Open science

The citizen's role in and contribution to research

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An overview of the consultation on open science held as part of the Corsham Institute Thought Leadership Programme 2017

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This report was produced following a consultation at St George's House, as part of a programme of events in the Corsham Institute 2017 Thought Leadership Programme.

This report should be read in conjunction with the 'Building our Connected Society' summary report and the perspective papers from the series (which are available at www.randeurope.org/connectedsociety and https://corshaminstitute.org/research). The consultations in the 2017 programme were:

Digital learning: Digital technology's role in enabling skills development for a connected world – March 2017
Open science: the citizen's role and contribution to research – April 2017
Currency: Redefining the way we transact in a digital world – May 2017
Civic engagement: How can digital technology encourage greater engagement in civil society? – June 2017

This programme hosted at St George's House was developed in partnership by Corsham Institute and RAND Europe.

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Foreword

The pervasiveness and ubiquity of all things digital has accelerated over the past 20 years and continues to grow exponentially. Digital technology is becoming increasingly intertwined with everyday life: from schooling and education, to political engagement, and even financial and health management. Developments in digital technology, and the speed at which they emerge, drive innovation and new applications that touch our lives in different and often profound ways. While there are numerous opportunities and aspirations associated with digitalisation, there is also a crucial need to understand and mitigate the challenges it presents to society.

In partnership, Corsham Institute and RAND Europe design and deliver an annual programme of Thought Leadership, at St George's House. From its inception in 2016, the aim of the programme has been to explore the opportunities and challenges that digital technologies are creating within different aspects of society.[1]

The Open Science Consultation on 6 and 7 April 2017 was the second of the four consultations which took place as part of the 2017 Thought Leadership Programme. Other events in the series focused on:

- Education and skills
- Currency and the future of transacting
- Civic engagement

'Building our Connected Society', a summary of the key findings identified across the four events in the 2017 Thought Leadership Programme, is published alongside this report.

1 For more information, visit: https://www.rand.org/randeurope/research/projects/corsham-institute-thought-leadership-programme.html or https://www.corshaminstitute.org/research/

Background

Open science represents a set of approaches to the scientific research process that encourage openness, transparency and access to knowledge through research collaboration and participatory, bidirectional modes of interaction between researchers and society.

'Citizen science' is part of the growing open science movement. It is of particular significance to a digitally connected society, as it takes open science activities beyond the purview of professional scientists' circles by exploring the involvement of citizens in scientific research and the implications of these activities on and within society.

Digital technology is reinvigorating the historical practice of amateur scientists contributing to the scientific endeavour, and emphasises core scientific values, including a spirit of exploration and an appreciation for sharing knowledge that some say has been eclipsed in modern science. Historically, there are many examples of amateur scientists conducting distinguished research. For example, Charles Darwin went aboard *HMS Beagle* as an unpaid companion to its captain, and Benjamin Franklin was simultaneously a scientist and inventor, as well as a statesman, printer and political theorist.[2] A growing movement of new citizen scientists is tapping in to the fast-changing environment, which is characterised by the rapid emergence of novel and innovative digital technology, to conduct collaborative and ambitious research that helps to address pressing local and global societal issues. 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.[3] Other impacts identified include improved social well-being, the empowerment of communities to influence local environmental decision making[4] and the increased representation of women and minorities in the scientific process.[5]

With these considerations in mind, the overarching question of the consultation was:

> **How can digital technology better support the involvement of citizens in research for the benefit of everyone in a connected society?**

This question enabled us to focus our discussions on how digital technology can better support and extend the involvement of the public in scientific research.

The consultation was held at St George's House. As is the case for all Thought Leadership consultations, our discussions were held under 'The St George's House Protocol' and 'The Chatham House Rule'.[6] Participants at the event included senior figures from academia, industry, government and third-sector organisations (for a full list of organisations represented, see page 21).

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2 Silvertown, Jonathan. 2009. 'A New Dawn for Citizen Science.' *Trends in Ecology & Evolution* 24(9): 467-71.

3 Evans, Celia, Eleanor Abrams, Robert Reitsma, Karin Roux, Laura Salmonsen & Peter P. Marra. 2005. 'The Neighborhood Nestwatch Program: Participant Outcomes of a Citizen-Science Ecological Research Project.' *Conservation Biology* 19(3): 589-94.

4 Newman, Greg, Andrea Wiggins, Alycia Crall, Eric Graham, Sarah Newman & Kevin Crowston. 2012. 'The Future of Citizen Science: Emerging Technologies and Shifting Paradigms.' *Frontiers in Ecology and Environment* 10(6): 285-90.

5 Groulx, Mark, Marie Claire Brisbois, Christopher J. Lemieux, Amanda Winegardner & LeeAnn Fishback. 2017. 'A Role for Nature-based Citizen Science in Promoting Individual and Collective Climate Change Action? A Systematic Review of Learning Outcomes.' *Science Communication* 39(1): 45-76.

6 See: https://www.chathamhouse.org/about/chatham-house-rule

Ahead of the consultation, a short thought-piece was developed for the participants in order to provide background information on some of the issues as well as set the scene for the discussions.[7]

The following report gives an overview of the discussions between the participants over the two-day consultation. It aims to capture preliminary ideas and thinking on the role of digital technology in expanding the role and scope of citizen science within a more connected society, as well as recommendations for further research. It should be noted that the views and proposals contained in this report may not necessarily be endorsed by everyone involved in the consultation.

