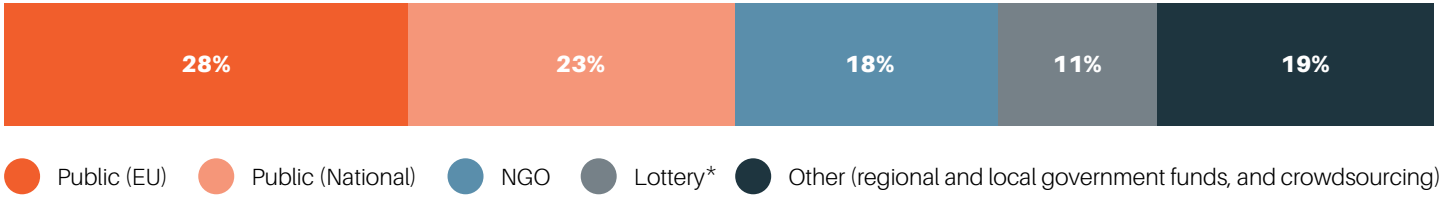
Co-Created projects are designed by professional researchers together with members of the public. At least some members of the public are actively involved in most or all aspects of the research process.

Collegiate projects are run by citizens with no involvement from professional researchers.

Contractual projects are conducted by professional researchers at the request of members of the public.

(Adapted from Shirk, J. L., H. L. Ballard, C. C. Wilderman, T. Phillips, A. Wiggins, R. Jordan, E. McCallie, M. Minarchek, B. V. Lewenstein, M. E. Krasny, and R. Bonney. 2012. Public participation in scientific research: a framework for deliberate design. Ecology and Society 17(2): 29.)

C **Sources of project funding by share of overall funding reported by all respondents (estimated)**



* Lotteries are organisations that award grants with funds from (generally national) public lotteries.

surveyed involved citizens providing data, while the other half involved citizens helping to refine project design, citizens co-creating projects, or citizens running projects entirely, with no professional scientist involvement (Figure 2b). More than 50 per cent of the funding for these projects came from public sources, either at EU, national or local level (Figure 2c).

Emergent findings in the recent literature about the impact of citizen engagement with scientific research point to trends in long-term community-level involvement, increased adult civic interest, and improved understanding and collective mobilisation to tackle global challenges, such as climate change. Other impacts identified include improved social well-being, the empowerment of communities to influence local environmental decision making (Newman et al. 2012), and the increased representation of women and minorities in the scientific process (Groulx et al. 2017). There are educational benefits emerging from pilot citizen science projects with young people, such as a project in Spain where students at Molins de Rei secondary school investigated how the colours of their school walls affected educational performance (Ruiz-Mallen et al. 2016). Students who took part described being motivated by the challenge of the study and reported that their attitudes towards science and their negative stereotypes of scientists had changed, with some considering a career in science and technology. Students also reported increased confidence in their abilities and noted that the project reinforced the notion of scientific progress as a collective process (Ruiz-Mallen et al. 2016).

There are educational benefits emerging from pilot citizen science projects with young people

One of the best ways to understand the role of citizen science in scientific research is through specific examples of projects or initiatives, such as the effect on students at Molins de Rei of engaging in a scientific research project. Recently, RAND Europe developed a 'monitor' to track open science trends in Europe, to support the European Commission's policymaking approach to open science (RAND 2017; European Commission 2017). As part of this work, RAND Europe developed a set of case studies on citizen science projects to show the breadth of initiatives and the diversity of benefits that citizen science has brought (see examples below).

Examples of citizen science projects

Foldit (https://fold.it/)

Foldit is an online game enabling players to solve puzzles in order to predict protein structures and to thereby contribute to research, including the development of potential new drugs. Citizen scientists are engaged in protein 'folding', and they also contribute to the game design. Protein structures are difficult to identify because of the countless possibilities. Predicting and identifying these structures is considered to be one of the biggest challenges in the field of biology. The collaborative approach enables Foldit players, research partners and funders to contribute to agenda setting by proposing proteins to be studied.

Zooniverse (https://www.zooniverse.org/)

Zooniverse is a public web portal where people from around the world can assist professional researchers with scientific projects, with the results made available to the general public. The objective of Zooniverse is to enable collaborative research from volunteers through a publicly accessible online platform. The platform hosts projects from a range of disciplines (48 projects from 11 disciplines as of late December 2016). Zooniverse research projects have resulted in new discoveries, useful datasets, more than 100 publications and results that are accessible for educational purposes.