7 Elta Smith, Sarah Parks, Salil Gunashekar, Catherine A. Lichten, Anna Knack, Catriona Manville. *Open Science: The citizen's role and contribution to research.* Santa Monica, CA: RAND Corporation, 2017. https://www.rand.org/pubs/perspectives/PE246.html

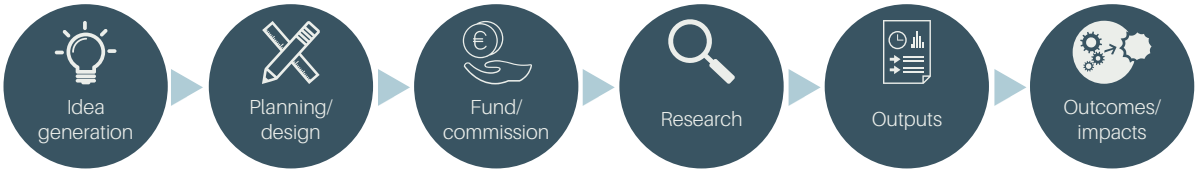
1. What is citizen science?

We commenced our discussion by considering what the term citizen science meant to participants, in order to establish a common understanding regarding the precise use of the term. Traditionally, citizen science has been seen as an activity in which volunteers help academic researchers with data collection and data analysis, but during the consultation, several examples of citizen science were highlighted that demonstrate the broad diversity of emerging activities across the research life-cycle (see Figure 1) that can potentially be included within the definition of citizen science. For instance, beyond data collection, citizen scientists can help in the planning and design of the research itself, as well as data analysis and dissemination of findings. One example mentioned was the James Lind Alliance, which brings patients, carers and clinicians together in partnership to set priorities for health research.[8]

Not all participants had previously considered the definition of citizen science to include all phases of the research lifecycle, and there was general enthusiasm and support for taking a wider definition of the activities which should be considered part of citizen science. Participants also discussed whether citizen research might be a more appropriate term than citizen science, as it would be more inclusive of research fields beyond the natural sciences, for example, also including arts and humanities subjects.

The consultation was attended by representatives of organisations that are actively involved in citizen science projects across many different areas of inquiry. Some of these projects were described by the participants as conforming to the more traditional thematic focus of citizen science projects, covering science, technology, engineering and mathematics (STEM) fields (see box below), while others constituted a broader perspective on citizen science, with subject definitions that extend, for example, to the social sciences and the arts and humanities.

Figure 1. The research life cycle



8 Madden, M., & R. Morely. 2016. 'Exploring the Challenge of Health Research Priority Setting in Partnership: Reflections on the Methodology used by the James Lind Alliance Pressure Ulcer Priority Setting Partnership,' *Research Involvement and Engagement* 2(12). doi:10.1186/s40900-016-0026-y

Nappy Science Gang

A project supported by the Wellcome Trust called the Nappy Science Gang[9] is helping equip parents with evidence-based information about their nappy-related concerns. The impetus for the project was parents' frustration with the conflicting information online regarding reusable nappies and the Wellcome Trust wanting to build an evidence base to find out which information is reliable. As a citizen science project, they are asking amateur scientists to do research and to design experiments, as well as participate in weekly online question-and-answer sessions with detergent chemists, fabric testing experts and epidemiologists.[10]

A further example of the wider definition of citizen science was provided through the Old Weather project on Zooniverse (see box below), where volunteers are asked to explore, mark and transcribe weather logs from ships that went on Arctic sea voyages in the 19th and early 20th centuries. This data can be used by historians and climate scientists for such applications as climate model assimilation, retrospective analysis, and for other types of research.[11]

Zooniverse

Zooniverse is an example of a citizen science platform that was discussed during the consultation. Zooniverse is an online platform that connects professional researchers with a diverse volunteer base who are invited to carry out a range of tasks, such as transcription, identifying and counting animals captured in camera trap images, and identifying features of galaxies, supernova and other objects in space. Zooniverse began with the project Galaxy Zoo, in 2007, with a small science team and one web developer. Galaxy Zoo presented images of a million galaxies and asked volunteers to help sort them into types by answering basic questions, such as: 'Is it spiral or is it flat?' The project was unexpectedly successful. The initial call for participants attracted thousands of people, who were able to process more data in one week than a PhD student at the University of Oxford was estimated to be able to do in their three years of study; the crowd performed roughly 70,000 classifications an hour.[12] The success of the project inspired the creation of other projects in disciplines such as climatology and the humanities, and ultimately led to the Zooniverse platform, which now hosts a free project builder where anyone can create their own project. Today, Zooniverse has more than 1.5 million registered volunteers, and although not all of them are active at once, a substantial proportion of these volunteers actively take part in the research projects, ranging from transcribing manuscripts by Shakespeare's contemporaries, to counting penguins. Each project has its own URL and a discussion area called 'Talk', which allows researchers and volunteers to communicate and generate discussion, which facilitates a feedback loop of interactions whereby researchers and volunteers can share ideas and make corrections to erroneous data that can then be used to continuously improve the delivery of the project. More than 100 papers have been published about Zooniverse or based on data produced by the Zooniverse crowd. As of August 2017, 108 projects had been launched on the platform.

9 Nappy Science Gang. 2017. 'Nappy Science Gang: A Citizen Science Project about Cloth Nappies.' As of 16 August 2017: https://nappysciencegang.wordpress.com/category/live-chat-write-ups/

10 Gray, Kate Arkless. 'In Search of the Truth on Reusable Nappies.' As of 16 August 2017: https://blog.wellcome.ac.uk/2015/08/13/in-search-of-the-truth-on-reusable-nappies/

11 Old Weather. 2017. 'The Project.' Old Weather. As of 16 August 2017: https://www.oldweather.org/about.html

12 Galaxy Zoo. 2017. 'The Story So Far.' Galaxy Zoo. As of 16 August 2017: https://www.galaxyzoo.org/#/story

Some participants noted that citizen science research is often characterised as being driven by real-world concerns that seek to address salient social issues in pursuit of contributing towards the public good, as opposed to more theoretical concerns.

One observation that was expressed during our discussions is that citizen science research can be distinguished by a different set of incentives to those that are typically associated with more academic reward systems. Participants noted a real difference in emphasis: academic researchers' focus on individual attribution and ownership of information contrasts with the free flow of information and collective sense of achievement associated with citizen science, in line with the principles of open science. One participant summarised this by explaining that the essence of open science is to share knowledge openly and as soon as possible, rather than to publish and claim intellectual property.

There was considerable debate about whether both passive and active data collection warranted inclusion within the group's definition of citizen science. Some felt that agency is a key component of citizen science, and rejected data collected through such mechanisms as crowdsourced social media and mobile app data as constituting data that is collected or provided by 'citizen scientists'. To illustrate this point, examples were given of individuals who record their own data but are not actively pursuing collaboration with others, or individuals who are not motivated by a particular research question, and there was much debate as to whether these people could be considered citizen scientists. The individual's data might be freely available online, and the decision by a researcher to use the data may be made after and not before the data was collected; however, there was no consensus on whether this should fall within the definition of citizen science. A similar point was made concerning individuals who geotag their photos to mark and broadcast to others, for example, where snow is falling. Although their broadcasts might contribute useful information for research, these individuals are not necessarily actively engaging with specific research objectives.

Others argued that it may not necessarily be useful to draw a distinction between passive and active engagement in citizen science research, and that the public's involvement and level of collaboration should be viewed as more of a spectrum of activities. For instance, although an individual may not be directly involved in a research group's efforts, there is still scope for collaboration in terms of having contributed to the public good, whether knowingly or unknowingly. In such cases, the more defining issue is whether the research is conducted for the public good.

Finally, some participants felt that applying an artificial definition to the citizen science movement may actually risk curtailing the great breadth of potential for research which is possible through citizen science, particularly within the context of rapidly accelerating digital technology, and that we should maintain a broad and inclusive definition of the activities that are considered part of citizen science.

2. Benefits and challenges of citizen science

Our discussions continued by exploring the potential benefits and challenges which greater levels of citizen science activity might create within society, from the perspective of three different stakeholder groups: citizens (as participants in citizen science), academic researchers and funders, and policymakers.

Citizen participants

Although the benefits to individuals engaging in citizen science activities largely depend on the manner in which any research is undertaken, some generalisable benefits were identified, including personal development, the opportunity to gain new skills and social currency, and the personal satisfaction and general enjoyment which can be gained from being part of citizen science activity.

We also heard how citizen science can offer individuals the opportunity to learn new skills in terms of designing, conducting and reporting research and in terms of engaging with digital technology and tools. Individuals volunteering to take part may also gain new connections and friendships with similarly minded people all over the world through cooperation. The more altruistic motivations behind citizen science also allow participating citizens to feel a high degree of personal satisfaction from engagement in a civic activity as well as experience the reward of seeing their work contribute to the wider public good. Finally, perhaps one of the most important rewards identified for citizens engaging in these activities is that citizen science is inherently fun; it is an opportunity to derive high levels of personal enjoyment from participating in enriching activities.

Awareness is considered to be one of the most important barriers to increasing the scope and scale of citizen science initiatives. The term citizen science and the developments associated with it are largely unknown outside of academic communities and the groups that have direct contact with citizen science projects.

There were mixed views about whether citizen science had to be voluntary, or whether participants could be reimbursed for their time and participation in projects. Several examples were provided in which expenses were paid, but generally it was felt that doing citizen science should be a voluntary activity. There was a concern that paying people to participate could undermine the intrinsic value of citizen science in promoting scientific exploration for intellectual curiosity's sake. In addition, there was also a concern that providing a monetary incentive may reduce the care with which people review the data, as they seek to maximise their financial reward. Some participants also expressed the concern that making a small payment to people participating in citizen science activities could be considered insulting to people who have provided their time and expertise as skilled amateurs.

Others, however, acknowledged that not providing a financial incentive may exclude some citizens from participating because they lack the free time. 'Time poverty' was flagged during our discussion as a challenge for disadvantaged groups in society. The need to earn a living and work long hours may mean that potential participants lack the time to donate to citizen science projects. Health and mobility issues may also limit people's freedom to determine their activities throughout the day. This is discussed further in section 3, on widening participation.

Academic researchers and funders

The principal benefit of citizen science for academic researchers is seen to be the

potential to make improvements to the scope, speed, quality and resource efficiency of their research activities, as well as the opportunity to widen dissemination and impact of their work, while also encouraging appreciation of science in future generations.

Through the sheer scale of participation in research using citizen science, professional researchers and scientists are able to collect and analyse more data than a single researcher could manage by themselves (for an indication of scale, see the example in the previous box: Zooniverse), and this means that academic researchers can be more ambitious with undertaking research that extends beyond their financial, labour and time resources. At the same time, collaboration from the very early stages of research also means that the research generates more buy-in, forging relationships with citizens at a global rather than a local level, so they are able to contribute to the wider dissemination and therefore to the impact of the research.