The Geo-Wiki project (http://geo-wiki.org/)

Geo-Wiki is an online platform for engaging citizens in environmental monitoring, such as monitoring deforestation through understanding where cropland is located. There is a lack of accurate data on land cover in some regions of the world. Geo-Wiki aims to address the lack of data by providing the necessary tools to volunteers to help improve the quality of global land cover maps, through collecting new data and validating existing data. The project increases interaction between game developers and volunteers and enhances public access to scientific data.

Sloan Digital Sky Survey (http://www.sdss.org/)

The Sloan Digital Sky Survey is an astronomical survey that collects large datasets via a 2.5 metre optical telescope run by New Mexico State University. The objective is to reflect the large-scale structure of our universe in multi-coloured images and, with these, to create comprehensive three-dimensional maps. It is the largest open access database of the universe in the world providing information to the public about our universe. Citizen scientists classify images through a website called Galaxy Zoo. This platform also provides lesson plans and tools to allow use of Galaxy Zoo in teaching and learning.

Polymath (https://polymathprojects.org/)

The Polymath project is an open collaborative initiative where researchers and interested people with a background in mathematics try to find solutions to unsolved problems in combinatorial mathematics. Unsolved problems are suggested by interested researchers and published on a blog and a wiki page that summarises all the knowledge developed for that specific problem. Research and discussion threads enable researchers to post their contributions and discuss solutions. The initiative has inspired a similar project specifically focused on educating high school and university students on how to conduct research in a collaborative way (the Crowdmath project).

Research Excellence Framework (REF) (www.ref.ac.uk/)

The Research Excellence Framework (REF) assesses the wider societal benefits of academic research occurring in the UK. REF 2014 assessed the impact of research that occurred between 2008 and 2013 and allocated funding to higher education institutions across the UK based on the outcomes observed. Research users worked alongside academic colleagues to provide evidence and validate impacts claimed, and they were involved in the assessment and evaluation of impact case studies.

The future of citizen science – Opportunities and challenges

Can citizen science support wider changes in research?

In recent years, we have observed changes in how some members of society perceive and value evidence, alongside a decline in trust of experts and a rejection of 'elites' (Gauchat 2012; Mathieson 2012). In response, members of the scientific community have called on researchers to pay more heed to the interests of citizens (Grant 2017) and to engage more with non-scientists and sectors outside science (Mathieson 2016). Citizen science offers one way to achieve this – providing a means for patients to influence health research, for concerned citizens to investigate environmental issues in their community, and for science enthusiasts to get involved in research (Stilgoe 2016). Citizen science can thus bring the scientific community and the public closer – potentially helping to counteract the rise in mistrust and ensure that science becomes more responsive to societal needs.

What might be holding back citizen science?

The evolution of citizen science is likely to be shaped by other trends in the open science movement; public interest in environment, health and other scientific issues; and the ongoing development of social media – which has enabled the democratisation of knowledge more widely. Funding and the development of quality standards and guidance for running citizen science projects are also important elements for shaping the future of citizen science (LERU 2016). Factors that could impede the growth of citizen science relate to attitudes in the scientific community – such as a perception that data collected by the public is of lower quality than other types of data or that citizen science could provide a channel through which private interests or special interest groups could undermine the rigour and objectivity of scientific inquiry or of research funding decisions. In general, researcher and public awareness about citizen science is low, which may be holding back growth in citizen science (Burgess et al. 2016).

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What next for citizen science?

Citizen science appears to offer many opportunities for more open scientific research, and digital technologies can enable, enhance and expand citizen science activities. In the future, will citizen science remain largely confined to specific research projects and particularly to data collection activities, or are we witnessing a major shift in the role of the citizen in the scientific enterprise? What role could digital technologies play? And what could be the as-yet-untapped role of citizen science for society? We have an opportunity to reflect on the opportunities for and barriers to citizen science and to consider whether and how it might shape the future.

Endnotes

[1] Reproduced with permission from the authors (Hecker et al. 2017; in prep.). Copyright: Helmholtz Centre for Environmental Research UFZ/ German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig

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About the Digital Society Thought Leadership Programme 2017

This Perspective explores the ways in which citizens can take an active role in research. The authors explore current examples of how citizens are involved in research and discuss the opportunities and challenges for the future. This Perspective is part of a series of four exploring the opportunities and challenges that digital technologies are creating within society, written ahead of the 2017 Thought Leadership programme at St George's House, Windsor, which has been designed and will be delivered by RAND Europe in conjunction with the Corsham Institute.

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