Research funders, meanwhile, also stand to benefit from citizen science through its potential for knowledge and capacity building of the public, as well as the improved relevance of the research agenda, the heightened scalability and ambition of research, and new opportunities for collaboration with industry. An example of such activity happening in practice is the Ocean Acidification Program, which funds technology development to monitor coastal pH measurements worldwide.[13]

At the same time, and because of the range of stakeholders that it attracts, some participants described citizen science as creating opportunities for jointly funded and administered projects (see box below), as well as supporting greater collaboration between funders and industry stakeholders, who are interested in citizen science as part of corporate social responsibility agendas. For instance, IT companies such as IBM and SAP have worked on producing citizen science platforms to support such projects.[14]

13 NOAA Ocean Acidification Program. 2017. As of 16 August 2017: http://oceanacidification.noaa.gov/Home.aspx

14 Wong, Kristine. 2014. 'IBM and SAP Open Up Big Data Platforms for Citizen Science.' Guardian.com. As of 16 August 2017: https://www.theguardian.com/sustainable-business/tech-giants-ibm-sap-citizen-science-big-data

Citizen science at the Natural History Museum

The Natural History Museum in the UK, an international research organisation with around 300 scientists, has been running a citizen science programme for more than 10 years. The programme is mainly based in the Centre for UK Biodiversity, but is expanding into global projects. Current projects include the Big Seaweed Search, which collects environmental data on seaweed found on UK coasts. Other projects are The Microverse, in which 129 schools and community groups analysed microbial samples from urban settings in cooperation with academic researchers,[15] and Miniature Lives Magnified, in which digital volunteers take two minutes to transcribe the Museum's microscope slides, helping to digitise the 80 million specimens in the Museum's collection.[16] The Museum also led the OPAL [Open Air Laboratories] Bugs Count survey, a project funded by the Big Lottery Fund, in which participants join an insect species hunting quest through a specially developed mobile app.[17] The museum issues guidelines and codified principles for citizen science practitioners and provides them with resources, particularly in an effort to support the conduct of good citizen science.[18,19] A challenge the museum has encountered has been how to widen participation and access for people beyond those groups that are already likely to take part, such as the very young or retirees. There is an ongoing initiative to better understand who is taking part in the museum's citizen science projects through questionnaires that ask participants about their demographic characteristics and to understand the learning outcomes for young people who take part, through a grant from the Wellcome Trust, the Economic and Social Research Council and the National Science Foundation. OPAL has also received funding from The Big Lottery Fund[20] to better engage hard-to-reach groups.

There was recognition that citizen science initiatives are often competing with more 'traditional' research models, with the latter perceived within academia and by research funders as more legitimate and robust in their approaches and outcomes.

There was also a perception that funders may be unlikely to rate citizen science highly and therefore may be less likely to recommend it for funding. One participant described a concern that citizen science is seen as 'fluff on the top' and rarely appreciated as being 'real' science, while others observed that it is not necessarily the funders themselves who are resistant to

15 Natural History Museum. 2017. 'The Microverse.' Natural History Museum. As of 16 August 2017: http://www.nhm.ac.uk/take-part/citizen-science/microverse.html

16 Natural History Museum. 2017. 'Miniature Lives Magnified.' Natural History Museum. As of 16 August 2017: http://www.nhm.ac.uk/take-part/citizen-science/miniature-lives-magnified.html

17 Natural History Museum and OPAL (Open Air Laboratories). 2017. 'Natural History Museum – OPAL partner.' OPAL Explore Nature. As of 16 August 2017: https://www.opalexplorenature.org/NHM#/0

18 Biological Records Centre and Natural History Museum. 2017. *Guide to Citizen Science: Developing, Implementing and Evaluating Citizen Science to Study Biodiversity and the Environment in the UK*. London: Natural History Museum. As of 16 August 2017: http://www.nhm.ac.uk/content/dam/nhmwww/take-part/Citizenscience/citizen-science-guide.pdf

19 Natural History Museum, Bristol Natural History Consortium, Stockholm Environment Institute and The Marine Biological Association. 2017. *Guide to Running a BioBlitz 2.0.* London: Natural History Museum. As of 16 August 2017: http://www.nhm.ac.uk/content/dam/nhmwww/take-part/Citizenscience/bioblitz-guide.pdf

20 OPAL. 2017. '£3m Lottery Grant to Roll Out OPAL across the UK.' OPAL Explore Nature. As of 16 August 2017: https://www.opalexplorenature.org/news/big-lottery-fund-uk-wide-grant-sep-13

citizen science, but the peer reviewers from the academic community, who tend to view citizen science unfavourably – a perspective that then spills over to the funders. Others suggested that funders have a role to play in removing the stigma that keeps citizen science marginalised in the scientific community.

Researchers and academia also grapple with challenges to ensure that research involving amateur scientists is sufficiently robust and of a quality that would be comparable to 'traditional' academic research. Due to continuing scepticism regarding the validity of citizen science research in some academic circles, some scientists are concerned that their involvement in citizen science projects may damage their careers. Furthermore, as much as citizen science projects tend to be motivated by personal enjoyment, there is an equal need to ensure that expectations of the participating public are managed. Sometimes research yields disappointing findings, or the research abruptly ends because of challenges that cannot be overcome, and when part of the motivation behind the research is a sense of purpose and personal enjoyment, dampening expectations may dissuade participants from continuing their involvement in citizen science activities.

Policymakers

For policymakers, it was felt that the main benefits of citizen science are its ability to offer insights from different perspectives, thereby elevating citizens' voices, raising public awareness and engagement on key societal issues, improving buy-in and grassroots ownership over local and national issues, and contributing to more agile responses to issues of social importance (e.g. curbing pollution).

Others felt that participation in citizen science opens up new channels for citizens to access policymakers, by allowing concerned citizens to coalesce and gain critical mass on issues of social and environmental importance. This could help support and drive greater citizen participation in policy formulation and make policies more relevant for citizens. In the Netherlands, for instance, pilot initiatives that have exemplified the spirit of this approach to citizen engagement include the Dutch government's open call to citizens requesting input on what scientists should be studying in preparation for the implementation of the Dutch National Plan Open Science.

Concerns for policymakers centred on the polarisation of policy and the potential for groups propagating 'bad science' to hijack particular research issues. We discussed how similar dynamics have led to the surge in populism, as evidenced by recent political events, and how this might make its presence felt in citizen science, leading to suggestion that there should be safeguards against politicised science.

Moreover, given that policymakers rely on the opinions of experts to ensure the relevance of policy, participants raised questions regarding the implications of an environment where anyone from the general public could be considered an expert. Questions were raised regarding how policymakers might be able to distinguish between claims of expertise, and whether the process of categorisation might unfairly rate citizen science lower, in favour of professional science.

3. Approaches to addressing the strategic challenges

In addition to exploring the benefits and challenges of greater involvement of citizens in scientific research, our discussions also identified a number of more strategic issues which will need to be addressed if growth in citizen science is to flourish across society. These are: (1) improving data quality, (2) demonstrating impact, (3) widening participation, and (4) ensuring transparency and openness.

Improving data quality

A key issue identified as part of our discussions is the need to improve and also ensure data quality if citizen science activities are to become more accepted within the research community. Upskilling individuals and the use of technology could help to address some of the concerns held by some members of the academic and policymaking communities, who are currently hesitant about the use of information gathered by the general public, fearing it will result in low-quality data.

The example was given of how technology can be used to help validate data quality in the Galaxy Zoo project, where individual images of galaxies are looked at by multiple individuals and a consensus-based classifier weighting method is used to filter outlying classifications, thus enabling researchers to preserve information on trends with a great deal of confidence, while down-weighting significantly outlying data.[21] When data is checked and monitored, incorrect information can be identified and removed. And although there are limitations to the scale at which this is possible, digital platforms could be designed to incorporate moderator roles with expertise on the scientific method and could also advise and help citizen scientists in terms of refining their approaches.

Overall, participants felt that there is a need to generate a higher level of trust in the citizen scientists' abilities. Some felt that visibility of projects and their outcomes might improve the reputation of citizen science, while others proposed that citizen science projects should be tested or evaluated against an agreed upon 'gold standard' approach (using 'conventional' research approaches) or have a randomised controlled trial, conducted by a respected scientist, to see how citizen science research compares in terms of quality and output. Such comparative evaluation might help to bring more legitimacy to citizen science projects.

In instances where citizen scientists are developing and delivering their own projects, the group felt that, as with traditional research, there is a need for a framework to curate the citizen science activity in order to increase the academic research community's trust in the citizen scientists' ability to make a contribution to the scientific endeavour. Such curation would support citizen science projects led by members of the public, by educating citizen participants about the conduct and analysis of robust and ethical research.

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21 Simmons, B. D., Chris Linnott, Kyle W. Willett, Karen L. Masters, Jeyhan S. Kartaltepe, Boris Häußler, Sugata Kaviraj, Coleman Krawczyk, S. J. Kruk, Daniel H. McIntosh, R. J. Smethurst, Robert C. Nichol, Claudia Scarlata, Kevin Schawinski, Christopher J. Conselice, Omar Almaini, Henry C. Ferguson, Lucy Fortson, William Hartley, Dale Kocevski, Anton M. Koekemoer, Alice Mortlock, Jeffrey A. Newman, Steven P. Bamford, N. A. Grogin, Ray A. Lucas, Nimish P. Hathi, Elizabeth McGrath, Michael Peth, Janine Pforr, Zachary Rizer, Stijn Wuyts, Guillermo Barro, Eric F. Bell, Marco Castellano, Tomas Dahlen, Avishai Dekel, Jamie Ownsworth, Sandra M. Faber, Steven L. Finkelstein, Adriano Fontana, Audrey Galametz, Ruth Gruetzbauch, David Koo, Jennifer Lotz, Bahram Mobasher, Mark Mozena, Mara Salvato & Tommy Wiklind. 2016. 'Galaxy Zoo: Quantitative Visual Morphological Classifications for 48,000 Galaxies from CANDELS.' *Monthly Notices of the Royal Astronomical Society*. doi:10.1093/mnras/stw2587

Capacity building could also be achieved through collaborations between citizen scientists and academics from the beginning of, and throughout, a project, for instance, in the Wellcome Trust's Nappy Science Gang project, or in the Natural History Museum's Microverse. At the same time, the group stressed the importance that training should not be too burdensome, so as not to dissuade interested citizens from getting involved with citizen science.

Demonstrating impact

If citizen science is to become more widely accepted, there is a need for the approach to demonstrate impact. We heard about how citizen science can improve public appreciation for science and the natural world, and that evidence of impact already exists anecdotally. Examples include the Neighborhood Nestwatch Program, which claims that citizen science encouraged participants to become more aware of the value of backyard ecosystems for birds and other organisms.[22] Real contact with wildlife has been said to stimulate greater appreciation for nature.[23]

There is also evidence that some citizen scientists report a change in their appreciation for science more generally.[24] However, participants felt that citizen science projects would benefit from more evaluation, greater publication of personal stories and longitudinal studies to demonstrate impact.

Dissemination of findings is also seen as a critical component of demonstrating impact, and citizen scientists need to ensure that they are convincingly demonstrating the impact of their research projects, including, possibly, unintended impacts. Digital technology could be used as a medium to raise such awareness, and also to communicate the compelling personal stories, which can be impactful and powerful motivators to encourage new participants to become involved in citizen science.

Widening participation

A challenge noted throughout this consultation was how to extend and widen participation in citizen science to groups who are not currently engaged in such initiatives. This could include low-income groups, people with disabilities and people of ethnic minority origin, as well as other groups not currently engaged.[25] A number of participants observed that digital technology could help to make citizen science more accessible for people from these groups through online-based projects that can be accessed from home, although digital technology also brings challenges, as skills and accessibility remain uneven and this may contribute to the potential for social exclusion. Additionally, some funders such as the Big Lottery Fund set specific targets on projects to reach a certain percentage of people from 'hard to reach' or disadvantaged communities. For example, in the OPAL project, 23% of the 965,000 people reached were from such communities.[26]

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22 Evans et al. 2005.

23 Devictor, Vincent, Robert J. Whittaker & Coralie Beltrame. 2010. 'Beyond Scarcity: Citizen Science Programmes as Useful Tools for conservation Biogeography.' *Diversity and Distributions* 16(3): 354-62.

24 Jordan, Rebecca, Steven A. Gray, David V. Howe, Wesley R. Brooks & Joan G. Ehrenfeld. 2011. 'Knowledge Gain and Behavioural Change in citizen-Science Programs.' *Conservation Biology* 25(6): 1148-54.

25 West, S., & R. Pateman. 2017. 'Recruiting and Retaining Participants in citizen Science: What Can Be Learned from Volunteering Literature?' *Citizen Science: Theory and Practice* 1(2): 15. doi:10.5334/cstp.8

26 OPAL. n.d. 'OPAL – Exploring Nature Together: Findings and Lessons Learnt.' As of 15 September 2017: https://www.opalexplorenature.org/sites/default/files/Opal_report_LOW.pdf

Historyworks

Historyworks is a production company working across the media and education sectors that seeks to link knowledge generation in the universities and tech companies with public engagement, especially targeting harder to reach young people and disadvantaged families via schools and youth programmes. The British Broadcasting Corporation (BBC) initiated an education program based on the Micro:bit by ARM, a pocket-sized, codable, hand-held device that the BBC hopes will inspire digital creativity and encourage future generations of tech pioneers.

Young people work with Professor Helen Weinstein and the team at Historyworks on location at a museum or heritage site, and to encourage their participation, Historyworks organises fun, educational activities that utilise cutting edge technology based on the team's technological expertise derived from the media industry. For example, Historyworks marries the adventure idea of the BBC Micro:bit with a traditional museum guide, producing interpretative trails and interactive questing or puzzle initiatives that use Bluetooth beacon digital technology to merge public art, public history and citizen science projects into visually beautiful and playful products, which are critical ingredients for Historyworks in attracting young generations to interact with objects from the past.

The Historyworks team behind these creative trails also found that children participating in the project were able to help widen participation by drawing in their parents and grandparents to promoted public events to pilot citizen science projects which the children had helped co-create, an unintended effect of inter-generational digital learning that has helped diversify participants in Historyworks' citizen science projects. Recruitment for Historyworks projects is kept at low cost and targeted through the usual channels of stakeholder participation and newsletters to schools and community groups, but it is by making short films and audio tasters and using Facebook advertisements alongside Twitter campaigns to engage a wider public that it has been possible to reach thousands of potential participants. In the future, the Historyworks team hopes to entice not only digital experts to become involved in their projects, but STEM experts as well.

Throughout the consultation, it was suggested that digital platforms such as Zooniverse function as places where people can generate citizen science ideas collectively, allowing collaborators to share ideas, as well as coalesce around research opportunities. Some of the participants felt that digital technology presents momentous opportunities to change what society does as a whole, provided that citizen science is carefully geared towards enfranchisement and citizen engagement.

Another interesting development raised by participants is the innovative use of gamification and alternative online rewards systems, as well as mobile apps, which can reward and encourage participation of amateur scientists. Digital technology offers the potential to provide small rewards, for example, through mobile applications that gamify engagement in citizen science by enabling point scoring, essentially to incorporate the fun elements of games in to a rewarding and productive activity.

Others highlighted that financial support for wider participation could come in the form of the resources required to conduct the research rather than paying a direct wage to the citizen scientist. For example, some participants

mentioned that there may be more merit in providing a citizen scientist with the software required to process their data, or to provide the citizen scientist with travel expenses rather than paying them for their time.

The importance of having realistic role models with similar backgrounds to a possible citizen scientist candidate was also stressed by the group as an important mechanism in extending reach and participation in citizen science. Such activity helps the potential citizen scientist to imagine his or her involvement in a more realistic manner and makes citizen science more accessible.

It was felt that, in the long term, initiatives that work towards the mainstreaming of citizen science, coupled with efforts that increase the public's capacity to conduct scientific research (including training) and the incorporation of citizen science in educational curricula, were going to be key. Towards this end, digital technology can help with scaling citizen science at the global level, distributing many voices and democratising access to the tools and skills required to participate in the citizen science movement.

Ensuring transparency and openness

The challenge of transparency and openness was the fourth strategic challenge identified by the group and seen as a wider issue in scientific enquiry more generally. Scientific research findings and data have not always been easily accessible, and this has been an issue prior to the emergence of open science. Many questioned how we can improve data access for use in citizen science research, and how to attribute ownership in an environment which is characterised by openness and collective effort. Some ways to address this issue that were mentioned by the participants include reversing the conventional perception of citizen science as an activity where a professional researcher reaches out to the public for data collection, and instead exploring models where professional researchers make their data more transparent for use by the public in digitally enabled citizen science projects.

At the same time, we noted the importance of providing early clarity to citizens about their data protection rights, as well as a concurrent need to ensure that citizens are educated to ask for consent for their personal data to be used. Researchers have an obligation to inform collaborators about risks, and they should avoid jargon wherever possible and ensure that language is appropriate and targeted to their audience. For instance, there are gradations in the usage of creative commons licences, which allow individuals to offer their work and make it available for others to share and use, and yet allow citizens to be more explicit about their expectations regarding the usage of their work.

In terms of transparency and openness, digital technology was considered by some participants to be a challenge for citizen science. Users cast a digital shadow, sometimes unwittingly, which can expose personal or organisational information and bring about risks to the individual. And yet, as the Internet of Things continues to proliferate, so, too, do the tools to protect the public, including anonymisation, encryption, and digital 'safe harbour' protection laws, thereby demonstrating how digital technology can simultaneously create solutions and challenges for society.

4. A future vision for citizen science

Having explored the current situation, as well as the benefits and challenges facing greater use of citizen science, it was felt that we should look to the future and agree what the aspiration should be for citizen science in a more connected world, particularly because the way that citizen science was conceived is becoming increasingly challenged and perceptions of what constitutes citizen science are evolving.

The first conclusion established by the group was that we cannot predict too far into the future, given the rapid rate of change and evolution of digital technology. The ubiquity of smartphones and patient-monitoring apps, and the potential for big data or autonomous technology, was unimaginable to the majority of the population not too long ago, and it is difficult to imagine what the next generation of technology will be like in, say, 15 years' time.

The group nevertheless identified a series of ideal elements and scenarios that might make up a future vision for citizen science, and this is outlined below (box below).

A future vision for citizen science

- Science would no longer be confined to the laboratory, but would embrace real-world experiments and issues.
- Research would become society-centred.
- There would be opportunities to explore research that may fill gaps that academic researchers are unwilling or unable to address otherwise.
- Citizen science would be a legitimised activity. Guidelines and protocols would also become more accessible to the public. There would be trust in and recognition of the value of the citizen scientist's work.
- Citizens would be engaged not only in data collection, but also in setting the research agenda; they would produce research calls, as well as answer them.
- As part of the curriculum, opportunities to become involved in citizen science projects would be embedded into the curriculum, to engender the skills and confidence required to participate in citizen science early in life, and such teaching would continue as part of lifelong learning, entering the mainstream and day-to-day parlance as an activity as ubiquitous as reading or playing music. It would no longer be necessary to use the term citizen scientist, similar to the way that the act of playing music does not necessarily require a person to say they are a 'citizen musician.'
- The accessibility of citizen science to the underprivileged would improve dramatically, perhaps by pooling resources, sharing tools and connecting with existing networks of citizen scientists embedded in the movement.
- Citizen science would be championed by local and national policymakers, as well as role models closer to home, such as classmates, neighbours, and siblings.
- Ultimately, a citizen scientist would be able to recognise themselves as part of a movement that is at once local and global, knowing that collaborative efforts are taking place around the world.

Participants identified a number of societal benefits that may arise from expanding engagement with citizen science to the point where such activities might become part of everyday life, including:

- the emergence of opportunities for people to find a sense of place in local and global communities;
- collaborative research facilitating the formation of enfranchised groups who can then harness their power to make a change in society;
- research partnerships that could create wide networks of collaboration acting in concert for the public good, perhaps for conservation or for contributing towards health advancements;
- re-engaging with society and reconnecting with other people in new ways, listening to people's concerns and making people feel more valued, thus improving citizens' general wellbeing; and
- a greater understanding by society of the risks, benefits and impacts of their actions.

5. Enabling a future vision for citizen science

Participants emphasised that in order to make the future vision a reality, citizen science needs to remain responsive, and to evolve along with the rapid progress of digital technology. Upskilling and training of potential citizen scientists will be essential, in conjunction with supportive structures, such as monitoring mechanisms that hold people to account.

It was noted by the group that a decision needs to be made regarding whether citizen science is to be defined as a different type of research that does not necessarily seek to make a contribution to scientific knowledge, but is equally valuable and potentially more impactful than conventional science because of the integration of a large audience and the potential for outreach.

Citizen science administrators should be encouraged to utilise existing digital portals and social media further, in order to reach more people. This does not necessarily mean creating new apps and citizen science websites; there is a need to focus on the opportunity and advantage of advertising on platforms that already receive a high degree of participation. In effect, citizen science needs to be 'marketed' better, by explaining what it is to groups outside the 'usual suspects' and by making the general public more aware of both the purpose and the benefits of citizen science. This could involve bringing the personal stories and individual cases that illustrate and enliven the citizen science concept to a greater number of people.

Policymakers should be responsive to the messages relayed by citizen science research. If citizen scientists are unconvinced of the impact generated by their work and if the message is ignored by policymakers, there is a risk that the momentum behind societal issues may hollow out. Buy-in from policymakers means involvement by local policymakers and authorities, as well as politicians.

It was recognised that some institutions already have a significant degree of public engagement with open science and that they could be encouraged to reinforce citizen science activities. Establishing the networks and collaborations to pool resources and co-operating to raise citizen science on the agenda, instead of keeping citizen science as a separate activity from open science, can bring new opportunity. Projects may also be more scalable this way, rather than duplicating efforts on different initiatives occurring in parallel.

6. Conclusion

In conclusion, this consultation recognised that while citizen science remains a niche area, it is expanding and becoming an increasingly important opportunity for society and for the engagement of citizens in issues that matter to them.

While it has traditionally been defined as an activity where volunteers collect or analyse data to support professional researchers, citizen science today needs to be considered as an activity that may occur throughout the research process, starting from the point of idea generation, through to data collection, analysis and dissemination of the findings, through to policy implications. At the same time, it is important to recognise that while citizen science has historically been undertaken in the environmental sciences, it is becoming increasingly common across many other research fields, from history to physics.

The benefits of citizen science are many and varied. They include new skills, personal development and the creation of social currency, as well as personal enjoyment for individual volunteers and professionals alike. Researchers obtain benefits from improved speed, quality and resource efficiency in their activities. Citizen science can also mean wider dissemination and use of research results. Policymakers may be able to use insights from citizen science projects to better understand an issue. This could, in turn, improve public sentiment and buy-in regarding that issue.

At the same time, we need to recognise that there are challenges to overcome in fully realising these benefits. Key among them is awareness of citizen science activities, which remains relatively low among both the public and professional researchers. A related challenge is how to expand citizen involvement to include more culturally, socially and economically diverse groups.

Professional researchers may perceive citizen science to be less robust or of lower quality than more 'traditional' research approaches; this view may also be shared by funders and research institutions, which in turn may be less likely to reward citizen science efforts as a result. And policymakers may be sceptical of citizen science where it calls into question their ability to distinguish between 'expert' claims.

Nevertheless, we concluded that there were ways to overcome many of these challenges. Concerns about data quality can be overcome through creative use of technology, and there are tried and tested methods of data validation (such as consensus by multiple-participant observation), which digital technology can support and enable at scale. Capacity building can also be built into citizen science projects through engagement between volunteers and professional researchers from the outset of a project and throughout its lifespan. Impact might be demonstrated through evaluations, longitudinal studies and personal stories, and digital technology has the potential to make citizen science initiatives more accessible, which may help to overcome challenges with diversity, participation, and transparency and openness of research more generally.

A vision for citizen science emerged from the consultation which sought to test the limits of citizen science as it is currently conceived, moving towards a new set of practices that is less confined to laboratories and more about 'real-world' experimentation, where research focuses strongly on the needs of society. Under such a vision, citizen science would occur throughout the research process, as a matter of course, and would become embedded in education programmes. Researchers, funders and policymakers alike would support, not penalise, citizen science activities, and as a result of all of these changes, citizens could become part of both local and global movements that places citizen collaboration and public engagement at the heart of science.

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Organisations

Corsham Institute

Corsham Institute (Ci) is a not-for-profit organisation that is working for a fair, inclusive, prosperous and creative society based on trust and security.

Our focus is on education and research, going beyond traditional ideas of knowledge to promote lifelong learning in the digital age. We aim to empower citizens to develop the critical thinking and creative problem-solving skills they need to make the most of the opportunities that our increasingly networked, connected and data-rich society provides.

The Thought Leadership Programme provides an opportunity to explore the potential and impact of digital technology within society today, focusing on shaping a future where citizens are empowered with the knowledge and skills they require to live their lives socially, economically and even politically.

Our wider programme of work encompasses Research, Learning and Enterprise, placing the citizen in control of the creation, acquisition and exploitation of their knowledge.

RAND Europe

RAND Europe is a not-for-profit organisation whose mission is to help improve policy and decision making through research and analysis. As part of the RAND Corporation, we were founded in 1992 in Europe to provide quality research and rigorous, fact-based analysis to serve policy needs in EU institutions, governments, charities, foundations, universities and the private sector, where impartial research is required.

Our work lies on the spectrum between that of universities and consultancies, combining academic rigour with a professional, impact-oriented approach. In other words, we operate as a research-focused business, using a professional services model, within the context of a public good mission.

We combine deep subject knowledge across many policy areas – including health, science, innovation, defence and security, transport, infrastructure, criminal justice, education, employment and social policy – with proven methodological expertise in evaluation, impact measurement and choice modelling. Our clients include European governments and institutions, charities, foundations, universities and private sector firms.

St George's House, Windsor Castle

St George's House was founded in 1966 by HRH The Duke of Edinburgh and the then Dean of Windsor, Robin Woods as a place where people of influence and responsibility can gather to grapple with significant issues facing contemporary society.

The House offers a safe physical and intellectual space set in the narrative of history but focused firmly on the future. You will find here an environment receptive to new ideas, conducive to taking intellectual risks and to thinking through challenging topics in imaginative ways. The House is a sanctuary, removed from the pressures of everyday life, where the topic to hand takes precedence. It is this focus that encourages creative thinking, informed debate and sustained engagement. The emphasis throughout our carefully crafted Consultations is on dialogue and discussion. Participants are in a place where a real contribution to society can be made, where personal enrichment and social progress are mutually compatible, a place where Wisdom is nurtured.

In order to offer a safe and secure intellectual space our Consultations are run on the understanding that all debate and conversation takes place under the House Protocol.

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